STANDARDISATION OF TECHNOLOGY FOR VALUE ADDITION OF COCOA

(Theobroma cacao L.)

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Standardisation of technology for value addition of cocoa (*Theobroma cacao* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"Standardisation of technology for value addition of cocoa (*Theobroma cacao* L.)"** is a record of research work done independently by **Mr. K.Sunilkumar,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Dedicated to
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Son and Wife

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Introduction

1. INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of the important commercial crops of the world and mainly grown in the tropical regions of Africa, Asia and America. World area of cocoa is 70.81 lakh ha with a production of 28.09 lakh tonnes (FAO, 2003). In India, the crop is cultivated in an area of 16,175 ha with a production of 7,650 tonnes. Kerala accounts for 55.3 per cent (8949 ha) of the area and 63.7 per cent (4874 tonnes) of production (Balasubramanian, 2002).

The developed countries have high levels of consumption of chocolate and other cocoa based products. Nearly two-third of imports of cocoa products is accounted by Western Europe and North America. Among them, Netherlands and USA are the major consumers. During 2002, India imported 2214 tonnes of cured cocoa beans worth US $ 3.62 million (FAO, 2003). With respect to per capita consumption of chocolate, Switzerland ranks first with 10.18 kg per annum and the world average is 0.525 kg per annum (Taylor, 2000). However, in India, the per capita consumption is only 0.2 kg per annum.

Chocolate manufacture and marketing being the monopoly of multinational companies, the small farmers who produce more than 90 percent of world's cocoa are at the mercy of these companies. Thus, there is great disparity between the prices realised by the farmer and the finished products. Such monopolistic exploitation by multinational companies make it necessary to take up processing and marketing at farmers' level or in small scale units. At present, the potential for growth in consumption is high, especially with the increased purchasing power of the middle class in the post-economic liberalisation era. Also the reported health benefits, due to antioxidant properties of cocoa, in reducing cardio-vascular diseases and protecting against cancer may propel increase in per capita consumption.

In Kerala, the acreage of cocoa was 29,000 ha in 1980-81 which declined drastically to its one–third during 2001-02. This happened because of the very low prices

offered by the multinational companies and exploitation by the middle men in the prevailing procurement system. Presently, the farmers are not processing their produce mainly because of the limited availability of viable technologies for processing of cocoa at farm level.

At Kerala Agricultural University attempts were made to standardise primary and secondary processing of cocoa at small scale level (Kumaran *et al.*, 1980; Ganesan, 1982 and Amma *et al.*, 2004). Though, the products developed are popular, their acceptability is not on par with that of commercial brands available in the market. In this context, the present study was taken up to standardise viable technologies for primary and secondary processing of cocoa and product development with the aim of fetching maximum returns to the small farmers. This will also generate more employment opportunities in the rural areas. Thus, the whole activities of production, processing and marketing of cocoa could be done at the farmers' level to optimise their returns. The existence of well organised self help groups such as 'kudumbasree', women groups, co-operative societies etc. in Kerala make the task very much feasible.

Review of Literature

2. REVIEW OF LITERATURE

The primary processing or curing is the process by which dry cocoa beans are prepared for the market. This involves two steps viz., fermentation and drying. It was done at farmers' level in the producing country. The manner in which it is done determines the flavour and the aroma of the finished product.

The various steps involved in the conversion of cured beans into different finished products viz., roasting, kibbling, grinding, mixing of different ingredients, conching, tempering and moulding. This is often done in specialized factories away from the producing region.

This chapter presents the recent research work done in cocoa processing under the following sections.

i) Primary processing of cocoa
ii) Secondary processing of cocoa
iii) Value addition and product development in cocoa

2.1 PRIMARY PROCESSING

Generally there are two peak seasons of harvest with the major peak in June-August and the minor peak from December-November (Bopaiah and Shamabhat, 1989). However at Thrissur condition in Kerala, following the pre-monsoon shower of April-May, there is apparently a peak flowering in May which result in harvest peak in October-November. Another minor peak was observed in April-May as a result of successful fruit set after harvest of main crop (Amma *et al.*, 2002).

2.1.1. Storage of Pods

Beneficial effect of pod storage for varying periods has been reported by several workers. Storing of pods prior to splitting has been recommended by Howard (1984) for cocoa beans which were difficult to ferment. Premalatha and Mohanakumaran (1989a) secured optimum fermentation temperature, desirable dried

bean pH and high proportion of commercially acceptable beans by storing harvested pods for two to six days.

Postharvest storage of pods was reported to improve aeration of ferments resulting in a rapid increase in temperature to greater than 45^0C with in 20 hours (Meyer *et al.*, 1989). As a result, suppression of lactic acid bacteria and increased respiration by yeast over alcoholic fermentation, significantly lower concentration of lactic acid and a higher pH occurred in the product.

Kirchoff *et al.* (1989) studied fermentation of cocoa beans, which were obtained from pods stored for 10 days. Artificial conditions were created to provide 40^0C for 20 hours and 50^0c for the next 48 hours of fermentation. Results indicated that free acidic amino acids disappeared during initial 20 hours and later on leucine, phenylalanine, alanine and tyrosine were predominantly released.

Dias and Avila (1990) could not find any effect on holding pods for up to five days prior to fermentation with respect to duration of fermentation or final acidity. Tomlins *et al.* (1993) at Cocoa Reseach Insitute of Ghana studied the effects of post harvest pod storage along with different methods of fermentation for two cultivars. The pods were stored for period ranging from one to seven days. They observed that pods stored for seven days showed an increase in pH and a rapid early rise of temperature during fermentation.

According to Samah *et al.* (1993) unripe beans had a lower pH (5.0) than ripe beans (5.6) after six days of fermentation. About 40 per cent of ripe beans achieved a chocolate colour compared to 27 per cent in the case of unripe beans at the end of fermentation period.

Bhumibhamon *et al.* (1993) reported that when the beans extracted from pods stored for four days were subjected for fermentation it took 48 hours to rise the temperature of fermenting mass to 45^0C where as the beans from pods stored for seven days took only 24 hours to reach the same level during fermentation..

Effendi (1993) suggested post harvest pod storage of 10 to 15 days to get lower acidity and a stronger chocolate flavour in beans on fifth day of fermentation. The storage of pods for five days was found insignificant. Effendi and Panji (1994) stored cocoa pods for 10 days before subjecting the beans for fermentation and compared the effect with that of freshly harvested pods. After 18 hours of fermentation the fermenting beans from stored pods recorded a temperature of 11^0C higher than that recorded by beans from freshly harvested pods. On fifth day of fermentation, beans of stored pods had a pH of 5.5 and total acid content lower than the upper limit for consumer requirement (15 meq NaOH/100g beans). The acid content of beans from freshly harvested pods exceeded the limit at this stage.

According to Arikia *et al.* (1994) pod storage was the single most important factor in improving flavour quality. Jinap *et al.* (1994) compared the flavour compound from freshly harvested and ten day stored pods and found that the highest proportion of flavour compound (2,3,5-trimethyl pyrazine) was present in beans from stored pods. Biehl and Voigt (1995) indicated that correct nib acidification (adjustment of seed pH to not less than five) through pulp pre-conditioning was important for formation of aroma precursors in cocoa. This was achieved by pod storage as well as bean spreading.

2.1.2. Fermentation

Cocoa beans are to be fermented for development of chocolate flavour upon roasting. When beans from freshly harvested pods were dried with out subjecting to fermentation, typical flavour and aroma associated with the chocolate was not formed. During the fermentation process, complex molecules such as polyphenols, proteins and sugars break down to form flavour precursors as a result of microbial activities outside the beans and biochemical changes within the beans.

2.1.2.1 Methods of fermentation

The manner in which beans were fermented vary considerably among and even with in the same region of production. In West Africa, which produces the best quality beans, the heap method is followed (Rohan, 1963). In this method, the duration of fermentation varied from three to eight days with an optimum of six days. Amma *et al.* (2002) reported that the season influence the duration of fermentation mainly through its effect on temperature and humidity. At lower temperature and high humidity fermentation period will be usually longer. In addition to heap method tray and box methods were considered as the standard and widely adopted ones.

The heap method essentially involves keeping a mass of not less than 50 Kg wet beans over a layer of banana beans. Quantities beyond 2.5 tonnes result in poor aeration in heap method. For ease of handling 500 Kg is optimum (Wood and Lass, 1985; Amma *et al.*, 2002).

In the case of tray method, wet beans of about 45 Kg were spread on wooden trays of size 90 x 60 x13 cm. The thickness of beans was maintained at 10 cm to facilitate aeration and there is no turning of the mass during fermentation. Such trays were stacked on over the other and generally six trays were kept with total quantity of 270 Kg wet beans. The fermentation would be completed in 4 days (Amma *et al.*, 2002).

The box method is suitable for handling large quantities of beans. The boxes are made of teak wood with a standard dimension of 1.2 x 1.2 x 0.75 m, which can hold about one tonne of wet beans. Mixing of the fermenting mass was achieved by transferring the beans from one box to another and hence a total of three trays were necessary (Wood and Lass, 1985).

2.1.2.2 Conditions of fermentation

The correct fermentation and drying of cocoa are of vital importance, as no subsequent processing of the bean will correct bad practice at this stage. A good

flavour in the final cocoa or chocolate is closely related to good fermentation (Minifie, 1989). The effectiveness of fermentation is influenced by many factors and some of the important factors are discussed hereunder.

2.1.2.2.1 Season and temperature

Kumaran *et al.* (1981) reported that when cocoa beans were fermented in mini box and mini tray methods, the temperature rose from 27-29^{0}C to a peak of 44-45^{0}C on fourth day. There after the temperature dropped slightly on fifth day and remained as such up to seventh day.

In ideal fermenting condition, the temperature of the mass was found to rise slowly at first, then more rapidly reaching 40-45^{0}C after 48 hours of fermentation. When the beans were given turning at this stage, the temperature increase recorded was to the tune of 48-50^{0}C. After reaching that level, temperature decreased slowly and then rose again on next mixing. After six days of fermentation, the temperature was around 45-48^{0}C (Wood and Lass, 1985).

Malini (1986) described the temperature profile of cocoa fermentation under south India condition. The initial temperature recorded was 32^{0}C. It increased to 46^0 C on sixth day of fermentation during September season. During July, the initial temperature was 30^{0}C, which increased to 49^{0}C on sixth day.

Several workers had recorded effect of season and temperature on fermentation of cocoa. The season influence fermentation mainly through its effect on temperature development. Temperatue rise is low in wet weather during June-July. Fermentation during the dry season was better than the wet season (Premalatha and Mohanakumaran, 1989b). Dias and Avila (1993) recorded higher volatile acid content in May than in June.

Hiiching *et al.* (2002) reported that in small holder techniques of cocoa fermentation using plastic sack, the temperature recorded was around 40^{0}C as against 50^{0}C or above in the case of shallow box and other methods.

2.1.2.2.2. pH

The pH or acidity of the cocoa bean strongly influenced the quality of the cured bean as well as final product. Several workers reported that pH of pulp increased and that of bean decreased to reach uniform values on completion of fermentation.

Dougan (1981) suggested that the loss of highly dissociated citric acid and its replacement with the less dissociated lactic and acetic acids as the reasons for rise in pH of pulp from an initial value of 3.5 to 4.5-5.0 or even higher. The normal pH of cocoa sweating was reported to range between 3.5 and 3.8 (Ansah, 1983; Adomako, 1984).

Malini (1986) reported the seasonal influence of change in pH of pulp and the bean during fermentation process. The pH of pulp increased from 3.65 to 4.93 and that of nibs decreased from 6.47 to 4.78 due to fermentation during September. When fermentation was done during July, the pH of pulp increased from 3.94 to 4.37 and that of nib decreased from 6.42 to 4.36.

According to Minifie (1989) the pH of pulp initially rose from 3.5 to 4.5 and then to 5 during fermentation. This was attributed to the absorption of acetic acid by cotyledons, which was formed due to the oxidation of sugar in the pulp in the presence of oxygen during turning. The Cotyledon absorbed some of the acetic acid to attain a pH of 5. Tomlins *et al.* (1993) noted that when smaller quantities of beans were fermented by heap method, the pH, acidity, temperature and aeration were almost stagnant.

Senanayake *et al.* (1995) studied the pH change in cottage scale fermentation of cocoa. The initial pH of cotyledons ranged from 5.81 to 6.54 which on seventh day of fermentation dropped to 5.25 -5.30. In the case of pulp, an initial pH of 3.26 - 3.95 increased to 5.1-5.32 on seventh day of fermentation. Bhumibhamon *et al.* (1997) evaluated the chemical and sensory properties of mix culture fermented beans

and found that beans fermented for four days by mix culture was preferred to those fermented naturally. The mix culture fermented beans had a pH of 5.18-5.34.

Hiiching *et al.* (2002) evaluated small holders' fermentation techniques such as rattan basket, plastic bucket, plastic sack and jute sacks against shallow box method. The pH measured on sixth days was less than five in small holders' method which indicated the acidic nature of beans. Amma *et al.* (2002) reported that the fresh cocoa bean pulp was acidic with a pH of around 3.5 where as that of cotyledons was very much higher around 6.5. As the fermentation progressed, the pulp pH increased and the cotyledon pH decreased to reach almost uniform values for both.

2.1.2.2.3. Role of microorganisams

The role of micro flora associated with the process of fermentation has been unravelled by different workers. The beans inside cocoa pod are devoid of microorganisms. As soon as pods are broken to take out the beans they become inoculated with a variety of micro organisms present on the pod surface, the workers hands, the container used for transporting beans to the fermentary, etc. The presence of sugar and citric acid in the fresh pulp make them an excellent medium for the development of micro organisms. Initially, the condition within the mass of beans was anaerobic which favour yeasts. The yeasts convert most of the sugars in the pulp to alcohol where by a large amount of carbon dioxide is also produced. The yeast activity dominates for up to first 24 to 36 hours. The loss of citric acid by drainage of juice as sweating as well as through microbial metabolism cause an upward drift in pH. This together with the increasing levels of alcohols and better aeration inhibit yeasts so that their activity is declined (Wood and Lass, 1985).) The changed environment of fermenting mass was better suited to the lactic acid bacteria which soon dominated until after the first turning (Schwan, 1984). Then the increased aeration and rise in temperature to about 45°C favoured the acetic acid bacteria and other aerophyllic spore forming bacteria and they dominated from the forth day onwards. Moulds were found in small numbers through out the fermentation periods. During the drying phase loss of acetic acid and drop in temperature caused a proliferation of moulds until the loss in moisture inhibited their growth.

Ardhana and Fleet (2003) studied the microbial ecology of cocoa bean fermentation in Indonesia, by determining individual species at specific intervals through out the process. The first two to three days of fermentation was characterised by the successful growth of the species of filamentous fungi, yeast, lactic acid bacteria and acetic acid bacteria. The later stages of fermentation was dominated by the presence of *Bacillus* species. Samah *et al.* (1993) reported that there exist a positive correlation between sizes of the relevant microbial population and the amount of acids produced during fermentation.

2.1.2.2.4. Moisture

Malini (1986) studied the moisture variation during fermentation for two season viz. July and September under South Indian condition. During July, the initial moisture content was 83.74 for pulp and 39.61 per cent for nibs. The moisture contents were changed to 80.22per cent and 43.71per cent respectively for pulp and beans on sixth day of the fermentation. During September, the initial moisture content of pulp was 84 per cent which was reduced to 49.64 per cent on sixth day of fermentation. In the case of nibs the initial moisture content of 40.5per cent was increased to 46.11per cent on sixth day. Amma *et al.* (2002) reported that the moisture content of fresh pulp was around 84per cent and that of cotyledon was around 40 per cent. After curing, the moisture content of beans was reduced to six to seven per cent.

2.1.2.2.5. Sweatings

The pulp surrounding the beans when liquefied run off as sweatings which amount to 12 to 15 per cent of the weight of wet beans. The flow of sweating is normally completed by the end of first 24- 36 hours of fermentation (Wood and Lass, 1985). According to Buamah *et al.* (1997) cocoa sweating, the pale yellowish liquid that drains of during cocoa fermentation was the break down product of the mucilage surrounding the cocoa bean. Sweatings constituted 10 per cent of the weight of cocoa fruit. They suggested that cocoa sweatings could be used for production of wines,

alcohols, marmalade, jam and syrup. Rapid collection of good quality sweatings in large quantities was recommended as the first step in utilizing sweatings on a commercial scale. They also reported that under controlled conditions the yeast species *Sacharomyces chevalieri* generated higher yield of sweatings. The quality of bean was also best with fermentation by the species.

2.1.2.2.6. Enzymes in fermentation

The action of pectolytic enzymes during fermentation of cocoa beans caused break down of mucilage surrounding the fresh bean which in turn resulted in the formation of sweatings. The pectolytic activity was brought about mainly by microorganisms, although to some extent endogenous enzymatic activity had been observed (Ansah and Dzogbefia, 1990). Bhumibhamon and Jinda (1997) reported that the quality of fermented cocoa beans treated with commercial pectinase enzyme was found more promising. The per cent of fully fermented beans increased with increasing duration of enzyme soaking. Kashyap *et al.* (2001) reported the use of commercial pectinase enzyme in fermentation of coffee, tea etc.

Commercially, pectinase consisted of primarily three enzymes viz. polygalacturonase, pectin methyl esterase and pectin lyase. All the three contributed to the break down and modification of pectin from wide varieties of plant materials. Apart from these, the commercial preparation often contain cellulase and other cell wall degrading activities during fermentation. At present *Aspergillus niger* formed the important source of commercial pectinase and the temperature at which pectinase worked best was around 45- 55°C. In general a concentration range of 0.1 – 0.5per cent pectinase (with accompanying 0.5-1.5per cent cellulase) used at 24-37°C for periods of one to sixteen hours gave good results.

The enzymes like endoprotease, aminopeptidase, carboxypeptidase, invertase (cotyledon and pulp), polyphenol oxydase (catachol oxydase) and glycosidases are of key importance in flavour precursor formation and in pigment degradation during cocoa fermentation (Hansen *et al.*,1998). The enzymes exhibited large differences in pH optima and stability during fermentation. Aminopeptidase, invertase in cotyledon and pulp and polyphenol oxydase were strogly inactivated. Carboxypeptidase was partly inactivated, and endoprotease and glycosidases remained active through out the fermentation. Although the actual period of enzyme action was short, many key enzymes remained active till the end of fermentation.

2.1.2.2.7. Biochemical changes during fermentation

There had been a great deal of research in the past on the biochemical mechanism of fermentation. But our understanding of the process is not yet complete. Here in this section, an effort is made to review recent works on the subject.

The major change inside the bean was death of the bean followed by various chemical changes that are vital to the development of chocolate flavour. The bean death was due to the high acidity imparted by acetic acid, increased temperature and formation of alcohol from the sugars (Wood and Lass, 1985). The cotyledons contain a small portion of intensely coloured cells. The coloured cells contain mostly polyphenolic compounds. These polyphenols play an important role in the internal biochemical changes of beans. When the beans die, cell disruption occurs allowing various enzymes and their substrates to come together and react. Under anaerobic condition during the initial phase of fermentation, the anthocyanins are destroyed by the hydrolytic reactions. This lead to bleaching of cotyledons and subsequently

oxidation reactions occur. At those stages polyphenols get oxidised by polyphenol oxidise enzyme leading to the development of dark colour.

Kirchoff *et al.* (1989) reported that during fermentation there was an increase in free aminoacids mainly due to degradation of seed proteins., leucine, alanine phenyl alanine and tyrosine were the aminoacids accumulated to a far great extent than others during cocoa fermentation. These aminoacids are especially reactive during roasting. Thus, they could be considered to play an important role in formation of cocoa flavours.

Beihl *et al.* (1993) recorded a very high proteolytic activity in ripe ungerminated cocoa seeds, which digested the vacuolar storage protein during fermentation. These were suggested to be responsible for the release of hydrophobic aminoacids and a large number of oligopeptieds which were the essential cocoa flavour precursors.

Voigt *et al.* (1994a) found that the free aminoacids and oligopeptides were the essential aroma precursors. Voigt *et al.* (1994b) suggested that the combined action of two enzymes viz. aspartic endoprotease and carboxy peptidase on cocoa bean protein appeared to be required for the generation of cocoa specific aroma precursors.

Cros and Jeanjean (1995) reported that polyphenolic compounds account for upto 10 to 15 per cent of the weight of an unfermented dried bean. These compounds contributed to the astringency of cocoa. During fermentation, the soluble polyphenol content falls by 70 to 80 per cent by diffusion, tanning and oxidative polymerisation. This in turn caused a substantial reduction in astringency and increased heat related

volatile development in cocoa. They have also reported that unfermented dried bean contain around 0.2 per cent free amino acids. These increased to three fold during fermentation. At the same time there was a five to ten fold increase in hydrophobic amino acids (valine, leucine, phenyl alanine etc.). The overall amino acid content reached a maximum on fifth or sixth day before falling down again.

Herrman (1995) studied the changes in polyphenols and their oxidative condensation during fermentations of cocoa. According to Bonvehi and Coll (1997) the optimally fermented cocoa beans have maximum total polyphenol content of 58 mg g^{-1}, a maximum tannin content of 31 mg g^{-1} and a maximum (-) – epicatechin content of three mg g^{-1}. These parameters were related to the sensory properties of cocoa and could be used to confirm fermentation deficiencies.

The anthocyanin content declined gradually during fermentation (Broadbent *et al.*, 1997). On the first day of fermentation the anthocyanin content of beans recorded was 270.64 mg 100 g^{-1} which declined to 46.1 mg/100 g on seventh day in box method of fermentation. When the beans were subjected to heap method of fermentation corresponding values for anthocyanin content were 258.15 and 52.44 mg 100 g^{-1}.

Zeigleder (1998) observed a strong correlation between precursors of cocoa flavour (especially aminoacids) formed during fermentation with that of flavour development in beans. Almeida *et al.* (1998) observed a continuous decrease of (-) – epicatechin and procyanidins during fermentation.

Brito *et al.* (2001) found that the free aminoacids of beans increased from 27.7 ± 0.7 mg g^{-1} in fresh beans to 32.1 ± 1.8 mg g^{-1} at 72 hours of fermentation. A

gradual decline in protein content was observed during the initial 72 hours of fermentation. Concomitantly the amount of amino-terminal groups as well as free amino acids increased with time. The rate of production of free amino acids during fermentation was related to the rate of flavour and aroma development. They also reported that the total polyphenol was 231 ± 5 mg g^{-1} tannic acid in fresh bean which changed to 213 ± 5 mg g^{-1} after 72 hours of fermentation. This indicated that there was no significant difference in the phenol content during the first 72 hours of fermentation.

The pigment cells constitute about 11 to 13 per cent of the tissue in cocoa bean, which contain 65 to 70 per cent polyphenols and three anthocyanins. During fermentation the polyphenols undergo a variety of reactions including self condensation and reaction with protein and peptides. Approximately 20 per cent of the polyphenols remain at the end of fermentation process. As a result of fermentation the anthocyanin was converted to quinonic compounds which gave characteristic brown colour of the cured bean.

Brito *et al.* (2002) reported that the total phenols in cocoa get reduced during fermentation to 30 per cent of the initial value and the (-) – epicatechin, the principal substrate of cocoa polyphenol oxidase was reduced by 90 per cent with a proportionate increase in catechin content.

2.1.3 Effect of Drying

The main objective of drying of cocoa beans after fermentation was to reduce the moisture content of the beans to a level which was safe for storage and transportation. Usually the moisture of seven per cent or less was considered safe.

During drying the process of oxidation continues which played an important role in reducing bitterness and astringency. In case of rapid drying the oxidative changes are prevented leading to excessive acidity. In case of too slow drying, the chance of mould development was found high. So any method of drying should take into consideration of the development of total quality than simply reducing the moisture level (Wood and Lass, 1985).

2.1.3.1 Method of drying

Mainly there are two methods of drying of cocoa beans viz. sun drying and artificial drying. Sun drying formed the simplest and most popular method. It was done by spreading the beans on mats raised off the ground or using movable trays. The duration required for drying varied from 12 to 20 days. With respect to artificial drying the major parameters recognised were temperature, rate of air flow, bean depth and extent of bean stirring.

Several mechanical driers were used in large plantations. They included either movable tray driers circulating in a tunnel through which hot air was circulated or rotary driers where hot air was passed over beans contained in a movable cylinder. Yusianto *et al.* (1995) found that conventional high temperature drying was undesirable as it produced low chocolate flavour and strong off flavours. Bonaparte *et al.* (1998) reported that open-end air drying favoured high incidence of external mould than beans from the solar driers, although the differences were minor. According to Augier *et al.* (1998), gentle drying at 40^0 C lead to a substantial reduction in acid content. Cunha *et al.* (1988) reported a plat form drier, which was effective in artificial drying of cocoa more economically and efficiently.

2.1.3.2 Changes during drying

Malini (1986) studied the changes in physical and biochemical parameters during drying of fermented cocoa beans under South Indian condition. The initial moisture content of 48.2 per cent in nibs was reduced to 6.46 per cent after 112 hours of drying. The pH of nibs increased from 4.6 to 5.18 on drying of Thirthahalli samples and 4.48 to 5.12 for Sullya samples.

Almeida *et al.* (1998) assessed the cocoa bean quality obtained from two drying methods viz. sun drying and drying using movable trays in a tunnel through which hot air was blown at 70 to 90^0 C (Tromag drier). They observed a direct correlation between undesirable sensory attributes and phenolic compounds. The phenolic content was lower for sun dried samples which lead to the conclusion that natural drying produced cocoa with better quality than artificial drying.

Brito *et al.* (2000) studied the structural and biochemical changes in cocoa during natural drying. They found that the total phenol (mg tannic acid g^{-1}) changed from 231 ± 5 to 157. The free amino acid content increased from 25.7 ± 0.7 to35.3±1.3 mg glycine g^{-1} and the amino terminal group from 21.6 ± 0.2 to 32.6 ± 1.9 mg g^{-1}. The effect of exogenous application of polyphenol oxidase (PPO) along with or without air on total phenol and tannin content of beans was studied by Brito *et al.* (2002). The total polyphenol phenol content was 7.9 mg g^{-1} after treating the cured beans with PPO, air and water.

2.1.4 Storage of Cured Beans

To ensure continuous supply of raw material for the processing units it is necessary to store the cured beans. Recent studies related to storage of cocoa beans and the related changes are reviewed here under.

2.1.4.1 Methods of storage

Cocoa bean when stored for long period, face the problem of quality deterioration mainly through mould growth and insect attack. Therefore, storage of cured beans for more than three months required protection from mould as well as insect pest. More over, cocoa beans being hygroscopic, absorb moisture under very humid conditions until equilibrium moisture content was reached. To prevent the uptake of moisture, storing the beans in polythene lined jute bags was recommended. Other methods like storage under vacuum in polythene container, storage under controlled humidity were being tried (Wood and Lass, 1985).

Bopaiah (1992) recommended storage of cured cocoa beans in jute bags up to 36 weeks without affecting quality under south Indian condition. Tegua *et al.* (2004) reported storage of cocoa bean under CO_2 rich atmosphere to safe guard them from fungal growth. Storage of cured beans upto six months in double lined jute bags was beneficial as reported by Amma *et al.* (2004).

2.1.4.2 Changes during storage of beans

Increase in free fatty acid content of beans during storage resulting from mould attack was reported by Wood and Lass (1985). Premalatha and

Mohanakumaran (1989b) reported an increase in pH of beans when they were stored for 28 weeks.

Bopaiah (1992) reported increased mould damage after 36 weeks of storage of cured beans under south Indian condition. He could isolate mycotoxin from the stored beans and the internal mould to the extent of three to four per cent. It was found to affect flavour and aroma of cured beans. The mould growth was found to be encouraged by a moisture content of eight per cent and above and the attack was increased with prolonged period of storage. Redrying and packing after 36 week of storage was suggested to retain quality of bean.

Dharmaputra *et al.* (1999) surveyed the occurrence of insects and moulds in stored cocoa beans at farmer, trader and exporter levels in Indonesia. The moisture content was observed to be higher than tolerable limit recommended viz. 7.5 per cent in all samples. All the samples from traders and exporters were found infected with mould and insects beyond tolerable limits. The predominant insect found to cause damage was *Tribolium castaneum.* They concluded that storage practises adopted by traders and exporters were improper.

Weight loss of beans during storage was reported by Dharmaputra *et al.* (2000) for both fermented and unfermented samples. The weight loss was more in case of samples with high initial moisture content. The per cent of insect damaged beans as well as total fungal population were lower for fermented beans than for unfermented beans.

Tegua *et al.* (2004) reported growth of *Aspergillus flavus* on beans, aflotoxin production and formation of free fatty acids during storage of beans. The beans were

stored at normal and CO_2 enriched atmospheres at three moisture levels viz. 7, 11 and 15 per cent. At increased CO_2 concentration the fungal growth and aflatoxin production was found inhibited. The aflatoxin content was found to increase.

Amma *et al.* (2004) recommended storage of cured beans upto six months under South Indian conditions. The pH of the bean did not vary considerably during storage and the values ranged between 5.12 and 5.28. When the stored beans were subjected to redrying at monthly interval there was rapid deterioration in quality as evidenced from the organoleptic score of chocolates made out of such a sample.

2.2. SECONDARY PROCESSING OF COCOA

Secondary processing refers to the steps involving the conversion of cured beans into different finished products. The major products still continue to be chocolate. Chocolate is a homogeneous product obtained by an adequate process of manufacture from a mixture of one or more of ingredients viz. cocoa mass, cocoa press cake, cocoa powder, with or without addition of sugars, cocoa butter, milk solids including milk fats and flavouring agents (Amma *et al.*, 2002). The principles and processes of chocolate manufacture have been elucidated by various workers (Wood and Lass, 1985; Minifie, 1989; Mossu, 1992 and Beckett, 1994).

The essence of chocolate manufacture lies in the development of flavour by roasting the beans followed by extraction of cocoa butter from the nib to obtain cocoa powder. Thus the major steps in secondary processing are alkalisation or dutching, roasting, kibbling, grinding, butter extraction and preparation of chocolates or other finished products by adding various ingredients (Amma *et al.*, 2002).

2.2.1. Alkalisation

Alkalisation is the process of treating cocoa with alkali in view of improving the colour, flavour and taste of finished products developed from it. Alkalised cocoa developed dark colour and better flavour. The cocoa powder obtained was commercially known as soluble cocoa. Amma *et al.*, (2002) reported that both quantity of alkali and duration of treatment have profound influence on final quality of the product. Saturated solutions of sodium or potassium carbonate or bicarbonate were mostly used for alkalisation at a temperature of 80 - 85°C.

According to Minifie, (1989) alkalisation or dutching was done mainly to change colour and the process consisted of treatment of cocoa beans, liquor, nibs or powder with solution or suspensions of alkali. The process obviously found to raise pH from 5.2-5.6 to the range of 6.8-7.5. He also stated that the effectiveness of alkalisation was less when done for whole beans, since alkali was mostly absorbed in the shells.

2.2.2. Roasting

Roasting consist of subjecting cocoa beans to hot air which was essential for development of latent chocolate flavour in the beans (Riedel, 1977). In addition to loosening of shell roasting results in removal of excess moisture and other undesirable volatile mater. The most favourable temperature for proper roasting of cocoa beans for chocolate making was reported to be between 120 and 125°C.

John (1980) carried out roasting study by grouping cocoa beans into big (average weight – 1.32g), medium (average weight 0.96g) and small (average weight <0.96g). The bold or big beans gave two to three per cent higher nib yield than medium ones. It was observed that increase in time of roasting resulted in migration of more fat to shells. The fat loss in these ways could be reduced if the beans were cooled immediately after roasting.

Ganesan (1982) fabricated a rotating type roaster with provision for agitation during roasting and was recommended it for using in small-scale units. Minifie (1989) described roasting as the process by which beans were initially subjected to heating for about 10 minutes at a temperature just below 100^0C which reduced the moisture to two to three per cent. In the second stage, the temperature was raised to reach 130^0 C over a period of 15 to 20 minutes. According to him, roasting was mainly of two types viz. roasting by direct heating or indirect heating. Based on the opration there were continuous or batch type roasters.

Heinzler and Eichner (1991) suggested that the amadori compounds formed by the reaction of reducing sugars (aldoses) and aminoacids in roasted beans were the precursors of Maillard reactions leading to the formation of aroma compound. Nobesney and Rutkowski (1998) reported a reduction of total and volatile acidity when beans were subjected to increased temperature of roasting from110 ^{0}C to 150^0C. However there was an increased loss of fat as well.

Brito *et al.* (2000) studied the structural and chemical changes during roasting of beans for 30 minutes at 150^0C in electric oven and found that total free aminoacids were reduced during roasting. The microscopic analysis of roasted beans revealed the degradation of protein and phenolic bodies and cellular damage due to roasting. Misnawi *et al.* (2003) studied the effect of roasting cocoa liquor on polyphenolic

content and its hydrphobicity. The total polyphenols decreased by two to 3.3 per cent and total tannins by 19.5 to 33.1 per cent after roasting. Hydrphobicity and astringency were also reduced during roasting.

Amma *et al.* (2004) studied the effect of cocoa bean roasting in small scale units using microwave oven, shallow pans of stainless steel with or without copper bottom and 'uruli' roaster. The results indicated that for roasting five kilogram beans in stainless steel pan took 15-20 minutes. In case of *Uruli* roaster the time required was 30 minutes for 10 kg beans. Small sized beans took less time for roasting. They have reported that uniformity in size of beans was an important factor in achieving proper quality while roasting.

Misnawi *et al.* (2004) described the effect of roasting time and polyphenol concentration on development of cocoa flavour compound, the pyrazine. Increased concentration of polyphenols (from 41 to 170 g kg^{-1}) and prolonged roasting (from 15 to 45 minutes) was found to reduce the development of pyrazines. This was attributed to the increased binding of free aminoacids and sugars with polyphenols and their less availability for pyrazine formation.

2.2.3 Grinding and Extraction of Butter

The particle size was the most important factor that affected chocolate quality. Finer the particles, better the quality. In large factories nibs are ground for durations upto 72 hours. However in small scale units employing domestic type wet grinders such a prolonged grinding is not possible. Though prolonged grinding produce cocoa mass with very fine particles (98 per cent of which passed through 400 mesh sieve) during pressing extraction of butter was difficult. Hence, bigger

particle size viz. 98 per cent of which passed through 200 mesh sieve was recommended as optimum (Minifie, 1989).

Ganesan (1982) developed a cocoa butter extractor for use in small scale units which utilized the pressure developed by hydraulic jackets for pressing.Wood and Lass (1985) reported low fat content for beans of smaller size. Recovery of butter from the mass was reported to vary with bean size, type of grinder used and duration of grinding. (John, 1980; Amma *et al.*, 2004). The bean count varied from 76.3 to 151.6 among different size grades. Butter recovery was maximum (31.5 per cent) and the shell per cent was the least for big sized beans.

Broadbent *et al.* (1997) used a small scale portable expeller for cocoa butter extraction. It had a capacity of 40 kilogram per hour. According to them, adjustment of the bean moisture content to 10 per cent and heating them to 100^0 C gave an extraction efficiency of 65 per cent. Amma *et al.* (2004) carried out grinding trials with two types of grinders viz., table top ULTRA of one litre and a tilting type SANTHA of two litre capacity for durations varying from 30 minutes to 120 minutes. The butter recovery was the maximum in table top ULTRA grinder viz.31.8 per cent when ground for 60 minutes duration against 26.7 per cent in SANTHA grinder. Thus, such grinders would be useful in small-scale units with grinding durations of one to 1.5 hours. The cocoa butter recovery was the maximum of 31.5 per cent for big sized beans and hence they suggested bean count as an important factor affecting butter recovery.

2.3 VALUE ADDITION AND PRODUCT DEVELOPMENT

Value addition of agri-horticultural produce formed the most important method to minimize the post harvest losses, to ensure continuous supply of food materials and to stabilise the market prices which other wise is very unstable. It is achieved through the development of various processed foods with enhanced shelf life, nutritional value and often at reduced cost.

Among various food processing methods, dehydration is the oldest and most important one which offers the advantages of long term storage with least deterioration (storage stability) and lower energy consumption when compared to other method. Dehydrated foods are convenient, versatile and incur reduced handling cost (Loesecke, 1998 and Hayashi, 2003).

2.3.1 Preparation of Powder

There are different methods of dehydration. Selection of a particular method was governed by the nature of commodity to be dried, the desired form of the finished products, labour and operating condition (Loesecke, 1998). As such spray drying is one of the dehydration methods widely adopted for preparation of value added products especially powder formulations.

Human beings, now a days are able to enrich their eating habits by dehydrated and powdered foods. Powder products are easy for transportation, handling, enhanced shelflife and often cheaper also. Thus, ready to use powders have gained wide acceptance among consumers world wide. Powered food is made from various raw materials such as grains, milk, fruits, vegetables and a combination of them through dehydration process (Hayashi, 2003).

2.3.2 Spray Drying

Among various methods of preparing dehydrated products, spray drying is the most important one. Spraying is the method of choice due to its continuous design and flexibility. Spray drying delivers a powder of specific particle size and moisture content in relation to the drier capacity or product's heat sensitivity. In a continuous operation it delivers a highly controlled powder quality with relatively easy manipulation (Deis, 1997). Accordingly the objective of spray drying is to produce a spray of high surface to mass ratio droplets (ideally of equal size) and

then to uniformly and quickly evaporate the water. Evaporation keeps the products temperature to a minimum, which in turn reduces the chance of high temperature deterioration of the products. Further spray drying minimises loss of volatile flavours as against other dehydration techniques.

The simplest form of spray drying consisted of four separate process stages viz., atomisation of the feed, spray-air contact, drying and separation of the dried products from the drying air. The feed can be a solution, a suspension or a paste, in the simplest form. The dried product can be powder, granules or agglomerates. The dry product forms can be varied depending on the feed, drier design and process conditions (Deis, 1997).

Loesecke (1998) reported that in spray drying, the material that was reduced to the form of a solution, suspension, slurry or sludge was finely atomised in gaseous heating medium like air. The air transmits its heat to the individual particles of spray and the moisture is leaving behind the solids as a powder floating in the air stream.

2.3.2.1 Standardisation of spray drying parameters

Chandrasekhara *et al.* (1966) developed an infant food powder based on soyabean. Powdered barley malt was added to debittered soya dhal, centrifuged and the liquor from the centrifuge was warmed to 60^0 C. Weighed quantities of ground nut oil, skim milk powder, acid hydrolysed starch and buffer salts were added, homogenised and spray dried at 250^0 C inlet and 100^0 C outlet temperatures.

Coulter and Breene (1967) successfully spray dried wide variety of fruits and vegetables using condensed milk as carrier in conventional milk drying equipment after sieving through a 0.70 mm screen. The proportion of skim milk solids ranged from zero per cent with peas and corn, 50 per cent with crane berry and blue berry and 60 to 70 per cent with tomatoes and other highly hygroscopic fruits like apple, banana and pineapple.

Liquid glucose (39-43 DE) proved to be the most effective additive as spray drying aid for concentrated orange juice (Brennan *et al.*, 1971). The highest feed rate (34 g min^{-1}) was possible at an air inlet temperature of 140^0C. Recovery was 90 per cent with inlet and outlet air temperatures of 130 and 85 ^{0}C respectively.

Spray dried mango milk-shake powder was developed by Sharma *et al.* (1974). Concentrated skim milk (30per cent Total Solids), cream and sugar were well mixed and preheated to 50°C. Glycerol monostearate and sodium alginate in the ratio of 1:1 at the rate of one per cent of total solids of the mix was added with vigorous mixing for complete incorporation. The heated mix was filtered and homogenized at a temperature of 65-70°C followed by pasteurization at 65.5°C for 30 minutes and cooled to 10°C. The fruit pulp (20 per cent TS) was mixed with cooled concentrated milk. Each 100 kg mix was made to contain 36 kg fruit, 10.8 kg sugar, 52.6 kg concentrated skim milk, 14.0 kg cream and 400 g stabilizer. The mix was filtered and spray dried at an inlet and outlet air temperature of 170-175°C and 98-160°C respectively to give a product with final moisture content of 2.5 per cent

Jayaraman *et al.* (1976) successfully spray dried mango pulp in admixture with skim milk powder or double strength fresh whole milk. Total solids of the mix was adjusted to 15-20 per cent with water to facilitate drying. Spray drying was carried out with inlet and outlet air temperatures of 160-180°C and 60-70°C respectively using compressed air at a pressure of 1-2 kg cm^{-2} and 2.5 to 3.0 kg h^{-1} feed rate.

Sharma and Gupta (1978) developed a milk-shake mix with 4 per cent fat and 13 per cent MSNF. The whole milk was warmed to 40°C and skim milk powder was slowly added with continuous stirring to make MSNF 13 per cent. The temperature of the mixture was then raised to about 70°C and sugar-stabilizer mixture was added slowly with thorough mixing followed by filtering, homogenization and pasteurization at 71°C for 30 minutes. The mix was then spray dried at an inlet and outlet air temperature of 180°C and 95°C respectively.

Ice cream mix of 37.3 per cent total solids and containing only 25 per cent of the total amount of sugar was spray dried and the powder was dry blended with refined sugar in the ratio 100 parts : 41 parts to obtain free flowing ice cream mix powder (Bhandari and Balachandran, 1984).

An infant formula was developed by Rao and Mathur (1987) by spray drying. Skim milk was concentrated to 20 per cent total solids mixed with freshly separated cream and ground nut oil (62:38) and heated to 95°C. Vitamin mix and malto-dextrin were added to the mix, homogenized and spray dried in a co-current spray drier maintaining inlet air temperature of 210°C and outlet air temperature of 90°C.

Dacosta and Cal-Vidal (1988) attempted spray drying of coconut milk by adding anticaking agents, surface acting agents and corn starch at 15-20 per cent w/v. Coconut milk was homogenized after adding the additives and successfully spray dried using disc atomizer (10000 rpm) using inlet and outlet air temperature of 200 ± 10°C and 85 ± 10°C respectively.

Apple juice blended with skim milk was spray dried by Planovskii and Golovach (1988). The product obtained had 1.1 per cent fat and five per cent moisture. They suggested the use of the powder in the manufacture of icecreams, beverages and other confectionary.

Camacho *et al.* (1989) reported that sweet lupin slurry balanced to 20 per cent total solids was formulated with a blend of 0.2 per cent sodium chloride, 0.3 per cent tricalcium phosphate, 0.09 per cent sodium bisulphate, 0.44 per cent cocoa and 0.12 per cent flavourings. When spray dried at an inlet temperature of 170-210 ^{0}C and outlet temperature of 90^{0}C using centrifugal atomiser (35000 rpm) it yielded a good quality powder.

To enhance the energy use efficiency of spray drying, it was necessary to remove as much as water as possible by vacuum evaporation of the feed mix. For concentrated skim milk, with 47 per cent and 57 per cent total solids the viscosities were 70 and 140 mPa s^{-1}. For a concentrate at 50 per cent total solids, a pressure of at least 25 m Pa was necessary to ensure effective atomisation. By using high atomisation pressure and inlet air temperature, the heat transfer efficiency of the spray drier could be increased (Hayashi and Kudo, 1989).

Andruschchenko and Kasurin (1990) suggested feeding solution having 20-30^0 Brix at 60^{0}C and drying with air having temperature of 100-120^{0}C at inlet 80-100^{0}C in the spray zone and 75-85^{0}C at the outlet as optimum to get products with little degradation of sucrose into reducing sugars.

El-shibiny *et al.* (1994) developed a spray dried beverage powder from a 1:3 mixture of carrot juice and ultra filtration permeate of whole milk added with 0.2 per cent stabilizer. They reported that homogenisation at 200 kg cm^{-2} and concentration under vacuum to 25 per cent total solids prior to spray drying gave a product with 4.42 per cent moisture.

A ready-to-reconstitute tea powder was developed by Jha and Mann (1995). Milk was concentrated to 40 per cent total solids, mixed with tea leaf infusion, 25 per cent of required amount of sugar, 0.5 per cent stabilizer and 0.5 per cent emulsifier and spray dried at an inlet temperature of 180°C and outlet temperature of 80°C.

Spray dried coconut skim milk powder was produced by Ganesan (1996). Coconut milk obtained by wet grinding and pressing of coconut kernels was centrifuged to obtain coconut skim milk. Coconut skim milk thus obtained was concentrated in vacuum evaporator to 40 per cent total solids and spray dried in Anhydro spray drier using atomizer speed of 22,000 rpm (feed rate 3 l h^{-1}, feed temperature 35°C) at an inlet temperature of 120°C and outlet air temperature of 80°C.

Conovas and Mercado (1996) reported that the retention time of feed in spray drier was vital for heat sensitive products which range from 5 to 100 seconds. The particle size of the dried products ranged from 10 to 500 μ m, which was very small when, compared with products from other dehydration methods.

Typical inlet/ outlet temperatures of a spry drier for milk was 356^0 F/ 203^0 F and this could be modified to 428^0 F/ 185^0 F for optimisation of energy use efficiency, without damaging the product quality. Skim milk for spray drying was concentrated to approximately to 50 per cent solids in evaporator prior to introduction to the atomiser and dried to about 3.1 per cent moisture (Deis, 1997).

A Ready to use Banana Milk Shake Powder (RBMSP) was developed by Laxminarayana *et al.* (1997) by blending cow milk with 'Musa cavandishi' variety of banana in 5:1 proportion. The homogenised slurry along with 0.015 per cent carboxy methyl cellulose (CMC) was spray dried with an inlet air temperature of 160-180^0 C and an out let temperature 85-95^0 C. Ground sugar was blended with dried mix to obtain a final sugar content of 42.5 per cent in RBMSP. The proximate composition of the powder was moisture – 2.6 per cent, fat – 6.95 per cent, protein – 14.08 per cent, ash – 3.1 per cent and carbohydrate – 75.86 per cent on dry matter basis.

Gokavi (2000) reported procedure for production of malted cereal and milk based infant food. Cereal malt was cooked to which pasteurized whole milk containing buffer salts, soya oil, vitamin and mineral premix was added. The homogenized mix was concentrated at 40°C and 27 Hg pressure in a single evaporator to 40° Brix and dried in a spray drier at 150°C inlet and 90°C outlet temperature.

A clarified guava juice powder was developed by Chopra and Basset (2001) by spray drying which was stable and economical when compared with freeze dried and tunnel dried products. A spray dried orange juice blended with skim milk

powder to obtain vitamin C enrichment of milk was developed by Rao and Gupta (2002). A ratio of 15:85 for orange juice concentrate (60 per cent TS) and skim milk (30-35 per cent TS) was adopted. The mixture was homogenized and spray dried with an inlet/ outlet temperature of 180/80-85 ^{0}C. Lanes *et al.* (2003) obtained a satisfactory chocolate drink powder by spray drying a mixture of water, Cupassu (*Theobroma grandiflorum*) powder, sugar, flavourings etc.

Maya (2004) developed an instant sapota – milk beverage powder through spray drying, roller drying and cabinet drying. The spray drying parameter standardised were fruit and milk solids in 1: 0.5 ratio (milk with one per cent fat), the inlet / out let temperature were 185 and 90◦C respectively. In case of cabinet drying the optimum temperature was 80◦C for duration of 4.5 hours.

Mary (2005) reported the development of spray dried banana powder using ripe banana pulp. The optimum inlet air temperature was found to be 150 - 160◦C which gave a product of acceptable flavour, better recovery and good free flowing properties. She also reported the use of two per cent maltodextrin and three per cent soluble starch (corresponding to 25 per cent additive level on dry basis) as additives.

2.3.3 Cabinet Drying

Ambadan (1985) developed a delicious product from sapota by drying in an electrical drier maintained initially at 70^{0}C and finally at 50^{0}C for four days with eight hours of operation per day

Cabinet driers consisted of drying chambers which may be divided into several compartments each holding one or two stacks of trays (Loesecke, 1998). They are particularly suited for drying fruits and vegetables and in situations where operation of the dehydrating plant was not continuous or where production was in small scale or on experimental basis.

Bains *et al.* (1989) dried apple puree in cabinet drier at a temperature of 70°C, which retained better colour and flavour characteristics than the products dried at higher temperature. Accordingly, two-stage operation with a two hour initial drying at 102°C followed by finish drying at 85°C for 3.5 h gave a good quality product.

The method of production of tray-dried khoa consisted of preparation of khoa from buffalo milk (5per cent fat and 9per cent SNF), heating the product to reduce the moisture to about 20 per cent and converting it to fine particles (Rajorhia ,1989). Ground khoa was then uniformly distributed in trays in a thickness of 1 cm and dried in a tray drier at 70°C to get khoa powder with 3.8 per cent moisture.

A cereal based papaya powder was reported by Aruna *et al.* (1998). Cooked wheat flour was mixed with papaya pulp at 80-85°C and heated at this temperature to reduce volume to half. The mix was then dried in a drier at 60°C to obtain a product with five per cent moisture content.

Hassan and Ahamed (1998) developed foam-mat dried pineapple juice powder. Egg albumin (1%) was added to pineapple juice, blended for 10 minutes in a blender and spread on a tray at 3 mm thickness and dried at 55-60°C for five hours in a cabinet drier to reduce moisture content to 6 per cent. The product was detrayed, ground with addition of one per cent magnesium stearate, passed through 0.5 mm sieve and vacuum packed in 300 gauge HDPE bags.

Development of mango powder was attempted by Sagar and Khurdia (1998) using ripe mango. The fruit was cut into six length wise slices, dipped in an equal amount of 70°Brix sugar solution containing 0.1 per cent KMS, heated for 2 minutes at 90°C and soaked in the same solution overnight to ensure complete immersion. Next day, the slices were drained and dried in a cross flow cabinet drier at 58-60°C to a final moisture level of about 5 per cent. These slices were powdered with the

help of a powder mill and sieved with 30 mesh sieve. Mango-shake obtained by mixing this with milk, water and sugar in the ratio of 6:12:6:1 was rated the best.

Maya (2004) reported cabinet drying of sapota milk beverage with optimum temperature of 80^0 C for duration of 4.5 hours.

2.3.4 Formulation of Cocoa Based Products

The recent developments in product formulation based on cocoa are reviewed here under. Even though chocolate continue to be the main product from cocoa , attempts were also made to develop diversified products.

John (1979) described various cocoa based products other than chocolate *viz.* cocoa malt beverage, chocolate milk flavoured beverage, chocolate vermicelli, chocolate flavoured banana powder, chocolate stock syrup, bitter sweet chocolate syrup, chocolate malted milk, cocoa bread pudding, chocolate bun, chocolate ice cream, chocolate biscuits, chocolate carmel toffy, chocolate wafer and so on.

The technology for the preparation of a deep red or black dutched cocoa was patented by Wiant *et al.* (1991). The product developed was useful in bakery products, desserts, ice creams, cocoa beverages, toppings of ice creams, biscuits, confectionary and component coatings. A method of producing cocoa beverage by mixing cocoa powder, non fat milk solid, malto dextrin an emulsifier and an artificial sweetener was developed by Pray and Scott (1993). The mixture was ground, agglomerated and dried after 120 seconds. The process was patented.

Aremu *et al.* (1995) supplemented cocoa in bread formulation to enhance protein content. The recipe composed of white flour incorporated with ten per cent defatted cocoa powder and the product was found well acceptable as white bread. Bowman and Siebenga (1995) prepared a chocolate crumb suitable for production of milk chocolate.

Apart from chocolates a large number of food items are being prepared from cocoa (Frassino *et al.*, 1998). Drinking chocolate, chocolate flavoured milk, chocolate ice cream, cocoa malt beverage, chocolate flavoured fruit powder, chocolate biscuits, pudding and chocolate cake are a few among them and they are in use in different parts of the world.

Kimura and Terauchi (1998) patented a process for producing granular cocoa. The process comprised of granulating cocoa powder in a fluidised bed drier which easily dissolved in warm milk or water. Folkenberg *et al.* (1999) described some 14 samples of instant hot cocoa drinks with three main ingredients viz., fat reduced cocoa, sugar and skimmed milk powder with non-dairy creamer. The cocoa content varied between 20 and 40 w/w per cent of dry matter and the sugar and milk ingredient varied between 30 and 50 w/w per cent of dry matter. Each composition of main ingredient was investigated for sensory properties with and with out xanthan gum as stabilizer at a concentration of one w/w per cent of dry matter.

Low fat and fat free chocolate ice creams with 2.5 per cent milk fat, cocoa butter or whey protein based fat replacers were developed by Prindiville *et al.* (2000). The total solids were regulated by adding polydextrose. Ice creams with milk fat had less intense cocoa flavour and was more resistant to structural changes over time compared with others.

Omobuwajo *et al.* (2000) developed a chocolate drink powder by thermal agglomeration through heating a mixture of cocoa powder and sugar on metal plates by constant agitation. The best ratio obtained was 1:4 for cocoa and sugar. The physical and sensory properties of the products were compared with that of the commercial products like Milo, Bournvitta etc.

Bergerem and Bergerem (2002) developed a dry mix for the preparation of cocoa beverage which contained water soluble or insoluble cocoa powder together with a powder made by partial thermal or enzymic decomposition of ground saponin free amaranth, quinola or kanawa seeds. Use of Kola nut and cocoa in beverage

production was reported by Jayeola and Akinwale (2002). An instant beverage powder was formulated by mixing 20 per cent kola alone or kola and cocoa together, 10 per cent milk, 10 per cent corn starch and 60 per cent sugar. The different proportions of kola and cocoa powder tried did not make any significant difference in the quality of powder.

Amma *et al.* (2002) reported the method of small scale processing of cocoa by which plain, white and milk chocolates as well as drinking chocolate were prepared. A cocoa flavoured Shrikhand (a highly viscous and palatable fermented milk product popular in western India) was developed by Vagdalkar *et al.* (2002) by incorporating 5 per cent cocoa powder to standard recipe and named as 'chocoshrikhand'. Geetha and Manimegalai (2002) prepared an instant ice cream mix using cocoa powderand found that the quality viz. acidity, sugar and mineral content changed with increase in storage time.

Kealy *et al.* (2001) developed a dry chocolate flavoured drink or beverage mix containing cocoa components with enhanced level of polyphenol for which a patent has been filed. He suggested the use of the product along with sweetener, vanillin and emulsifier for preparing chocolate flavoured drink by addition of milk (Kealy *et al.* 2003).

Ramli (2003) could develop an instant cocoa beverage along with milk cream powder on laboratory scale First the liquid ingredients (evaporated milk, flavours and stabilizers) were dried in table top fluid bed drier and mixed with dry mix ingredients(fine sugar, full cream milk powder, cocoa powder and malt extract powder) by the process of atomisation, agglomeration and drying of the ingredients.

An agglomerated cocoa drink powder was prepared by Kowalska (2003) and studied the physical properties by varying the proportion of cocoa, sugar, milk powder and maltodextrin. It was found that the general powder properties improved when the powder was coated with sugar solution.

An improved thickened instant cocoa beverage mix which readily dissolved in water at a temperature of 120^0 F or more was formulated by Meister and O'Conner (2003) with 12-50 per cent agglomerated starch (thickening agent) together with sugar and protein components.

2.3.5 Physical Properties of Dehydrated Products

Water is the major component responsible for depressing the Tg value of food materials as water has a very low Tg value of -135^0C. Roos and Karel (1991) reported that Tg value of a product decreased as the moisture increased. Addition of lecithin, agglomeration and spray drying were described by Kneil (1993) as the methods of improving dispersability of instant cocoa powders.

According to Wu *et al.* (1994) cocoa suspensions exhibited a Newtonian property at a low particle concentration (phi=0.02-0.35) but strong Newtonian and shear thinning behaviour where particle concentration was high (phi>0.40). The intrinsic viscosity was 5.044 and dependence of relative viscosity on particle concentration was 4.787.

Fang *et al.* (1995) studied the role of lecithin and moisture in the rheological behaviour of cocoa dispersion. Model cocoa dispersions with cocoa powder of 0.502 had viscosity of 1.45 Pa.S and it increased with increasing powder content and exhibited shear thinning behaviour. Lecithin was added at the rate of 0.63 weight per cent. It decreased the viscosity due to lesser number of flocs in the suspension where as addition of moisture increased the viscosity as a result of partial gelation of starch in cocoa powder.

Hofstaetter (1996) could improve wettability of cocoa beverage powder (obtained by agglomerated cocoa and sugar with lecithin) by microwave treatment and the intrinsic viscosity of cocoa dispersed in cocoa butter was four to five. According to Deis (1997) instantisation of skim milk was done by rewetting and

agglomeration while that of whole milk involved some additional problems due to its fat content. Thus, to instantize whole milk powder, the final agglomerate was finely coated with lecithin which improved wettability.

Shen and Rosenberg (1998) reported that the structure of spray dried microcapsule was affected by type of carbohydrate and whey protein isolate: carbohydrate ratio. Combination of whey protein isolate with high dextrose equivalent (DE) carbohydrate was effective in limiting surface dents formation.

Murphy (1998) suggested the use of 'Textra', a tapioca based starch to overcome the settling problem in instant cocoa drinks. The starch acted as a texturising agent, increased body in thin liquids and improved mouth feel. It had a low gelatinization point (60^0C) and was easily dispersible and rapidly hydrable and gave the most acceptable beverage suspension of instant cocoa.

Papadakis *et al.* (1998) found that the solubility and hygroscopicity of spray dried raisin extract increased with decrease of its moisture content. According to Ganesan and Gothandapani (1999), the properties of spray dried coconut skim milk was bulk density-0.57 gcc^{-1}, moisture- 3.0 per cent, solubility- 89 per cent, fat- 3.0 per cent, proteins-13.0 per cent and sugar- 9.0 per cent.

Ganesan and Gothandapani (1999) reported that Scanning Electron Microscopy (SEM) of coconut skim milk powder revealed the shape of particle as almost spherical or oval. The bulk density of cocoa powder having 12 per cent fat was reported (Beckett, 1999) as between 0.35 and 0.40 g cm^{-3} after compaction.

Hla and Hogekamp (1999) studied the wetting behaviour of instant cocoa beverage produced by steam jet agglomeration and found that the high fat content (from milk) lead to longer wetting time. The wetting time was seven minutes for milk with 0.3 per cent fat and 11 minutes three seconds for milk with 3.5 per cent fat. Wetting of the drink increased by 20 times when the average particle size of sugar was reduced from 130 to 40μ m. Higher content of finer particles and cocoa content

in the powder resulted in increased wetting time. At 25 per cent cocoa content, wetting time was 7 seconds and there after increased rapidly. They concluded that it was difficult to produce beverage powder with greater than 20 per cent cocoa content.

SEM examination of spray dried emulsions based on whey protein concentrate (WPC) and skim milk was carried out by El-salam *et al.* (2000). The use of high protein WPC showed excessive indentation while that prepared with low protein WPC and skim milk showed almost spherical particles irrespective of the fat content in the powder.

Aryana and Haque (2002) studied the microstructure and function of spray dried Cheddar whey protein concentrates using SEM and TEM (Transmission Electron Microscopy) and found that vacuum evaporation combined with spray drying caused the formation of electron dense aggregates, improved packing density(which are important in packing the powder in large scale units) and improved gel elasticity.

Gangopadhyay *et al.* (2001) compared the microstructure of cow milk rosogolla and soy rosogolla using SEM. Soy rosogolla exhibited less number of large vacuoles and it was reverse in cow milk rosogolla. There were folded thread like structures which were uniform in cow milk rosogolla than in soy rosogolla. According to Reh *et al.* (2003), the friability angle of a free flowing powder generally falls below 90 degrees. According to Yanes *et al.* (2001) the shear stress-shear rate relationship of commercial chocolate milk beverages at 25^0C fitted mostly to Newtonian model and the values ranged from 2.67 to 18.68 Pa.S.

The key criteria for selection of cocoa powder for bakery applications was reported as flavour, colour , fat content , pH/ alkalinity, fineness and water holding capacity (Groot, 2001). Glass transition temperature (Tg) refer to the temperature at which there is physical change from the hard solid glossy state to the soft rubbery liquid state that occur in amorphous solids when they were subjected to heating.

Ozmen and Langrish (2002) determined the glass transition temperatue (Tg) of skim millk powder using differential scanning calorimetry. The Tg value decreased as the moisture content increased. The Tg was 87.7 ^{0}C for moisture content of 1.65 g /100g of dry powder and 46.7^{0}C for high moisture content of 4.52 g /100g of dry powder. The Tg was found virtually the same as sticky point temperature measured using a thermo mechanical test (using viscometer).

Wauters *et al.* (2002) reported that storage of fruit powders at temperature lower than Tg prevented caking and lumping. The Tg value showed strong dependence on powder moisture content (water activity). As the moisture content increased the Tg value decreased. Elevation of the powder temperature above Tg promoted viscous flow and increased the potential of caking (Hashimoto *et al.*, 2003)

Combination of corn / potato starch-xanthan gum were reported to be useful as thickeners, stabilisers and texture providers for cocoa syrups(Sikora *et al.*, 2003). Xanthan gum worked as a protective colloid improving the resistance of starch to elevated temperatures and high acidity. It stabilized starch paste at a pH as low as three and prevented retrogradation tendency (structural changes over time) and the relatively big molecules were capable of immobilising many water molecules. The syrups with starch-xanthan gum showed non-Newtonian, pseudoplastic properties with more or less apparent thixotropic properties. The commercial formulation with skimmed milk had viscosity of 1.62 Pa.S at constant rate of shear and 1.66 Pa.S at controlled rate of shear. The total sensory scores of syrups containing corn starch and 0.02 per cent as well 0.025 per cent xanthan gum were better than those of the best commercial formulation.

Lan and Fang (2003) reported that the physical properties of dehydrated agricultural products to be examined were size, shape, density, surface area, adsorption-desorption kinetics and response o electro magnetic radiation. Powder flow properties are important in handling and processing operation especially from the hoppers and transportation and packaging. Fitzpatrick *et al.* (2003) measured such properties of cocoa powder and non fat milk (NFM) powder and found that

flow index, particle size, moisture and bulk density of coca powder were 1.5, 7.5μ m, 4.4 per cent and 360 kg m^{-3} respectively. For NFM powder the respective parameters were 3.8, 4.3μ m, 4.6 per cent and 690 kg m^{-3}. The flowability was found to increase with increase of flow index.

Reh *et al.* (2003) estimated the moisture content of instant milk powder and skimmed milk powder, which ranged from 1.19 to 5.28 weight per cent with an average of 3.5 weight per cent. Temperature together with water content played a major role in the process of plasticization, which led to agglomeration of food powders. Keogh *et al.* (2004) studied the effect of particle size of spray dried milk powder on properties of chocolate. The particle size of 132-162μm was found suitable for chocolate making.

2.3.6 Cost of Production

Maya (2004) worked out the cost of production for a pilot plant producing 1000 kilogram spry dried sapota milk beverage powder per day as Rs.70 per 500 g. In case of spray dried banana powder the cost of production was Rs.26.61 per 100 g (Mary, 2005). Among the different components of total cost, raw material alone accounted for 70.35 % and the cost of production of the spray dried powder was 42.65% higher when compared to drum dried powder.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on 'Standardisation of technology for value addition of Cocoa (*Theobroma cacao* L)' was taken up in the Department of Processing Technology, College of Horticulture Vellanikkara during the period 2002-2005. The facilities available at Cadbury-KAU, Co-operative Cocoa Research Project Vellanikkara and KAU Dairy Plant Mannuthy were utilised for the study.

The study comprised of the following experiments,

1. Standardisation of primary processing of cocoa for small scale unit.
2. Standardisation of secondary processing of cocoa for small scale unit
3. Development of value added product from cocoa *viz.*, ready to use beverage powder and evaluation of its suitability for preparation of other products.

3.1 STANDARDISATION OF PRIMARY LEVEL PROCESSING OF COCOA

Studies on primary level processing consisted of experiments on fermentation, drying and storage of beans

3.1.1 Effect of Pod Storage and Pectinase Application on Fermentation

In India, cocoa beans are usually subjected to heap method of fermentation (Wood and Lass, 1985). To enhance the rate of fermentation and to obtain maximum per centage of properly fermented beans the experiment was taken up.

Mature pods of cocoa cv. Forastero were harvested when yellow colour appeared and stored as heaps for varying periods viz. 0, 2, 4 and 6 days. Each lot consisted of around 3000 pods. At the end of specified periods beans were extracted from the pods manually by hitting the pods against stones. The beans from pods at different intervals of storage were then subjected to fermentation with and without adding pectinase. The treatments were as follows

T_1- beans from freshly harvested pods

T_2- beans from pods stored for two days

T_3- beans from pods stored for four days

T_4- beans from pods stored for six days

T_5- T_1 treated with 0.01 per cent pectinase

T_6- T_2 treated with 0.01 per cent pectinase

T_7- T_3 treated with 0.01 per cent pectinase

T_8- T_4 treated with 0.01 per cent pectinase

Beans under each treatment were subjected to heap method of fermentation for seven days (Wood and Lass, 1985). The heaps were set by spreading green plantain leaves on raised concrete floor with provision to collect sweating. The heaped beans were covered with green plantain leaves. Over the plantain leaves gunny sacks were spread and were kept in position by means of bricks to avoid loss of heat during fermentation process (Plate 1).

The pectinase solution (SRL make) was prepared by dissolving commercial pectinase at the rate of one gram in one litre of distilled water. Two litres of the solution was poured over each heap and mixed thoroughly. The heaps were dismantled and mixed thoroughly at alternate days interval to facilitate uniform fermentation and aeration.

The experiment was conducted during April- May, 2003(I) and September-October 2003(II), the two major cocoa harvest seasons of Kerala.

Design: CRD

Treatments: 16 (2x4x2)

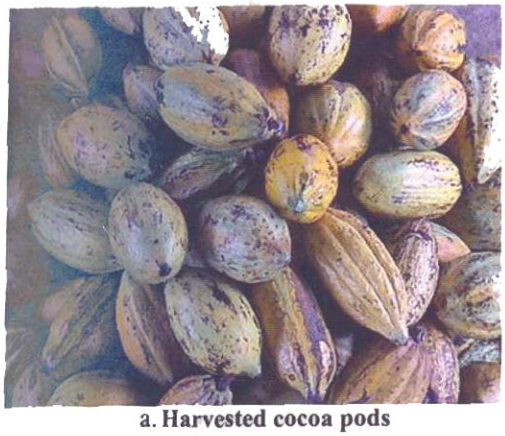
Replications: 3

Sample size: 50 Kg

3.1.1.1 Physical parameters

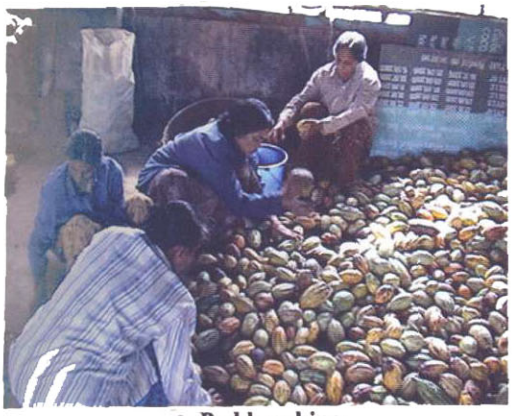
Observations were recorded daily on temperature and moisture content of fermenting mass and the amount of sweating exuded from the fermenting mass as

Plate 1. Primary Processing - Fermentation



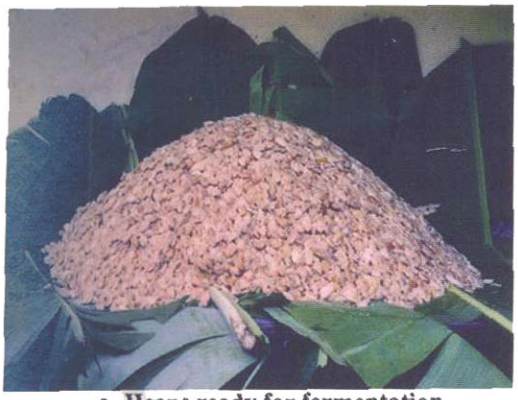
a. Harvested cocoa pods

b. Colour change on stored pods



c. Pod breaking

d. Whole and broken pod



e. Heaps ready for fermentation

f. Heap undergoing fermentation

given below. Samples were collected from three different positions from the heap and pooled together for recording various observations.

3.1.1.1.1 Temperature profile of fermenting mass

Temperature was measured by inserting an ordinary thermometer (0-50^{0}C range) into the fermenting mass at three different positions of heap. From each position observation was taken thrice and the average was calculated.

3.1.1.1.2 Sweating

Sweating was collected separately at the end of 24 and 36 hours of fermentation from each heap, measured in millilitres and pooled to get the total yield.

3.1.1.1.3 pH of pulp

Samples were drawn from three different positions of fermenting mass and pH of the pulp and cotyledon were measured separately using a digital pH meter (ELICO-612 model).

3.1.1.1.4 pH of bean

Measured as given in 3.1.1.1.3

3.1.1.1.4 Moisture

Samples were collected from three different positions of fermenting mass and moisture content of beans was determined by hot air oven method, average was calculated and expressed in per cent (Ranganna, 1986).

3.1.1.2 Biochemical parameters

Observations on the following biochemical parameters of fermenting mass were recorded on alternate days up to seventh day.

3.1.1.2.1 Anthocyanin

Anthocyanin content of beans was determined as described by Sweon and Hills (1959).

3.1.1.2.2 Amino acid

The amino acid content was measured as per the method given by Sadasivam and Manickam (1996).

3.1.1.2.3 Polyphenol

Determined as described by Sadasivam and Manickam (1996).

3.1.1.3 Microbial load

Microbial population of fermenting mass was determined by observing the total counts of bacteria, yeast and fungi through serial dilution and pour plate technique (Ranganna, 1986). The media used were Nutrient Agar for bacteria, Rose Bengal Agar for fungus and Sabourouds Dextrose medium for yeast. The media compositions are given in Appendix I. The observations were expressed as number of colony forming units (CFU) per gram.

3.1.2 Evaluation of Drying Methods

After fermentation, the beans from different treatments were subjected to two drying methods, viz., sun drying and cabinet drying. In the case of sun drying, after

dismantling the heaps, the beans were spread on bamboo mats at a thickness of one to one and half inches and raked occasionally (Plate 2). The drying was stopped when the beans produced a rattling sound during raking and the shell became brittle. Also, attainment of moisture content of beans to a level of six per cent or less was taken as confirmative criteria to determine the end point of drying.

For cabinet drying, the fermented beans were first spread on perforated trays till the dripping of exudates stopped. These trays were then loaded into the cabinet dryer and dried at a temperature of 60 ^{0}C. Raking was done occasionally till the beans were properly dried. Samples were drawn on alternate days from beans which were undergoing both sun drying and cabinet drying and analysed for the following parameters.

3.1.2.1 Moisture content of beans

Determined as given in 3.1.1

3.1.2.2 pH of the beans

Determined as given in 3.1.1

3.1.2.3 Polyphenol

Determined as given in 3.1.1

3.1.2.4 Amino acid

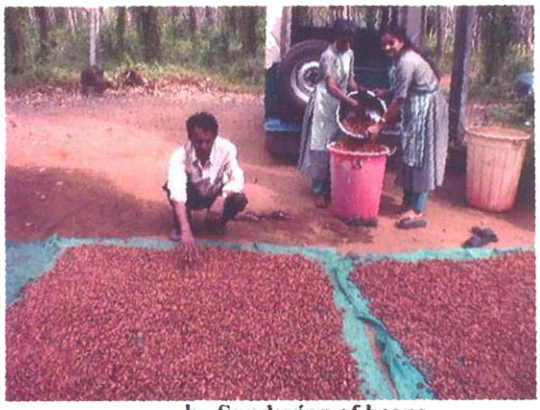
Determined as given in 3.1.1

3.1.2.5 Anthocyanin

Determined as given in 3.1.1

Plate 2. Primary processing - Drying

a. Fermented beans



b. Sundrying of beans

c. Sundried and oven dried beans

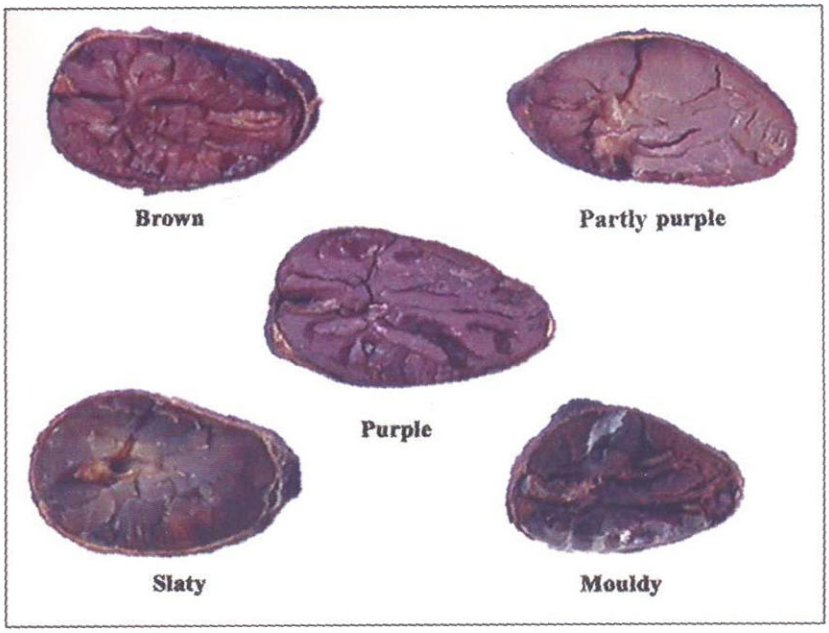


Plate d. Beans showing different degrees of fermentation (Cut test)

3.1.2.6 Cut test

The dried beans were subjected to cut test as described by Wood and Lass (1985). Based on this test, the beans were grouped into five categories *viz.*, brown, partly brown or partly purple, purple, slaty and mouldy. Relative weightages were assigned to each group of beans and the total score for each treatment was worked out (Appendix II).

3.1.2.7 Recovery percentage

Recovery percentage of dried beans was calculated as follows, after the beans were dried properly.

$$\text{Recovery per cent} = \frac{\text{Weight of dried beans x100}}{\text{Weight of fresh beans}}$$

3.1.3 Studies on Storage of Dried beans

The beans obtained from ideal fermentation and drying method identified through experiments 3.1.1 and 3.1.2 were subjected to the following storage treatments.

T_1-Beans packed in HDPE bags

T_2- Beans packed in polythene lined gunny bags

T_3- Beans packed in gunny bags with double lining of polythene

T_4- T_1+ neem leaves @ of 1Kg per 100 Kg beans

T_5- T_2+ neem leaves @ of 1Kg per 100 Kg beans

T_6- T_3+ neem leaves @ of 1Kg per 100 Kg beans

T_7- Control (beans stored with out packaging)

The experiment was carried out in CRD with three replications. Each treatment consisted of two kilogram beans. The beans were stored for one year and samples were drawn at bimonthly interval and analysed for the following parameters.

3.1.3.1 Moisture content

Determined as given in 3.1.1

3.1.3.2 pH of beans

Determined as given in 3.1.1

3.1.3.3 Amino acid content

Determined as given in 3.1.1

3.1.3.4 Polyphenol

Determined as given in 3.1.1

3.1.3.5 Anthocyanin

Determined as given in 3.1.1

3.1.3.6 Microbial load

Determined as per the procedures given in 3.1.1

3.2 SECONDARY LEVEL PROCESSING

3.2.1 Effect of Alkalisation and Storage on Cured beans

The beans obtained from ideal method of fermentation and drying (Expt. 3.1.1and 3.1.2) were subjected to alkalisation by soaking in sodium carbonate solution at a temperature of 80-85 ^{0}C. Soaking was done in two different concentrations of alkali viz., one per cent and one and half per cent for four durations viz., one , two, three and four hours.

Thus, the treatments were as follows

T_1 - One hour soaking in one per cent alkali

T_2 - Two hours soaking in one per cent alkali

T_3 - Three hours soaking in one per cent alkali

T_4 - Four hours soaking in one per cent alkali

T_5 - One hour soaking in 1.5 per cent alkali

T_6 - Two hours soaking in 1.5 per cent alkali

T_7 - Three hours soaking in 1.5 per cent alkali

T_8 - Four hours soaking in 1.5 per cent alkali

T_9-Control (soaking in warm water at 80 to 85^{0}C)

The beans were then drained and dried in the sun till the moisture content was reduced to about six per cent. The dried beans were packed in polythene lined gunny bags and stored for six months. Samples were drawn at bimonthly interval and analysed for the following parameters.

3.2.1.1 Moisture content

Determined as per the procedure given in 3.1.1

3.2.1.2 pH of beans

Determined as per the procedure given in 3.1.1

3.2.1.3 Amino acid

Determined as per the procedure given in 3.1.1

3.2.1.4 Polyphenol content

Determined as per the procedure given in 3.1.1

3.1.3.5 Anthocyanin

Determined as per the procedure given in 3.1.1

3.1.3.6 Microbial load

Determined as per the procedure given in 3.1.1

3.2.1.1 Sensory evaluation of chocolate

To assess the effectiveness of alkalisation treatments, chocolate was prepared (Amma *et al.*, 2004) at the end of storage period using the beans under each treatment separately. Sensory evaluation of the chocolate was done for colour, flavour, taste consistency and overall acceptability with a five point hedonic scale (Score card given in Appendix III) using a semi-trained panel consisting of ten members.

3.2.2 Effect of Size and Method of Roasting on Quality of Beans

The cured cocoa beans were grouped into three categories based on their size, considering the average weight and volume, as given below:

1. Big size: Average weight of 1.2g and volume of 1.45 cm^3
2. Medium size: Average weight of 0.85g and volume of 1.13 cm^3
3. Small size: Average weight of 0.68 g and volume of 0.98 cm^3

Each category of beans was subjected to two methods of roasting viz., roasting in shallow pans (conventional roaster) and roasting in small scale roaster available at the CCRP unit (Plate 3). Thus, there were six treatments replicated thrice in CRD design.

Samples were drawn from each treatment and analysed for the following parameters.

3.2.2.1 pH of nibs

Determined as per the procedure given in 3.1.1

3.2.2.2 Non volatile organic acid content

Estimated as suggested by Ranganna (1986) and was expressed as per cent acid equivalent to acetic acid.

3.2.2.3 Amino acid content

Estimated as per the method given in 3.1.1

3.2.3. Influence of Duration of Grinding on Quality of Chocolate

The beans subjected to ideal method of roasting were kibbled and the nibs obtained were ground in a small scale grinder (SHANTHA, 3 litre capacity) for varying periods given below.

T_1- Nibs ground for two hours

T_2- Nibs ground for four hours

T_3- Nibs ground for six hours

T_4- Nibs ground for eight hours

The ground mass under each treatment was then pressed separately in a hydraulic press and the butter and powder recovery were recorded. The powder was analysed for the following parameters.

Plate 3. Equipments used for secondary processing

Small scale roaster

c. Hydraulic press for butter extraction

b. Grinder

d. Hammer mill

3.2.3.1 Fat content

Total fat in the powder was determined using a Soxhlet apparatus as described by Ranganna, (1986).

3.2.3.2 Particle size

Five gram of the powder was placed in a Soxhlet apparatus extracted with petroleum ether (40-60^{0}C) for one hour to reduce the fat content. At the end of extraction, the material was removed from the thimble and evaporated on a steam bath to remove the petroleum ether completely. The lumps were disintegrated and 25 gram of the material was taken on an IS sieve 30 (0.5 mm). It was shaken for two minutes in a mechanical shaker and the materials that have passed through the sieve were collected and weighed (BIS, 1984).

Particle size was worked out using the formula,

Particle size = W1/W2 x 100

Where, W1= weight in gram of the material that passed through the sieve,

W2= weight in gram of the fat free material taken for sieving.

3.2.3.3 Bulk density, average particle density and per cent volume occupied by powder particle

Bulk density of the powder was calculated as per the method described by Beckett *et al.* (1962). Fifty millilitre hexane was taken in a 100 ml graduated glass cylinder and covered with aluminium foil. The volume of hexane (V_1) and total weight of cylinder with hexane (W_1) were recorded. Cocoa powder was then added slowly through a funnel into the cylinder to increase the volume by about 40 ml. The cylinder was again covered with aluminium foil and placed on a level and vibration free surface. After one hour, the volume of powder (V_3) and hexane (V_2) were noted in the cylinder (which is clearly demarcated by separate layers). The total weight of the cylinder with the contents (W_2) was also recorded. Bulk density was calculated using the formula,

Bulk density = $\frac{W_2 - W_1}{V_3}$

The average particle density was determined as $\frac{W2 - W1}{V2 - V1}$

and

the per cent volume occupied by the powder particle as $\frac{V2 - V1}{V3}$

3.2.3.4 Sensory evaluation

Chocolate was made out of powder obtained from various grinding treatments (3.2.3) and subjected to sensory evaluation as given in 3.2.1.1.

3.3 VALUE ADDITION AND PRODUCT DEVELOPMENT.

3.3.1 Experiments on Spray Drying

3.3.1.1 Standardisation of temperature regime for spray drying

Experiments were conducted to standardise the inlet/outlet temperature for spray drying of the instant chocolate beverage powder

3.3.1.2 Standardisation of feed composition for instant chocolate beverage

To standardise an ideal cocoa beverage mix, cocoa powder, milk, sugar and other ingredients (malto-dextrin, gelatine and lecithin) mixed in various proportions were subjected to spray drying.

3.3.1.2.1 Preparation of ingredients

Ingredients (% solid basis)	Cocoa (25% fat)	Milk solids
T_1	21	55
T_2	14	66
T_3	21*	70
T_4	14*	75
T_5	15	60
T_6	14	63
T_7	14	63

i) Cocoa powder

Cocoa powder produced by adopting the most ideal primary and secondary levels of processing evolved through the present study was used for preparing the beverage mix. The mean fat content of the powder was as 25 per cent. When cocoa powder with low fat content was required, it was produced by heating the ground cocoa mass upto 80^0 C in a water bath prior to pressing. The powder thus obtained was sieved using a 0.5 mm sieve for using in the trials.

ii) Milk.

Fresh cow milk obtained from the Dairy Plant, Kerala Agricultural University, Mannuthy, was used.

iii) Cane sugar, maltodextrin and other additives.

Cane sugar, soy lecithin, gelatin etc were obtained from the local market. Maltodextrin of 20 dextrose equivalent (DE) was procured from M/s Ridhi Sidhi, Bangalore.

3.3.1.2.2 Composition of beverage mix.

An intensive trial was taken up to standardize an ideal ingredient mix including cocoa powder, milk and other additives for developing an instant chocolate beverage powder (ICBP). Varying proportions of cocoa and milk solids tried were given above.

3.3.1.2.3 Preparation of beverage mix.

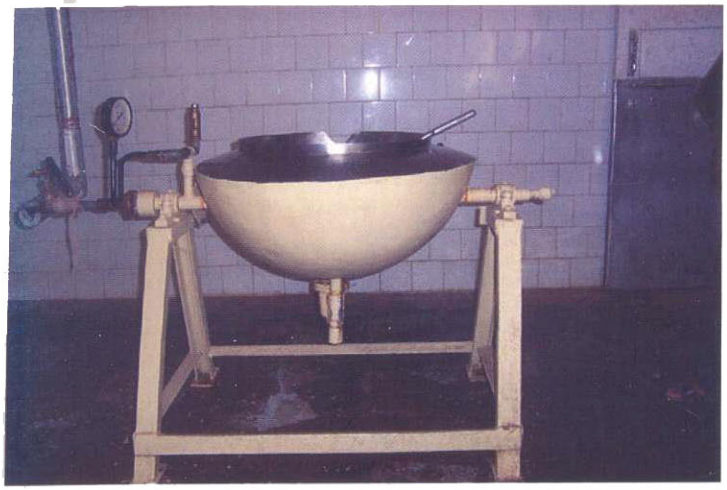
Fresh cow milk was collected and boiled in a steam jacketed vessel and then subjected to vacuum concentration in a vacuum evaporator (ANHYDRO, Denmark). The TSS of the concentrated milk was determined using Erma Hand refractormeter and the weight was recorded. Cocoa powder, maltodextrin, gelatin and lecithin were taken as shown under various treatments. Cocoa powder, maltodextrin and gelatin (after dissolving in 50 ml hot water) were added to one kilogram pre-boiled milk. A portion of sugar and the whole lecithin were also added to this mix whenever necessary. The mixture was then added to concentrated milk and mixed using a mixer grinder and then homogenised at a pressure of about 50 kg cm^{-3} in a two stage homogeniser (APV Gaulin, Gaulin Corporation, USA). The TSS of beverage mix was recorded and subjected to both spry drying and cabinet drying (Plate 4).

3.3.1.2.4 Spray drying of the beverage mix.

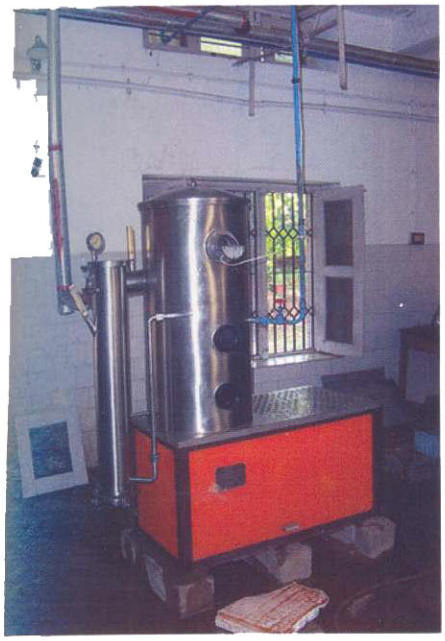
The prepared beverage mixtures were spray dried separately in a laboratory model spray drier (ANHYDRO, Denmark) with centrifugal disc type atomiser and co-current air flow (Plate 6).

The spray drier was thoroughly cleaned and the air blow and electrical heating system was switched on. When the inlet air temperature reached 110°C hot water at 80°C was fed in to the feed bowl. The atomiser was switched on and the disc speed was slowly increased and maintained at 22000 rpm. Water was fed into the

Plate 4. Equipments used in spray drying



a. Steam jacketed milk boiler



'ANHYDRO' vacuum evaporator

c. Homogeniser

Plate 5. Cabinet drying of bevrage mix

Plate 6. Equipments used in spray drying (contd.)

d. 'ANHYDRO' spray dryer (insight: Rotary atomiser)

atomiser with the help of a peristaltic pump. The feed rate of water was adjusted such that the out let air temperature was maintained at 90°C. When the inlet air reached the desired temperature and the out let air temperature was stabilized at 90°C, prepared beverage mix was fed into feed bowl. Atomisation of mix was observed through the sight glass. The beverage mix after atomisation got mixed thoroughly with the hot air in the drying chamber and was instantly converted to powder. The powder particles were collected at the conical bottom of the drying chamber and then carried by the air into the cyclone separator. Inside the cyclone separator powder particle were separated from the air and was collected in a basket. The powder collected in the basket was cooled and then packed.

3.3.1.3 Effect of ingredient proportion

The following physico-chemical properties of the feed material as well as spray dried powders were determined and compared.

3.3.1.3.1 Viscosity of feed material

Viscosity of the homogenised feed material was measured with a Brookfield Viscometer (Model HAT 204413) using spindle No. 2.

3.3.1.3.2. Moisture

Moisture content of the finished powder was determined using an infrared moisture meter and expressed as the percentage.

3.3.1.3.3. Bulk density

Bulk density was determined as per the method described in section 3.2.3.

3.3.1.3.4 Total fat content

Determined as given in 3.2.3.1

3.3.1.3.5 Particle size

Determined as given in 3.2.3.1

3.3.2. Cabinet Drying

Cabinet drying of the prepared beverage mix was done in a laboratory type drier with approximate dimensions of 0.9 x 1x 0.61 m^3 with 2 KW heating capacity (Plat 5). The mix was spread on a stainless steel plate at the rate of 2 Kg m^{-2} and dried at a temperature of 60°C. The dried material was separated as flakes from the plate. It was then ground to a fine powder in a dry grinder. The powder was sieved using a 0.50 mm sieve, cooled and packed.

3.3.2 Dry blending of Sugar

Both spray dried and cabinet dried powders were blended with calculated quantities of cane sugar in a grinder. First the sugar was ground to fine powder and sieved using 0.5 mm sieve and then used for dry blending with different beverage powder formulation. The quantity of sugar used was such that the final product contained about 50 per cent sugar.

3.3.3 Comparison of spray dried and cabinet dried beverage powders.

The following properties of the spray dried and cabinet dried powders were determined for comparing them.

3.3.4.1 Moisture

Moisture content of the finished powder was determined using an infrared moisture meter and expressed as the percentage.

3.3.4.2 Bulk density, average particle density and the per cent volume occupied

Bulk density was determined as per the method described in section 3.2.3.

3.3.4.3 Recovery per cent

Powder recovery per cent on dry weight basis was calculated using the formula,

$$\frac{\text{Weight of powder obtained x 100}}{\text{Weight of total solids in the feed material}}$$

3.3.4.4 TSS

The TSS was determined by using an Erma hand refractometer. For this, 25 g of the powder was reconstituted with 100 ml water and reading was taken.

3.3.4.5 Fat content

Determined as given in 3.2.3.1

3.3.4.6 Dispersibility

Dispersibility is inversely proportional to sedimentation. It is expressed as percentage of solid that got sedimented after 24 hours of reconstitution. For this 52 g powder was mixed with 400 ml water in a mixie for 20 seconds and allowed to stand for five minutes and kept in beakers of 25 ml capacities. The supernatant fluid was taken at zero and 24 hours to determine total solids (Sharma *et al.* 1974).

3.3.4.7 Flowability (angle of repose)

The flowability of the powder was determined by determining the angle of repose (Reineccius, 2004). The angle of repose was measured by dropping 10g powder through a funnel of 0.50 cm diameter on the neck kept at an elevation of five inches. The angle of the powder pile above horizontal plane was measured.

3.3.4.8 Sorption behaviour of the beverage powder.

Moisture sorption behaviour of the powder was studied as suggested by Ranganna (1986).

RH (%)	Normality of H_2SO_4
0	Concentrated H_2SO_4
5	22
10	19.5
15	18
20	16.8
25	15.8
30	14.9
50	11.5
95	2.3

The powder was exposed to atmosphere of different relative humidities ranging from zero to 35 per cent at constant temperature of 28 ± 2 until equilibrium was reached. Two grams of the powder in triplicate was used for each treatment. The required relative humidities were provided by use of different normalities of H_2SO_4 in a desiccator as given above. The critical and danger points were identified according to weight equilibrium method (Wink, 1946). Equilibrium Moisture Content and Equilibrium Relative Humidity were calculated and the values were plotted to get moisture isotherm.

3.3.4.9 Glass transition temperature (Tg)

Glass transition temperature was determined using Differential Scanning Calorimeter (DSC) of make Mettler Toledo and Model DSC 822e.

3.3.4.10 Microstructure

Scanning electron microscopy of spray dried and cabinet dried powder samples were done to study the morphology and particle size.

3.3.4.11 Cost of production

Cost of production of 500 gram each of spray and cabinet dried chocolate-milk beverage powder was estimated first and from this cost of 50 g ICBP (which gives 200ml beverage) packed in metallised polyester pouches was calculated. The following items of cost were considered for the estimation of cost of production.

i)Working capital: Working capital includes the cost of raw materials viz., cocoa, milk, additives and sugar, cost of fuel and labour involved for the production of five kilogram of the dried product.

(ii) Interest on working capital: Interest on working capital was estimated at the rate of 12 per cent per annum and apportioned based on the duration of working for the production of 5 kg of the product.

(iii) Depreciation of machineries: Depreciation at the rate of 10 per cent per annum was calculated and apportioned on the basis of working hours of each machinery (Appendix IV).

(vi) Interest on fixed capital: Interest on fixed capital, excluding land and building, at the rate of 12 per cent per annum and apportioned on the basis of working hours was taken for estimation of cost of production.

3.3.5 Suitability of ICBP for preparation of beverage and other products.

3.3.5.1 Reconstitution of beverage and sensory evaluation

Twenty five gram of the powder from selected treatments were reconstituted first by making it into a paste using required quantity of hot water and then making up the volume to 100 ml. The reconstituted beverage was subjected to sensory evaluation as given in 3.2.1.1

3.3.5.2 Chocolate

Chocolate was prepared with the most acceptable instant cocoa beverage powder selected through experiment 3.3.8.the standard recipe for preparation of chocolate in small scale units developed by Amma *et al.* (2004) as given below was used

Standard recipe

Milk powder	-	150 g
Sugar	-	150 g
Cocoa powder	-	30 g
Butter	-	40 g
Vanilla essence	-	one drop
Water	-	75 ml

As the ICBP already contains cocoa powder, sugar and milk powder they were not added further while preparing chocolate using the standard recipe. The quantity of ICBP was fixed as 330 g in all the treatments to provide approximately 150 g sugar and 150 g milk solids and 30 g cocoa powder.

The quantity of butter and water was varied and the treatments were as follows.

T_1 – 330 g powder + 40 g butter +75 ml water

T_2 - 330 g powder + 30 g butter + 75 ml water

T_3- 330 g powder + 20 g butter +50 ml water

Results

4. RESULTS

The results of the present study entitled 'Standardisation of technology for value addition of Cocoa (*Theobroma cacao* L)' are presented in this chapter under the following sections

1. Standardization of primary processing of cocoa for small-scale units.
2. Standardization of secondary processing of cocoa for small- scale units.
3. Development of value added products from cocoa.

4.1 STANDARDISATION OF PRIMARY PROCESSING FOR SMALL SCALE UNITS.

The data recorded on the physical parameters (temperature variation of fermenting mass, pH of pulp and bean, quantity of sweating produce during initial stage of fermentation and moisture content of beans), biochemical characters of beans (anthocyanin, polyphenol and amino acid content) and microbial load on fermenting mass in relation to storage of pods for varying periods (ranging from 0 to 6 days) and application of pectinase given to aid the fermentation process were analyzed and the results are presented here under.

4.1.1 Effect of pod storage and pectinase treatment on fermentation of beans.

4.1.1.1 Physical parameters

4.1.1.1.1 Temperature profile of fermenting mass

The data on daily mean temperature of fermenting mass under various treatments recorded during both the seasons are given in Table 1. There was significant difference between season as well as treatments with respect to temperature build up in the fermenting mass.

Table 1. Effect of pod storage and pectinase application on temperature profile of fermenting mass

Treatment	Temperature (°C)											
	Season I (April-May)						Season II (September-October)					
	Days of fermentation						Days of fermentation					
	2	3	4	5	6	7	2	3	4	5	6	7
T_1	33.33	34.16	32.67	36.67	37.50	34.83	31.83	35.00	39.00	37.00	42.00	42.33
T_2	30.50	32.16	35.50	36.67	35.50	35.83	33.33	36.00	39.00	41.33	43.00	42.33
T_3	30.33	34.66	38.83	41.33	41.50	28.50	32.67	34.33	38.83	42.67	43.33	42.33
T_4	32.50	32.83	33.33	33.67	34.83	34.17	31.50	35.83	38.50	41.83	42.17	41.67
T_5	33.00	32.83	36.50	37.00	37.33	35.00	30.17	36.83	41.83	37.00	41.33	41.33
T_6	32.33	34.30	34.16	34.17	38.00	36.17	31.33	35.33	38.17	43.00	40.00	42.00
T_7	32.33	34.00	34.50	33.83	35.33	33.33	38.83	42.83	46.33	45.83	44.33	45.00
T_8	29.33	33.66	34.83	36.50	37.00	35.67	32.33	36.00	37.50	39.00	39.67	39.33
Mean	31.75	34.16	35.05	36.23	37.13	34.19	32.75	36.52	39.83	40.96	41.98	42.04
SE	1.87											
CD	3.69											

Table 2. Effect of pod storage and pectinase application on collection of sweating

Treatment	Sweat collection (ml)					
	I season			II season		
	24h	36h	Total	24h	36h	Total
T_1	3990	2090	6080	6500	2400	8900
T_2	3100	1140	4240	3345	1285	4630
T_3	1455	773	2228	4050	3060	7110
T_4	1150	398	1548	2045	705	2750
T_5	6750	1889	8639	7590	2660	10250
T_6	2250	1312	3562	4990	1030	6020
T_7	3980	1464	5444	5540	1500	7040
T_8	2985	1357	4342	5400	3290	8690
Mean	3207.5	1302.9	4510.4	4932.5	1991.3	6923.8
SE	0.001					
CD	0.002					

Table 1. Effect of pod storage and pectinase application on temperature profile of fermenting mass

Treatment	Temperature (°C)											
	Season I (April-May)						Season II (September-October)					
	Days of fermentation						Days of fermentation					
	2	3	4	5	6	7	2	3	4	5	6	7
T_1	33.33	34.16	32.67	36.67	37.50	34.83	31.83	35.00	39.00	37.00	42.00	42.33
T_2	30.50	32.16	35.50	36.67	35.50	35.83	33.33	36.00	39.00	41.33	43.00	42.33
T_3	30.33	34.66	38.83	41.33	41.50	28.50	32.67	34.33	38.83	42.67	43.33	42.33
T_4	32.50	32.83	33.33	33.67	34.83	34.17	31.50	35.83	38.50	41.83	42.17	41.67
T_5	33.00	32.83	36.50	37.00	37.33	35.00	30.17	36.83	41.83	37.00	41.33	41.33
T_6	32.33	34.30	34.16	34.17	38.00	36.17	31.33	35.33	38.17	43.00	40.00	42.00
T_7	32.33	34.00	34.50	33.83	35.33	33.33	38.83	42.83	46.33	45.83	44.33	45.00
T_8	29.33	33.66	34.83	36.50	37.00	35.67	32.33	36.00	37.50	39.00	39.67	39.33
Mean	31.75	34.16	35.05	36.23	37.13	34.19	32.75	36.52	39.83	40.96	41.98	42.04
SE	1.87											
CD	3.69											

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Treatment	Sweat collection (ml)					
	I season			II season		
	24h	36h	Total	24h	36h	Total
T_1	3990	2090	6080	6500	2400	8900
T_2	3100	1140	4240	3345	1285	4630
T_3	1455	773	2228	4050	3060	7110
T_4	1150	398	1548	2045	705	2750
T_5	6750	1889	8639	7590	2660	10250
T_6	2250	1312	3562	4990	1030	6020
T_7	3980	1464	5444	5540	1500	7040
T_8	2985	1357	4342	5400	3290	8690
Mean	3207.5	1302.9	4510.4	4932.5	1991.3	6923.8
SE	0.001					
CD	0.002					

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Treatment	Temperature (°C)											
	Season I (April-May)						Season II (September-October)					
	Days of fermentation						Days of fermentation					
	2	3	4	5	6	7	2	3	4	5	6	7
T_1	33.33	34.16	32.67	36.67	37.50	34.83	31.83	35.00	39.00	37.00	42.00	42.33
T_2	30.50	32.16	35.50	36.67	35.50	35.83	33.33	36.00	39.00	41.33	43.00	42.33
T_3	30.33	34.66	38.83	41.33	41.50	28.50	32.67	34.33	38.83	42.67	43.33	42.33
T_4	32.50	32.83	33.33	33.67	34.83	34.17	31.50	35.83	38.50	41.83	42.17	41.67
T_5	33.00	32.83	36.50	37.00	37.33	35.00	30.17	36.83	41.83	37.00	41.33	41.33
T_6	32.33	34.30	34.16	34.17	38.00	36.17	31.33	35.33	38.17	43.00	40.00	42.00
T_7	32.33	34.00	34.50	33.83	35.33	33.33	38.83	42.83	46.33	45.83	44.33	45.00
T_8	29.33	33.66	34.83	36.50	37.00	35.67	32.33	36.00	37.50	39.00	39.67	39.33
Mean	31.75	34.16	35.05	36.23	37.13	34.19	32.75	36.52	39.83	40.96	41.98	42.04
SE	1.87											
CD	3.69											

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Treatment	Sweat collection (ml)					
	I season			II season		
	24h	36h	Total	24h	36h	Total
T_1	3990	2090	6080	6500	2400	8900
T_2	3100	1140	4240	3345	1285	4630
T_3	1455	773	2228	4050	3060	7110
T_4	1150	398	1548	2045	705	2750
T_5	6750	1889	8639	7590	2660	10250
T_6	2250	1312	3562	4990	1030	6020
T_7	3980	1464	5444	5540	1500	7040
T_8	2985	1357	4342	5400	3290	8690
Mean	3207.5	1302.9	4510.4	4932.5	1991.3	6923.8
SE	0.001					
CD	0.002					

The mean temperature of the fermenting mass increase progressively as the fermentation advanced and reached to higher level during fourth to sixth days of fermentation. Thereafter the temperature decreased slightly (as observed in first season) or remained without much change (as observed in second season).

The mean temperature of the fermenting mass recorded on all the days under observation was comparatively higher during second season. Also the temperature increase was high on fourth to sixth days after fermentation, which ranged from 39.83 to 41.98^{0}C on second season and 35.05 to 37.13^{0}C in the first season. During the first season, the mean temperature recorded was 31.75^{0}C on second day. It was increased to a maximum of 37.13^{0}C on sixth day and slightly declined on seventh day of fermentation. During second season the initial temperature of 32.75^{0}C recorded was increased to 42.04^{0}C on seventh day of fermentation.

Significant difference in temperature in response to various treatments was noticed throughout the period of fermentation. During the first season the maximum temperature on second day of fermentation was recorded with T_1 (33.33 ^{0}C), which was on par with other treatments except T_2 (30.5 ^{0}C), T_3 (30.33^{0}C) and T_8 (29.33^{0}C). On third, fourth, fifth and sixth day of fermentation T_3 recorded the maximum temperature viz., 34.66, 38.80, 41.33 and 41.5 ^{0}C respectively. On seventh day of fermentation T_6 recorded the maximum temperature (36.17^{0}C), which was on par with all the treatments except T_7 (33.33^{0}C) and T3 (28.5 ^{0}C).

During the second season the initial temperature of fermenting mass was the highest in T_7 (38.83 ^{0}C) and the lowest in T_5 (30.17 ^{0}C). Further T_7 (beans from pods stored for four days and treated with pectinase) recorded the highest temperature at all the stages of observation (46.3, 45.8 and 44.3 respectively). On fourth, sixth, and seventh day of fermentation the lowest temperatures of 37.5, 39.67 and 39.33 ^{0}C were recoded in T_8 (beans from pods stored for six days and treated with pectinase).

4.1.1.1.2 Quantity of sweatings produced during fermentation

The data on quantity of sweating obtained from the fermenting mass under various treatments at 24 and 36 hours of fermentations are presented in Table2.

On an average the total quantity of sweating produced was comparatively high during the second season at 24 and 36 hours of fermentation in all the treatments. Maximum quantity of sweatings produced was within the first 24 hours of fermentation. At this stage the mean quantity of sweating was 3207.5 ml and 4932.5 ml during first and second season respectively, which accounted for 71.11 per cent and 71.24 per cent respectively of the total quantity produced.

During the first season , highest quantity of sweatings at 24 hours of fermentation was recorded in T_5 (beans from fresh pod treated with pectinase) which was followed by T_1 (beans from freshly harvested pods without pectinase) and T_7 (beans from pods stored for four days and treated with pectinase) . However at 36 hours of fermentation maximum sweating was recorded was in T_1 followed by T_5. The total quantity of sweating was the highest in T_5 (8639 ml) and lowest in T_4 (1548 ml).

During the second season, after 24 hours of fermentation, T_5 recorded the maximum quantity of sweating (7590 ml) which was followed by T_1 (6500 ml) , T_7 (5540 ml) and T_8 (5400 ml) at 24 hours of fermentation. At 36 hours of fermentation the maximum quantity of sweating was produced by T_8 (3290 ml). Regarding the total quantity of sweating produced during this season the highest value was recorded by T_5 (10250 ml) and followed by T_1 (8900 ml) and T_8 (8690 ml).

Table 3. Effect of pod storage and pectinase treatment on pH of pulp

Treatment	pH of pulp													
	Season I (April-May)							Season II (September-October)						
	Days of fermentation							Days of fermentation						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
T_1	4.33	4.06	3.78	5.89	4.00	4.05	4.11	3.38	3.44	3.50	3.77	4.04	4.18	4.33
T_2	3.64	3.69	3.74	3.73	3.72	3.98	4.24	3.46	3.47	3.48	3.60	3.72	3.89	4.06
T_3	3.53	3.68	3.82	3.91	4.00	4.32	4.61	3.84	3.62	3.40	3.61	3.83	3.99	4.15
T_4	3.33	3.37	3.42	3.63	3.84	4.04	4.24	3.74	3.53	3.32	3.47	3.62	3.84	4.07
T_5	3.76	3.79	3.81	3.94	4.06	4.11	4.15	3.35	3.41	3.47	3.73	3.99	4.08	4.18
T_6	4.45	4.76	5.07	5.23	5.38	4.76	4.15	3.50	3.45	3.39	3.62	3.86	4.01	4.14
T_7	3.95	3.69	3.98	3.99	4.00	4.11	4.21	3.33	3.26	3.33	3.55	3.66	3.75	4.83
T_8	3.76	3.64	3.52	3.96	4.40	4.31	4.21	3.68	3.52	3.35	3.45	3.55	3.62	3.68
Mean	3.84	3.83	3.89	4.29	4.18	4.21	4.24	3.54	3.46	3.40	3.60	3.78	3.92	4.18
SE	0.095													
CD	0.188													

Table 4. Effect of pod storage and pectinase application on pH of beans

Treatment	pH of beans													
	Season I (April-May)							Season II (September-October)						
	Days of fermentation							Days of fermentation						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
T_1	5.10	5.06	5.02	4.90	4.77	4.57	4.36	4.90	5.01	5.11	5.08	5.05	4.69	4.33
T_2	5.26	5.01	4.77	4.68	4.60	4.52	4.56	4.77	4.59	4.42	4.41	4.41	4.44	4.47
T_3	5.30	5.02	4.82	4.87	4.92	4.79	4.66	5.03	4.59	4.15	4.20	4.24	4.36	4.48
T_4	5.33	5.09	4.85	4.72	4.58	4.45	4.32	5.17	4.81	4.44	4.54	4.64	4.58	4.53
T_5	5.32	5.26	5.19	4.90	4.60	4.46	4.32	5.23	5.12	5.01	4.91	4.81	4.65	4.49
T_6	5.93	5.68	5.44	5.21	4.98	4.77	4.56	4.46	4.40	4.35	4.45	4.55	4.57	4.60
T_7	5.23	4.93	4.64	4.57	4.50	4.59	4.68	5.03	4.50	4.33	4.15	4.11	4.06	4.75
T_8	5.58	5.00	4.80	4.71	4.62	4.55	4.48	4.98	4.63	4.29	4.42	4.56	4.41	4.27
Mean	5.38	5.13	4.94	4.82	4.70	4.59	4.49	4.95	4.71	4.51	4.52	4.54	4.47	4.49
SE	0.01													
CD	0.02													

4.1.1.1.3 pH of pulp

The pH of the pulp recorded daily during fermentation in response to pod storage and pectinase treatment of beans are given in Table 3. There was significant difference with respect to pH of pulp among both the seasons and the mean p^H of the pulp increased slowly from first to seventh day of fermentation. The mean p^H was raised from the initial value of 3.84 to 4.24 as a result of fermentation during the first season. During the second season, the mean pH of 3.54 recorded with the pulp on first day was raised to 4.18 on seventh day of fermentation.

The treatment effect on pH of the pulp was highly significant. The highest pulp pH during the first season was recorded with T_6 (beans from pods stored for two days and treated with pectinase) on first, second and third day of fermentation. On fourth day onwards, maximum values of pH was recorded with different treatments and on seventh day of fermentation the highest values for pH (4.61) was recorded with T_3 (beans from pods stored for four days). The lowest pH (4.11) was recorded with T_1, which was followed by T_5 and T_6.

During the second season also, the treatment effect on pH of pulp varied significantly at different stages of observation. Higher pH values of 3.84 and 3.62 were recorded with T_3 on first and second day respectively. Minimum values for pH of pulp at these stages were recorded with T_7 (3.33 and 3.26 respectively). On seventh day of fermentation, the maximum pH for pulp was recorded with T_7 (4.83) and minimum with T_2 (4.06) followed by T_4 (4.07).

4.1.1.1.4 pH of beans

The pH of the beans under various treatments recorded during fermentation for both the seasons are given in Table 4. The pH of the beans decreased slowly during the process of fermentation during both the seasons. The mean pH of 5.38 recorded during first day of fermentation was reduced to 4.49 on

Table 5. Effect of pod storage and pectinase application on moisture content of beans

Treatment	Moisture (%)													
	I season							II season						
	Days of fermentation							Days of fermentation						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
T_1	52.82	52.10	53.38	54.01	55.34	54.20	53.06	60.21	56.41	54.49	55.21	59.27	55.41	54.20
T_2	60.41	59.80	56.50	56.00	56.92	55.40	54.10	57.42	57.12	56.61	54.00	50.51	51.11	53.55
T_3	59.23	58.12	57.30	56.11	54.27	54.00	53.51	56.65	54.13	52.58	53.12	54.13	52.11	50.87
T_4	61.21	59.10	57.21	57.20	56.10	55.30	53.40	62.11	59.11	58.97	56.20	54.46	51.22	50.99
T_5	52.64	54.12	57.54	54.20	54.18	53.50	51.19	55.82	56.65	59.18	56.80	58.43	52.11	53.22
T_6	61.57	57.42	53.76	54.26	54.32	54.00	56.61	60.36	58.21	57.69	55.11	54.28	52.10	51.32
T_7	58.40	56.49	57.64	57.21	58.10	57.20	56.92	61.32	57.21	55.15	52.10	46.51	53.22	55.02
T_8	55.62	54.50	54.21	53.20	54.10	53.10	50.75	63.05	59.21	56.28	55.20	52.95	53.44	55.04
Mean	57.74	56.46	55.94	55.27	55.42	54.59	53.69	59.62	57.26	56.37	54.72	53.82	52.59	53.03
SE	0.55													
CD	1.10													

Table 6. Effect of fermentation anthocyanin content of beans

Treatment	Anthocyanin content (mg $100g^{-1}$)							
	Season I (April-May)				Season II (September-October)			
	Days of fermentation				Days of fermentation			
	1	3	5	7	1	3	5	7
T_1	176.33	129.43	81.03	46.23	161.77	149.57	86.27	54.70
T_2	180.17	125.03	54.37	52.13	92.80	62.23	48.60	25.63
T_3	131.80	98.03	57.60	31.03	174.43	129.43	70.67	46.30
T_4	124.20	91.97	63.00	48.13	77.30	58.77	46.20	38.30
T_5	170.40	149.40	86.23	51.07	181.53	128.07	54.37	52.17
T_6	92.80	62.20	48.70	27.80	86.90	61.10	65.17	40.07
T_7	77.30	58.76	46.43	38.30	132.07	83.13	57.53	30.97
T_8	84.50	61.10	65.17	40.50	124.20	92.07	63.00	48.23
Mean	129.69	96.99	62.82	41.90	128.88	95.17	61.48	32.05
SE	2.20							
CD	4.43							

seventh day during first season. Similarly, pH of the beans during the second season also showed a decline from the first day (4.95) to seventh day (4.49).

The extent of reduction in bean pH was more in the first season compared to second season. However, the mean pH of beans on last day of fermentation was not significantly different (4.49 and 4.50 during first and second season respectively).

During the first season the highest bean pH (5.93) was recorded with beans from pods stored for two days and treated with pectinase (T_6). The lowest pH was recorded in beans from freshly harvested pods (T_1). At the end of fermentation, higher bean pH of 4.68 and 4.66 were recorded with T_7 and T_3 respectively. The pH was the lowest with T_1 (4.36), which was followed by T_3 and T_5 (4.32 each).

During the second season, the highest pH of beans (5.23) was recorded with T_5 (beans from freshly harvested pods and subjected to pectinase treatment) and the lowest with T_6 (4.46) on first day of fermentation. In subsequent stages, the pH level varied with treatment and at final stage observation, the pH decreased to below five per cent in all the treatments. At this stage the highest bean pH of 4.75 was recorded with T_7 and the lowest with T_1 (4.33).

4.1.1.1.5 Moisture content of beans

The data on moisture content of the beans recorded during fermentation with respect to seasons under study and treatments are presented in Table 5. The moisture content of beans varied significantly with respect to season and treatment at different stages of fermentation.

During both the seasons, the mean moisture content of the beans decreased as the fermentation advanced. A mean moisture content of 57.74 per cent recorded on the first day of fermentation was reduced to 53.69 per cent at the end of fermentation during the first season. Similarly the moisture content of 59.62 per cent

recorded on first day during the second season was reduced to 53.03 per cent on completion of fermentation.

The moisture content was substantially high in T_6 (61.57 per cent), T_4 (61.21) and T_2 (60.41 per cent) on the first day of fermentation. The moisture content of beans in relation to treatments varied at different stages of observation and on the seventh day, the bean moisture content was high in T_6 and T_7 (56.61 and 56.92 per cent respectively). The lowest bean moisture content was recorded with T_8 (50.75%).

During the second season moisture content of the beans was significantly high in T_8 (63.05 per cent) and T_4 (62.11 per cent). The lowest bean moisture content of 55.82 per cent was recorded with T_5 (beans from freshly harvested pods and treated with pectinase). As the fermentation advanced the mean moisture content decreased progressively. On the seventh day, of fermentation T_7 (55.02 per cent) and T_8 (55.04 per cent) recorded higher values for bean moisture content. The lowest moisture content was recorded with T_3 (50.87), which was followed by T_4 (50.99 per cent).

4.1.1.2 Biochemical parameters

4.1.1.2.1 Anthocyanin content

The anthocyanin content of beans recorded at different stages of fermentation for two different seasons are given in Table 6. There was significant reduction in anthocyanin content of beans as the fermentation proceeded from first to seventh day during both the seasons. An anthocyanin content of 129.69 mg $100g^{-1}$ recorded on first day of fermentation for beans from freshly harvested pods was reduced to 96.99, 62.82 and 41.90 mg 100 g^{-1} during third, fifth and seventh days after fermentation. During the second season the average anthocyanin content recorded with beans on first day of fermentation was 128.88 mg 100 g^{-1}. It was reduced to 32.05 mg $100g^{-1}$ on seventh day after fermentation. The reduction in anthocyanin content was comparatively more during second season.

Table 7. Effect of fermentation on amino acid content of beans

Treatment	Amino acid (mg g^{-1})							
	I Season				II Season			
	Days of fermentation				Days of fermentation			
	1	3	5	7	1	3	5	7
T_1	22.86	18.58	22.67	14.44	23.19	15.59	24.61	15.44
T_2	15.13	18.88	10.07	9.98	17.41	15.72	22.02	12.64
T_3	10.96	18.49	16.84	12.25	16.05	11.31	18.83	17.88
T_4	15.51	8.15	14.36	13.38	18.63	14.57	15.97	9.97
T_5	23.12	31.51	10.26	10.40	20.99	18.87	15.73	18.66
T_6	15.56	5.63	7.69	12.30	24.54	19.27	24.49	15.09
T_7	8.58	22.14	11.92	16.41	26.80	21.00	21.39	15.49
T_8	10.98	6.84	13.26	11.30	21.61	20.40	19.16	15.45
Mean	15.34	16.28	13.38	12.57	21.16	17.08	20.28	15.08
SE	0.85							
CD	1.68							

Table 8. Effect of fermentation on polyphenol content of beans

Treatment	Polyphenol (mg g^{-1})							
	I Season				II Season			
	Days of fermentation				Days of fermentation			
	1	3	5	7	1	3	5	7
T_1	42.67	42.67	20.22	16.27	41.84	44.62	24.29	21.22
T_2	28.00	35.22	32.76	25.91	29.76	38.73	37.95	20.80
T_3	29.57	32.62	39.91	28.91	40.00	33.76	36.67	20.13
T_4	24.91	37.40	40.11	24.69	34.67	33.07	30.54	25.74
T_5	34.40	39.13	17.06	18.44	31.09	41.09	37.87	16.82
T_6	33.31	43.76	34.38	23.49	38.82	46.33	26.57	22.53
T_7	49.93	53.78	22.44	42.00	47.20	52.38	42.76	31.31
T_8	20.45	36.67	43.51	30.58	19.85	38.29	44.76	29.91
Mean	32.27	40.16	31.30	26.29	35.40	41.03	35.10	23.56
SE	1.125							
CD	2.226							

There was significant difference among treatments with respect to anthocyanin content at different stages of observation during both the seasons. During first season, the lowest anthocyanin content of 77.30 mg 100 g^{-1} was recorded with beans from pods that were stored for four days and subjected to pectinase (0.01 per cent) treatment (T_3). The anthocyanin content reduced progressively as the fermentation advanced and on the seventh day of fermentation, the lowest anthocyanin content of 27.80 mg 100^{-g} was recorded with T_6. The highest anthocyanin content of 180.17 mg $100g^{-1}$ was recorded on first day of fermentation with beans from freshly harvested pods and at final stage the highest anthocyanin content of 52.13 and 51.07 mg $100g^{-1}$ respectively was recorded with beans from pods stored for two days and subjected to fermentation with (T_5) or with out (T_2) addition of pectinase.

As observed in first season, the anthocyanin content of beans decreased as fermentation advanced in the second season also. During the second season on first day of fermentation, the lowest anthocyanin content (77.30 mg $100g^{-1}$) was recorded with the beans from pods stored for six days (T_4). At final stage of observation the anthocyanin content was comparatively less (25.63 mg $100g^{-1}$) in T_2 (beans from pods stored for two days). The maximum anthocyanin content (181.53 mg 100 g^{-1}) was recorded with the beans from freshly harvested pods when subjected to fermentation by adding pectinase. At final stage of observation, the highest anthocyanin contents of 54.70 mg 100 g^{-1} and 52.17 mg 100^{-g} were recorded in T_1 and T_5 respectively.

4.1.1.2.2 Amino acid content

The data on amino acid content of beans subjected to fermentation under various treatments for two seasons are given in Table7. The amino acid content varied significantly with respect to season, days of fermentation and treatments. During both the seasons, the amino acid content of beans was found to decrease as fermentation progressed and the rate of reduction was less during the second season compared to the first season. The average amino acid content of 15.34

mg g^{-1} recorded during first day of fermentation was decreased to 12.57 mg g^{-1} during the final stage of fermentation in the first season. During the second season, the mean amino acid content recorded with the beans on the first day was 21.16 mg g^{-1} which declined to 15.08 mg g^{-1} on the seventh day after fermentation.

Among the different treatments, T_5 (beans from freshly harvested pods treated with pectinase) recorded the highest values for amino acid on first and third day of fermentation during first season. Finally, the retention of amino acid during fermentation was found more (16.41 mg g^{-1}) in beans from pods stored for four days and treated with pectinase (T_7).

During the second season also, the amino acid content of beans was found to vary with respect to treatments at each stage of fermentation. The highest amino acid contents on first and third day after fermentation (26.80 and 21.0 mg g^{-1}) were recorded with beans from pods stored for four days and treated with pectinase (T_7). Lower amino acid contents of 16.05, and 17.41 mg g^{-1} were recorded with the beans stored for four and two days respectively. During second season, on seventh day of fermentation, beans from pods stored for four days (T_3, 17.88 mg g^{-1}) and beans from freshly harvested pods treated with pectinase (T_5, 18.66 mg g^{-1}) recorded higher amino acid contents. The amino acid content recorded was very low (9.97 mg g^{-1}) with beans from pods stored for six days and subjected to fermentation without pectinase.

4.1.1.2.3 Polyphenol content

The polyphenol content of beans subjected to fermentation under various treatments during both the seasons are given in Table 8. A reduction in polyphenol content was recorded during fermentation in both the seasons. The initial value of 32.27 mg g^{-1} was decreased to 26.29 mg g^{-1} at the end of fermentation during first season. During second season the polyphenol content decreased from 35.4 mg g^{-1} to 23.56 mg g^{-1} at the final stage of fermentation. The amount of decrease in polyphenol due to fermentation was more in the second season.

Table 9. Effect of pod storage and application of pectinase on yeast population during fermentation

Treatment	Yeast count ($x10^3$ CFU g^{-1})						
	Days of fermentation						
	1	2	3	4	5	6	7
T_1	5.33 (1.96)	36.00 (5.741)	34.00 (5.884)	59.67 (7.734)	43.00 (5.572)	12.67 (3.495)	12.67 (3.467)
T_2	65.67 (7.579)	48.00 (6.735)	66.67 (8.102)	24.33 (4.581)	15.67 (3.756)	10.67 (3.336)	9.67 (3.073)
T_3	55.33 (7.43)	49.00 (6.997)	48.00 (6.933)	18.33 (4.079)	65.33 (8.103)	17.67 (4.012)	27.33 (5.125)
T_4	18.33 (4.316)	22.33 (4.737)	26.67 (5.113)	54.00 (7.354)	15.67 (3.906)	18.67 (3.949)	6.00 (2.172)
T_5	17.00 (4.141)	17.33 (4.043)	15.00 (3.558)	29.33 (5.279)	30.67 (5.523)	5.00 (2.073)	9.33 (2.75)
T_6	20.33 (4.327)	30.33 (5.503)	39.33 (6.041)	20.67 (4.353)	10.00 (2.947)	12.00 (3.486)	7.00 (2.418)
T_7	52.00 (6.966)	11.00 (3.385)	37.00 (5.992)	9.33 (3.016)	67.33 (8.086)	32.33 (5.667)	38.67 (5.756)
T_8	33.66 (5.772)	11.33 (3.203)	45.67 (6.77)	20.00 (4.169)	8.33 (2.764)	7.67 (2.415)	13.00 (3.64)
SE	0.97						
CD	1.92						

Table 10. Effect of pod storage and application of pectinase on bacterial population during fermentation

Treatment	Bacterial count ($x10^3$ CFU g^{-1})						
	Days of fermentation						
	1	2	3	4	5	6	7
T_1	2.67 (1.77)	8.67 (2.964)	19.33 (4.451)	66.33 (7.947)	21.67 (4.705)	13.33 (3.517)	2.00 (1.321)
T_2	68.00 (8.158)	26.33 (5.136)	40.67 (6.326)	75.33 (8.682)	41.67 (6.149)	23.67 (4.593)	18.67 (3.96)
T_3	16.00 (4.007)	10.67 (3.166)	57.67 (7.389)	40.33 (5.811)	41.67 (6.151)	22.67 (4.632)	19.00 (4.256)
T_4	12.33 (3.489)	22.33 (4.737)	17.00 (4.16)	13.67 (3.703)	49.00 (6.621)	7.00 (2.337)	20.33 (4.134)
T_5	31.67 (5.566)	8.33 (2.941)	19.00 (3.899)	37.00 (5.149)	49.33 (7.045)	9.00 (3.016)	20.33 (4.267)
T_6	15.67 (3.667)	20.33 (3.986)	21.67 (4.642)	42.33 (6.278)	65.00 (7.957)	21.33 (4.127)	17.00 (3.872)
T_7	7.00 (2.70)	54.67 (6.935)	59.67 (7.326)	74.67 (8.542)	11.33 (3.299)	23.00 (4.803)	44.67 (6.395)
T_8	14.00 (3.157)	9.67 (3.089)	26.00 (4.507)	59.33 (7.635)	39.00 (5.926)	14.67 (3.808)	30.33 (4.782)
SE	1.179						
CD	2.211						

Figures in parenthesis represent transformed values

Table 11. Effect of pod storage and application of pectinase on fungal population during fermentation

Treatment	Fungal count ($x10^2$ CFU g^{-1})						
	Days of fermentation						
	1	2	3	4	5	6	7
T_1	1.00 (1.71)	0.33 (0.88)	1.67 (1.351)	1.00 (1.171)	1.67 (1.351)	5.33 (2.386)	0.67 (0.998)
T_2	1.67 (1.351)	1.33 (1.344)	2.34 (1.642)	2.67 (1.641)	3.00 (1.785)	2.67 (1.65)	3.33 (1.671)
T_3	1.33 (1.344)	4.00 (4.171)	3.33 (1.897)	3.33 (1.793)	3.67 (1.907)	3.33 (1.772)	0.33 (0.88)
T_4	0.00 (0.707)	1.00 (1.171)	0.67 (1.052)	2.33 (1.642)	3.33 (1.848)	2.00 (1.47)	7.33 (2.685)
T_5	0.33 (0.88)	1.67 (1.462)	0.33 (0.88)	2.67 (1.739)	1.67 (1.44)	1.00 (1.71)	1.67 (1.351)
T_6	1.67 (1.351)	1.33 (1.344)	1.33 (1.344)	2.00 (1.524)	3.00 (1.858)	4.00 (1.963)	2.00 (1.524)
T_7	2.00 (1.559)	9.00 (2.50)	0.33 (0.88)	2.33 (1.642)	0.00 (0.707)	1.67 (1.351)	6.33 (2.569)
T_8	1.00 (1.171)	0.00 (0.707)	2.33 (1.642)	1.00 (1.171)	3.00 (1.785)	2.33 (1.642)	4.00 (2.028)
SE	0.375						
CD	0.741						

Table 12. Effect of sun and oven drying on moisture content of beans - I Season

Treatment	Moisture (%)							
	Sun drying				Oven drying			
	Day of observation				Day of observation			
	1	3	6	9	1	2	3	4
T_1	52.82	27.2	8.42	6.12	52.82	25.42	7.21	5.82
T_2	60.41	29.56	11.26	6.89	60.41	27.64	6.36	5.01
T_3	59.23	28.64	9.58	6.01	59.23	29.22	6.91	5.78
T_4	61.21	21.46	8.46	6.92	61.21	31.11	6.85	5.24
T_5	52.64	24.86	9.25	5.96	52.64	23.2	6.11	4.56
T_6	61.57	21.2	7.56	6.85	61.57	27.45	7.01	5.21
T_7	58.4	18.45	9.26	6.23	58.4	26.66	6.23	4.94
T_8	55.62	26.4	8.25	6.11	55.62	29.4	5.94	4.89
Mean	52.21	22.86	8.89	6.57	52.21	25.34	6.74	5.49
SE	0.01							
CD	0.02							

Significant influence of treatments on polyphenol content during fermentation of beans was observed. At the initial stage of fermentation, polyphenol was the minimum (24.91 mg g^{-1}) in beans extracted from pods stored for six days, while it was the maximum (49.93 mg g^{-1}) in bean from pods stored for four days and treated with pectinase (T_7). The polyphenol content varied with respect to treatments in subsequent stages of fermentation and at final stage i.e. on seventh day of fermentation, minimum polyphenol content (16.27 mg g^{-1}) was recorded with beans from freshly harvested pods ($_{T1}$) and the maximum of 42.00 mg g^{-1} was recorded with beans from pods stored for four days and treated with pectinase (T_7).

During the second season also, the treatment influence was significant at each stage of fermentation. Initially, the maximum polyphenol (47.20 mg g^{-1}) was observed with the beans from pods that were stored for four days where as the minimum (19.85 mg g^{-1}) was with beans from six days stored pods. At final stage of observation, the maximum polyphenol content (31.31 mg g^{-1}) was observed for T_7 (beans from four days stored pods and treated with pectinase), where as the minimum (16.82 mg g^{-1}) was for (T_5).

4.1.1.3 Microbial population during fermentation

4.1.1.3.1 Yeast

The data on yeast count on the fermenting mass were recorded daily and are presented in Table 9. Significant difference in yeast population was observed with respect to different intervals of observation as well as treatments.

On the first, second and third day of fermentation, the highest yeast count of 65.67, 48.00 and 66.67 x 10^3 CFU g^{-1} respectively were recorded in T_2 (beans from pods stored for two days). On fourth day T_1 recorded the highest yeast count viz., 59.67 x 10^3 CFU g^{-1} . On fifth, sixth and seventh days of fermentation higher yeast count were recorded with T_7 (67.33, 32.33 and 38.67 x 10^3 CFU g^{-1}).

Table 13. Effect of sun and oven drying on moisture content of beans - II season

Treatment	Moisture (%)							
	Sun drying				Oven drying			
	Day of observation				Day of observation			
	1	3	6	9	1	2	3	4
T_1	60.21	16.01	8.85	6.533	60.21	27.96	7.89	5.97
T_2	57.48	25.01	10.11	6.108	57.48	24.38	8.21	6.47
T_3	56.65	26.2	9.24	6.868	56.65	26.22	6.52	5.67
T_4	62.11	32.4	9.86	6.523	62.11	25.12	7.11	5.51
T_5	58.82	36.7	12.41	6.974	58.82	26.54	6.54	5.91
T_6	60.36	31.33	11.25	6.245	60.36	28.2	7.06	6.06
T_7	61.32	18.72	8.46	6.12	61.32	26.15	7.42	6.21
T_8	63.04	34.6	14.66	6.339	63.04	24.58	6.91	6.68
Mean	54.22	25.44	10.32	6.63	54.22	24.13	7.30	6.28
SE	0.177							
CD	0.350							

Table 14. Effect of sun and oven drying on pH of beans-I season

Treatment	pH of beans							
	Sun drying				Oven drying			
	Days of Sampling				Days of Sampling			
	1	3	6	9	1	2	3	4
T_1	4.36	4.76	5.10	5.14	4.33	4.98	5.21	5.26
T_2	4.56	5.12	5.51	5.57	4.47	5.12	5.50	5.64
T_3	4.66	5.24	5.43	5.82	4.48	5.12	5.46	5.77
T_4	4.32	4.92	5.53	5.43	4.53	4.91	5.30	5.29
T_5	4.32	5.02	5.38	5.42	4.49	5.38	5.55	5.38
T_6	4.56	5.11	5.22	5.46	4.60	5.25	5.46	5.70
T_7	4.68	5.24	5.56	5.61	4.75	5.39	5.66	5.83
T_8	4.48	5.02	5.60	5.54	4.27	5.02	5.52	5.43
Mean	4.49	5.05	5.42	5.50	4.49	5.15	5.46	5.54
SE	0.097							
CD	0.192							

On first day the yeast count was the lowest in T_1 (5.3 x 10^3 CFU g^{-1}). At final stage of observation the lowest yeast count was 6.00 and 7.00 x 10^3 CFU g^{-1} recorded with T_4 and T_6 respectively.

4.1.1.3.2 Bacteria

The data on bacterial count recorded daily on the fermenting mass are presented in Table 10. The maximum bacterial population on second, third, fourth, sixth and seventh day of fermentation (54.67, 59.67, 74.67, 23.00 and 44.67 x 10^3 CFU g^{-1} respectively) was recorded in T_7 (beans from pods stored for four days and treated with pectinase) . The lowest count of 2.67 x 10^3 CFU g^{-1} was recorded in T_1 (beans from freshly harvested pods without pectinase treatment) at all the stages except on fourth day of fermentation.

4.1.1.3.3 Fungus

Data on mean fungal count recorded daily on the fermenting mass are given in Table 11. The fungal count varied with respect to treatments at different stages of observations. On third day the lower fungal population was recorded in T_5 and T_7 (0.33 67 x10^3 CFUg $^{-1}$ each). The treatment T_1 recorded the lowest fungal count on fifth and seventh day of fermentation (1.67 and 0.67 x10^3 CFUg $^{-1}$ respectively). The lowest fungal count on final day was 0.67 x10^3 CFUg $^{-1}$ in T_1 followed by 0.33 in T_3.

4.1.2 Effect of Methods of Drying on Quality of Beans

The beans subjected to various fermentation treatments (3.1.1) were given sun and oven drying separately. The quality of beans in response to fermentation and drying treatments were analysed based on recovery percentage of dried beans, index on cut test and biochemical characters (moisture, anthocyanin, polyphenol and amino acid content of beans).

Table 15. Effect of sun and oven drying on pH of beans-II season

Treatment	pH of beans							
	Sun drying				Oven drying			
	Days of Sampling				Days of Sampling			
	1	3	6	9	1	2	3	4
T_1	4.33	5.13	5.13	5.17	4.36	5.21	5.44	5.42
T_2	4.47	4.90	5.22	5.43	4.56	5.32	5.48	5.50
T_3	4.48	5.04	5.41	5.59	4.66	5.56	5.70	5.68
T_4	4.53	4.97	5.21	5.41	4.32	5.31	5.42	5.51
T_5	4.49	5.09	5.21	5.38	4.32	5.50	5.70	5.72
T_6	4.60	5.03	5.25	5.47	4.56	5.34	5.41	5.40
T_7	4.75	5.19	5.46	5.62	4.68	5.41	5.71	5.84
T_8	4.27	4.84	5.32	5.41	4.48	5.43	5.70	5.73
Mean	4.49	5.02	5.28	5.43	4.49	5.39	5.57	5.60
SE	0.089							
CD	0.176							

Table 16. Effect of sun and oven drying on polyphenol content of beans - I season

Treatment	Polyphenol (mg/g)							
	Sun drying				Oven drying			
	Days of sampling				Days of sampling			
	1	3	6	9	1	2	3	4
T_1	16.27	36.82	42.20	24.95	33.27	16.27	33.24	27.59
T_2	25.91	42.27	37.42	22.95	30.60	25.91	34.09	30.20
T_3	28.91	35.82	47.53	19.48	25.98	28.91	26.20	27.03
T_4	24.69	42.33	50.50	20.82	27.75	24.69	32.89	28.44
T_5	18.44	37.42	36.82	24.85	33.13	18.44	35.31	28.96
T_6	23.49	41.56	49.76	22.00	29.33	23.49	32.27	28.36
T_7	42.00	28.20	38.58	44.83	44.78	27.00	38.89	36.89
T_8	30.58	52.40	47.56	21.88	29.18	30.58	35.96	31.90
Mean	26.29	39.60	43.73	25.22	31.75	24.41	33.61	29.92
SE	0.872							
CD	1.173							

Table 17. Effect of sun and oven drying on polyphenol content of beans - II season

Treatment	Polyphenol (mg/g)							
	Sun drying				Oven drying			
	Days of sampling				Days of sampling			
	1	3	6	9	1	2	3	4
T_1	29.87	28.25	31.45	28.59	29.87	32.42	31.51	20.31
T_2	26.80	27.47	29.51	23.93	26.80	35.58	32.84	26.84
T_3	26.56	28.23	31.79	27.43	26.64	29.09	27.13	34.11
T_4	30.42	50.57	35.17	29.41	30.42	29.49	27.18	28.40
T_5	25.20	12.01	31.17	23.91	25.20	39.16	41.47	26.67
T_6	32.49	20.25	32.01	28.85	32.49	33.55	35.36	27.57
T_7	57.73	26.81	16.45	22.75	36.73	50.87	40.22	34.45
T_8	32.58	18.65	30.76	27.75	32.58	33.47	45.31	41.07
Mean	31.96	22.78	29.79	26.58	30.09	35.45	35.13	29.92
SE	0.97							
CD	1.92							

Table 18. Effect of sun and oven drying on amino acid content of beans - I Season

Treatment	Amino acid (mg g^{-1})							
	Sun drying				Oven drying			
	Days of sampling				Intervals of sampling			
	1	3	6	9	1	2	3	4
T_1	17.77	19.19	21.12	19.92	17.77	13.70	11.52	19.38
T_2	13.16	14.81	19.40	12.60	13.16	13.75	15.29	12.09
T_3	12.35	12.37	14.99	15.49	12.35	17.91	10.25	10.35
T_4	13.38	18.58	13.27	20.24	13.38	17.35	18.70	30.96
T_5	10.44	15.25	13.37	15.28	10.44	29.71	18.57	20.57
T_6	12.30	11.18	14.35	16.87	12.30	14.43	10.23	24.39
T_7	16.38	23.91	18.24	25.60	16.05	15.99	11.84	21.00
T_8	7.92	10.71	15.18	19.48	11.30	14.14	11.60	22.47
Mean	12.96	15.75	16.24	18.19	13.34	17.12	13.50	20.15
SE	0.74							
CD	1.46							

4.1.2.1 Moisture content

The data recorded on moisture content of beans subjected to sun and oven drying for the two seasons are given in Tables12 and 13 respectively.

The mean moisture content of beans was reduced from the initial level of 52.21% to 6.57 per cent in sun drying method, over a period of nine days. In oven drying method, the removal of moisture was fast and the initial moisture content of 52.21 per cent was reduced to 5.49 per cent within a period of four days. During the second season also drying was comparatively fast in oven method. The initial mean moisture content of 54.22 per cent recorded was reduced to 6.63 per cent over a period of nine days in sun drying method. In case of oven drying, the level of moisture reached about 6.28 per cent over a period of four days.

The effect of treatments (fermentation and drying) on moisture content of beans was significant at different stages of observation during both the seasons.

The initial moisture content recorded was the highest in T_6 (beans from pods stored for two days and treated with pectinase, 61.57 per cent), which was followed by 60.41 per cent in T_2 (beans from pods stored for two days without pectinase treatment) during the first season. The lowest initial moisture contents *viz.*, 52.64 and 52.82 per cent were recorded with T_5 (beans from freshly harvested pods with pectinase treatment) and T1 (beans from freshly harvested pods without pectinase treatment) respectively. On sixth day of sun drying, during first season , the moisture content of 11.26 per cent recorded with T_2 was the highest compared to other treatments. The lowest moisture content of 7.56 per cent was recorded with T_6. On ninth day of drying highest moisture content (6.92 per cent) was recorded with T_4, which was followed by T_2 (6.89 per cent). Moisture content of T_5 was the lowest compared to other treatments (5.96 per cent) at this stage.

When the samples (under various fermentation treatments) were subjected to oven drying during the first season, the initial moisture content of 61.57 per cent

recorded with T_6 was the highest at initial stage of observation. On second, third and fourth day of drying, the effects of treatments on moisture content of beans varied significantly. At final stage of observation T_5 recorded the lowest moisture content (4.56 per cent) whereas the highest was in T_1 (5.82 per cent).

During second season the highest moisture content was recorded with T_8 (63.04 per cent) and the lowest with T_2 (57.48 per cent). The effects of treatments on moisture content of beans varied significantly at each stage of observation and at final stage the moisture content was comparatively low in T_2 and T_7 (6.11 and 6.12 per cent respectively). The highest moisture content was recorded with T_5 (66.97 per cent). In oven drying, during the same season rapid removal of moisture was evident from beans as compared to sun drying. On third day of observation the mean moisture level reached below 8.5 per cent and maximum moisture content of 8.21 per cent was recorded with T_2. The lowest moisture content of 6.54 per cent was recorded with T_5. At final stage of observation the highest moisture content (6.68 per cent) was recorded with T_8 and the lowest (5.51 per cent) with T_4.

4.1.2.2 pH of beans

The pH values recorded for the beans subjected to sun and oven drying (after fermentation under varying treatments) during both the seasons are given in Tables 14 and 15 respectively.

The mean pH of beans subjected to both methods of drying was same (4.49) during the first and the second season. The pH values recorded a progressive increase during drying and reached close to six per cent over a period of nine days in case of sun drying. The same level of pH was reached over a period of four days in case of oven drying during both the seasons under study.

During first season, the maximum pH (5.82) was recorded with T_3 at final stage of sun drying and the minimum (5.14) with T_1. On completion of drying by oven method, the highest value for pH was recorded with T_7 (5.84) and the lowest

Table 19. Effect of sun and oven drying on amino acid content of beans-II Season

Treatment	Amino acid (mg/g)							
	Sun drying				Oven drying			
	Intervals of sampling				Intervals of sampling			
	1	3	6	9	1	2	3	4
T_1	20.86	14.42	18.03	17.81	21.25	21.76	17.72	15.47
T_2	16.64	11.46	17.27	14.92	17.93	15.12	22.42	18.37
T_3	10.10	9.48	14.27	15.72	12.81	12.49	17.77	19.89
T_4	12.49	14.49	21.44	15.53	12.09	18.04	23.94	17.05
T_5	9.95	12.01	24.39	19.14	11.66	14.68	26.87	22.06
T_6	17.52	17.89	27.78	19.49	22.11	22.46	30.20	25.38
T_7	21.47	12.98	24.33	16.13	23.10	17.85	27.42	19.81
T_8	7.58	9.41	18.47	17.40	11.53	16.19	20.29	20.49
Mean	14.58	12.77	20.75	17.02	16.56	17.32	23.33	19.81
SE	0.65							
CD	1.30							

Table 20. Effect of sun and oven drying on anthocyanin content of beans – I Season

Treatment	Anthocyanin (mg $100g^{-1}$)							
	Sun drying				Oven drying			
	Days of sampling				Days of sampling			
	1	3	6	9	1	2	3	4
T_1	51.03	31.60	19.66	14.06	49.6	32.2	20.8	15.0
T_2	37.37	28.53	20.06	15.30	48.4	34.3	19.3	14.3
T_3	43.50	38.00	19.43	14.13	49.9	32.0	19.3	14.3
T_4	34.16	28.83	19.26	15.05	50.8	21.0	14.2	9.2
T_5	42.80	25.73	14.86	15.56	45.1	36.5	22.1	17.0
T_6	44.96	25.00	19.80	14.08	43.8	36.3	19.7	14.1
T_7	37.63	30.33	16.13	11.33	43.9	35.9	18.1	13.1
T_8	40.60	31.00	17.70	12.87	35.2	20.4	10.9	5.6
Mean	41.51	29.89	18.40	14.05	45.8	31.1	18.0	12.8
SE	0.01							
CD	NS							

with T_6 (4.56). During the second season, at final stage of drying the pH was comparatively high (5.62) with T_7 when subjected to sun drying and low with T_1 (5.17). When the beans were dried in oven, the highest bean pH of 5.83 was recorded with T_7 and the lowest with T_1 (5.26).

4.1.2.3 Polyphenol content of beans

The results of the experiments on drying methods viz., sun and oven drying of beans during fist and second season are presented in Table 16 and 17 respectively. There was significant difference in the polyphenol content of beans that had undergone sun drying and oven drying at various intervals of observation.

During the first season the initial polyphenol content of 26.29 mg g^{-1} was increased to 39.6 and 43.73 mg g^{-1} respectively on third and sixth day of sun drying. It was then reduced to 25.22 mg g^{-1} on completion of drying. While in case of oven drying, the initial polyphenol content of 31.75 mg g^{-1} was reached to 33.61 mg g^{-1} on third day and 29.92 mg g^{-1} on completion of drying (on fourth day).

There was significant difference with respect to polyphenol content of various treatments during the first season. During first season on the first day of sun drying, the lowest polyphenol was recorded in T_1 (16.27mg 100^{-g}), which was followed by T_5. The treatment T_7 recorded the maximum polyphenol content on first (42.0 mg g^{-1}) and final (44.83 mg g^{-1}) stage of drying. The polyphenol content was significantly low (19.48mg g^{-1}) in T_3 when dried in the sun. In case of beans subjected to oven drying, T_7 recorded the maximum polyphenol on the first (44.78 mg g^{-1}), third (38.89 mg g^{-1}) and fourth (36.89 mg g^{-1}) day of drying. The lowest polyphenol on first (25.98 mg g^{-1}), third (26.02 mg g^{-1}) and fourth (27.03 mg g^{-1}) days were recorded in T_3.

During the second season the initial polyphenol content of 31.96 mg g^{-1} was reduced to 26.58 on ninth day of sun drying. In the case oven drying, the

initial polyphenol content of 30.09 mg g^{-1} was reduced 29.92 mg g^{-1} on completion of drying , ie. on fourth day.

During the second season also there was significant difference between treatments with respect to polyphenol content. On the first day of drying under sun, the lowest polyphenol was recorded in T_5 (25.20mg g^{-1}), which wasfollowed by T_3 (26.56 mg g^{-1}). The treatment T_7 recorded the maximum polyphenol content (57.73 mg g^{-1}) at this stage. The polyphenol content was significantly low in T_7 on sixth and ninth day of drying (16.45 and 22.75 mg g^{-1} respectively). The maximum polyphenol content on third, sixth and ninth day of drying (50.57, 35.17 and 29.41 mg g^{-1} respectively) was recorded by T_4. In case of beans undergoing oven drying, T_7 recorded the maximum polyphenol on the first (36.73 mg g^{-1}), and second day (50.87 mg g^{-1}) of drying. The lowest polyphenol on first day was recorded in T_5 (25.20 mg g^{-1}). On third day the maximum polyphenol was noticed in T_8 (45.31 mg g^{-1}) and the lowest in T_3. On fourth day, T8 recorded the maximum polyphenol content of (41.07 mg g^{-1}) and the lowest polyphenol content in T_1 (20.31 mg g^{-1}).

4.1.2.4 Amino acid content of beans

The amino acid content of beans varied significantly with respect to treatments (fermentation and drying) at intervals of observation during both the seasons (Table 18 and 19). In the first season, the beans undergone sun drying recorded an average amino acid content of 12.96 mg g^{-1} on first day which gradually increased to 18.19 mg g^{-1} on completion of drying.

There was significant difference in amino acid content among treatments and the maximum amino acid content of beans given sun drying was recorded in T_1 (17.77 mg g^{-1}) followed by T_7 (16.38 mg g^{-1}) on first day of drying. The lowest amino acid content, 7.92 mg g^{-1} was recorded with T_8. During the third and ninth day of drying T7 recorded the maximum amino acid content of 23.91 and 25.6 mg g^{-1} respectively. The lowest amino acid on completion of drying (12.6 mg

g^{-1}) was recorded in T_2. In the case of the beans subjected to oven drying, at initial stage the maximum amino acid was recorded by T_1 (17.77 mg g^{-1}), which was followed by T_7 (16.05 mg g^{-1}). The lowest amino acid content was in T_5 (10.44 mg g^{-1}).On second day of drying, T_5 (29.71 mg g^{-1}) recorded the maximum amino acid content followed by T_7 (15.99 mg g^{-1}). The lowest amino acid content during second day was recorded in T_1 (13.7 mg g^{-1}). On the third day, the lowest content was recorded in T_3 and T_6 (10.25 and 10.23 mg g^{-1}) respectively.

During second season, in sun drying the initial amino acid content of 14.58 mg g^{-1} recorded on first day was increased to 20.75 mg g ⁻1 on sixth day and reduced to 17.02 mg g^{-1} on completion of drying. In case of oven drying, the initial amino acid content of 16.56 mg g^{-1} was increased to 23.33 mg g^{-1} on third day and reduced slightly to 19.81 mg g^{-1} on completion of drying.

During the second season, the maximum amino acid content of beans subjected to sun drying on the first day was 21.47 mg g^{-1} in T_7 followed by 20.86 mg g^{-1} in T_1. On second day the maximum amino acid was recorded by T_6 (17.89 mg g^{-1}) and the lowest in T_8 (9.41 mg g^{-1}). On third day, the maximum amino acid was in T_6 (27.78 mg g^{-1}) followed by T_7 (24.33 mg g^{-1}) and T_5 (24.39 mg g^{-1}). On completion of drying, T_6 (19.49mg g^{-1}) retained the maximum amino acid content followed by T_5 (19.14 mg g^{-1}). The lowest amino acid content was recorded by T_2 (14.92 mg g^{-1}). The final amino acid content of oven dried samples was the highest in T_6 (25.38 mg g^{-1}) and the lowest in T_1 (15.47 mg g^{-1})

4.1.2.5 Anthocyanin content of beans

The date recorded on anthocyanin content of beans in response to sun and oven drying (after varying fermentation treatments) during both the season are given in Table 20 and 21.

There was significant difference in the anthocyanin content of beans in response to different methods of drying during both the seasons. In the first

season, the beans subjected to sun drying recorded an average anthocyanin content of 41.51 mg $100g^{-1}$ which gradually decrease to 14.05 mg $100g^{-1}$ on completion of drying. With respect to oven drying method, the initial anthocyanin content of 45.80 mg $100g^{-1}$ decreased to 12.8 mg $100g^{-1}$ on fourth day i.e. on completion of drying.

During the first season, the minimum anthocyanin content of 34.16 mg $100g^{-1}$ was recorded with T_4, followed by T_2 (37.37 mg g^{-1}) on the first day of drying. The highest anthocyanin content was recorded in T_1 (51.03 mg $100g^{-1}$). On third day the lowest anthocyanin content was recorded with T_6 (25.0 mg $100g^{-1}$), followed by T_5 (25.73 mg $100g^{-1}$). On sixth day of drying T_5 recorded the lowest anthocyanin, followed by T_7 (14.86 and 16.13 mg $100g^{-1}$ respectively). On completion of drying, T_7 recorded the lowest anthocyanin content (11.33 mg $100g^{-1}$) followed by T_8 (12.87 mg $100g^{-1}$). In case of oven drying T_8 recorded the lowest anthocyanin content at all stages of drying. The next best treatment in terms of lower anthocyanin content was T_4.

During the second season, the initial anthocyanin content of 43.58 mg $100g^{-1}$ on the first day was reduced to 17.35 mg $100g^{-1}$on completion of drying. With respect to oven drying, the initial anthocyanin content of 40.10 mg $100g^{-1}$ was gradually decreased to attain a mean value of 18.0 mg $100g^{-1}$ on completion of drying. There was significant difference with respect to anthocyanin content among various treatments. On the first day of sun drying, T_7 recorded the lowest anthocyanin content of 37.56 mg $100g^{-1}$ and the highest in T_8 (50.10 mg $100g^{-1}$). On the second day, the minimum anthocyanin content was recorded by T_3 (24.86 mg $100g^{-1}$) followed by T_8 (29.03 mg $100g^{-1}$). On sixth day, T_4 and T_5 recorded lower anthocyanin contents of 19.86 and 21.30 mg $100g^{-1}$ respectively. On completion of sun drying, the lowest anthocyanin retention was found in T_8 (12.04 mg $100g^{-1}$) followed by T_4 (14.68 mg $100g^{-1}$). In the case of oven drying on the first dayT_8 had the lowest anthocyanin content of 24.2 mg $100g^{-1}$, which was followed by T_5 (33.6 mg $100g^{-1}$). On second day, T_4 recorded the lowest anthocyanin content of 22.1 mg $100g^{-1}$ followed by T_8 (26.3 mg $100g^{-1}$). On third and final stage of drying, T_7

Table 21. Effect of sun and oven drying on anthocyanin content of beans-II Season

Treatment	Anthocyanin (mg $100g^{-1}$)							
	Sun drying				Oven drying			
	Days of sampling				Days of sampling			
	1	3	6	9	1	2	3	4
T_1	43.06	38.63	23.5	18.06	47.1	29.9	25.6	20.5
T_2	45.83	41.36	28.63	25.6	42.1	28.8	19.0	13.1
T_3	47.83	24.86	22.93	17.09	45.6	37.0	22.2	16.9
T_4	41.2	36.43	19.86	14.68	43.0	22.1	16.1	11.4
T_5	41.1	32.5	21.3	16.72	33.6	29.9	38.8	30.4
T_6	41.96	33.06	21.96	16.05	41.0	32.1	31.9	24.1
T_7	37.56	32.8	25.46	18.56	44.3	29.4	15.5	10.5
T_8	50.1	29.03	17.03	12.04	24.2	26.3	22.5	17.4
Mean	43.58	33.59	22.60	17.35	40.1	29.4	23.2	18.0
SE	1.56							
CD	3.09							

Table 22. Effect of fermentation and drying treatments on recovery % of dried beans

Treatment	Recovery (%)			
	Sun dried		Oven dried	
	I season	II season	I season	II season
T_1	38.5 (4)	34.56 (7)	31.5 (4)	29.6 (6)
T_2	37.75 (6)	38.62 (5)	30.75 (6)	33.95 (4)
T_3	39.86 (2)	40.16 (3)	32.86 (2)	32.8 (5)
T_4	40.5 (1)	40.92 (1)	33.5 (1)	34.5 (3)
T_5	37.7 (7)	32.44 (8)	30.7 (7)	29.3 (7)
T_6	39.7 (3)	40.24 (2)	32.7 (3)	35.15 (2)
T_7	38.25 (5)	37.94 (6)	31.25 (5)	34.5 (3)
T_8	40.5 (1)	40.02 (4)	33.5 (1)	36.06 (1)
Mean	39.095	38.113	32.095	33.23
Chi square			14	
Asymptotic significance			5.10%	

(Significant at 10% level with probability of 0.051)
Figures in parenthesis represent mean ranks

Table 23. Effect of fermentation and drying on cut test index

Cut test index				
Treatment	Sun dried		Oven dried	
	I season	II season	I season	II season
T_1	46.6 (7)	40.8 (8)	37.0 (6)	75.4 (5)
T_2	71.4 (3)	59.4 (5)	40.0 (3)	78.4 (4)
T_3	70.0 (2)	76.0 (2)	40.5 (2)	79.1 (3)
T_4	45.8 (8)	60.4 (4)	35.0 (7)	36.0 (8)
T_5	49.6 (6)	46.6 (7)	39.0 (4)	49.6 (7)
T_6	65.0 (5)	54.4 (6)	34.67 (8)	81.4 (2)
T_7	74.6 (1)	102.2 (1)	41.67 (1)	83.8 (1)
T_8	66.2 (4)	69.8 (3)	38.83 (5)	52.8 (6)
Mean	61.15	63.7	38.33	67.06
Chi square			14	
Asymptotic significance			5.10%	

(Significant at 10% level with probability of 0.051)
Figures in parenthesis represent mean ranks

followed by T_4 recorded the lowest values for anthocyanin contents (10.50 and 11.40 mg $100g^{-1}$ respectively).

4.1.2.6 Effect of fermentation and drying treatments on cut test

An index of cut test score was worked out by assigning relative weightages to each group of beans viz. brown, partly brown / partly purple, purple, slaty and mouldy beans and the same is given in Table 23. The cut test details are presented in Appendix -II.

The highest index of cut test score was recorded by sun dried samples during first season. The mean index for sun dried samples was 55.53 during first season, where as it was only 36.75 for oven dried samples. During second season, the score index registered for sun dried and oven dried samples did not differ significantly (63.76 and 62.80 respectively).

In the first season the highest index of 75 and 74.6 was recorded inT_3 and T_7 (beans from pods stored for four days and treated with or without pectinase). This was followed by 71.4 in T_2, 66.2 in T_8 and 65.0 in T_6. The lowest index of cut test score was recorded in T_1 (45.80). During the second season also T_7 recorded the highest index of cut test score (102.2), which was followed by T_3 (76.0), T_8 (69.8) and T_4 (60.4). The index was the lowest in T_1 (40.8).

In the case of oven dried samples the highest index of cut test score viz., 42.33 and 41.67 was recorded in T_3 and T_7 respectively. This was followed by T_2, T_5 and T_8 (40.0, 39.0 and 38.33 respectively) during the first season. During second season the highest index of 83.8 was recorded in T_7 which was followed by T_6 , T_2 and T_1 (81.4 , 78.4 and 75.4 respectively). The lowest index viz., 36.0 was recorded in T_4.

Table 24. Effect of packaging and storage on moisture content of beans

Treatment	Moisture content of beans (%)													
	1 Season (May 2003-April 2004)							II Season (October 2003-September 2004)						
	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS
T_1	6.36	6.31	6.44	7.17	7.55	7.00	7.87	6.30	6.37	6.48	7.21	7.54	7.26	7.51
T_2	6.36	6.45	6.64	6.94	7.22	7.33	7.46	6.30	6.59	7.25	8.30	8.49	8.37	8.55
T_3	6.36	6.83	7.03	7.31	6.74	6.99	6.99	6.30	6.59	6.61	6.86	6.74	6.70	7.32
T_4	6.36	7.22	7.43	7.72	7.92	7.85	7.97	6.30	7.12	7.47	8.49	8.53	8.73	9.13
T_5	6.36	5.87	5.96	6.20	6.90	6.83	7.02	6.30	6.52	7.52	8.48	8.38	8.52	8.57
T_6	6.36	6.92	6.97	7.26	7.24	7.20	7.21	6.30	6.79	6.97	7.38	7.24	6.74	7.26
T_7	6.36	6.81	7.44	7.99	8.78	8.34	9.28	6.30	7.81	8.50	9.66	10.33	11.06	11.39
Mean	6.36	6.63	6.84	7.23	7.48	7.36	7.69	6.30	6.83	7.26	8.06	9.61	8.20	8.52
SE	0.72													
CD	1.42													

Table 25. Effect of packaging and storage on pH of beans

Treatment	pH of beans													
	1 Season (May 2003-April 2004)							II Season (October 2003-September 2004)						
	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS
T_1	5.37	5.20	5.21	5.12	5.14	4.94	4.96	5.62	5.64	5.65	5.61	5.55	5.43	5.45
T_2	5.37	5.31	5.32	5.27	5.31	5.24	5.21	5.62	6.01	5.65	5.54	5.50	5.48	5.41
T_3	5.37	5.22	5.14	4.95	5.05	4.93	4.96	5.62	5.60	5.61	5.56	5.51	5.48	5.50
T_4	5.37	5.35	5.22	5.12	5.14	4.96	4.97	5.62	5.64	5.65	5.51	5.48	5.46	5.48
T_5	5.37	5.36	5.31	5.23	5.25	5.21	5.14	5.62	5.69	5.71	5.62	5.51	5.41	5.47
T_6	5.37	5.36	5.22	5.04	5.15	5.01	4.97	5.62	5.55	5.48	5.48	5.49	5.53	5.61
T_7	5.37	5.63	5.57	5.67	5.73	5.63	5.61	5.62	5.61	5.63	5.84	6.21	6.55	6.58
Mean	5.37	5.32	5.28	5.20	5.25	5.13	5.12	5.62	5.68	5.63	5.59	5.61	5.62	5.65
SE	0.027													
CD	0.052													

Table 26. Effect of packaging and storage on amino acid content of beans

Treatment	Amino acid (mg g^{-1})													
	I Season (May 2003-April 2004)							II Season (October 2003-September 2004)						
	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS
T_1	16.38	17.69	18.00	10.64	9.63	7.07	4.59	21.47	17.61	21.41	9.31	7.55	7.22	11.88
T_2	16.38	28.34	17.90	11.91	9.75	6.27	4.66	21.47	21.37	17.91	12.29	10.07	9.79	11.39
T_3	16.38	19.60	19.72	10.92	9.44	5.48	4.21	21.47	24.39	17.58	9.88	9.67	6.91	10.40
T_4	16.38	19.38	16.59	10.51	9.74	5.78	7.07	21.47	21.56	15.96	12.02	9.14	5.56	8.19
T_5	16.38	12.86	17.07	7.80	9.56	6.03	9.76	21.47	21.37	21.25	9.84	12.29	12.19	12.05
T_6	16.38	22.59	17.78	9.97	9.53	6.07	6.20	21.47	17.42	17.88	10.70	11.44	10.06	12.84
T_7	16.38	12.10	11.42	9.84	8.84	6.01	4.20	21.47	16.62	15.39	6.91	5.77	5.41	5.81
Mean	16.38	18.94	16.64	10.23	9.50	6.10	5.81	21.47	20.05	18.20	10.14	9.42	8.16	10.37
SE	0.52													
CD	1.04													

Table 27. Effect of packaging and storage on polyphenol content of beans

Treatment	Polyphenol (mg g^{-1})													
	1 Season (May 2003-April 2004)							II Season (October 2003-September 2004)						
	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS
T_1	38.58	34.77	27.23	22.30	23.25	22.61	19.63	44.89	40.20	31.52	22.96	21.89	20.29	18.67
T_2	38.58	20.67	19.60	25.73	22.49	20.17	16.95	44.89	37.58	29.67	21.24	18.42	17.48	16.53
T_3	38.58	19.67	16.05	27.45	22.96	19.64	15.10	44.89	35.80	25.85	20.05	18.22	15.13	12.04
T_4	38.58	20.34	18.83	26.64	25.35	20.04	21.16	44.89	38.73	34.93	31.63	15.87	13.15	10.44
T_5	38.58	27.87	24.69	26.17	18.76	26.46	19.60	44.89	44.98	27.52	26.16	17.82	14.44	11.07
T_6	38.58	32.90	27.87	24.36	24.13	23.80	22.46	44.89	40.36	30.83	25.23	15.79	13.91	12.03
T_7	38.58	26.45	24.52	22.62	20.33	21.69	13.60	44.89	30.62	34.72	26.13	17.39	14.48	11.58
Mean	38.58	26.09	22.60	25.04	22.47	22.06	18.36	44.89	38.32	30.72	25.34	17.91	15.55	13.19
SE	0.72													
CD	1.42													

MAS: Months After Storage

Over both the seasons, sun drying was found better than oven drying with respect to index of cut test score. Considering the treatment effect T_3 and T_7 which scored highest cut test index were ranked superior.

4.1.2.7 Recovery per cent of cured beans

The recovery percentage of cured bean in relation to various fermentation and drying treatments are presented in Table 22. During first season, the recovery per cent of beans dried in sun was comparatively higher (39.09 per cent) than that recorded in the second season (38.11 per cent). In case of oven dried samples the recovery per cent was higher during second season (33.23 per cent) than the first season (31.09 per cent).

With respect to method of drying, the recovery per cent was higher for sun dried samples (39.09 and 38.11 per cent during first and second season respectively). The oven dried samples recorded lower recovery percentage (32.10 and 33.23 per cent during first and second season respectively).

The treatment effect on recovery percentage of cured beans varied significantly. The higher recovery percentage of 40.50 was recorded in T_4 and T_8 during the first season in case of sun dried samples. The lowest recovery per cent (37.70) was recorded in T_5. During the second season, T_4 (40.92), T_6 (40.24), T_3 (40.16) and T_8 (40.02) recorded higher percentage recovery of cured beans. Among the oven dried samples, T_4 and T_8 recorded the highest recovery of 33.50 per cent each during first season. During second season, T_8 (36.05%) had the highest recovery. Recovery was lowest in T_2 (30.75 per cent) and T_1 (29.60) during first and second season in oven dried samples.

4.1.3 Identification of Suitable Storage Techniques for Cured beans

The change in moisture content, pH, amino acid, polyphenol and anthocyanin content of beans stored in different packing materials for a period of one year was analyzed and the results are presented here under.

Moisture content

The data on moisture content of beans during storage period are given in Table 24. During both the seasons there was a substantial increase in moisture content of beans during storage. During first season (April – May), the initial moisture content of 6.36 per cent on an average was increased to 7.69 per cent at 12 months after storage. During second season (October – November) the initial moisture content of 6.30 per cent was raised to 8.52 per cent. Thus, the percentage increase in moisture level of beans was high (2.22 per cent) during second season as compared to that of first season (1.33 per cent).

The influence of packaging of beans on absorption of moisture was evident from the study. Even though, the moisture content of beans stored in different packing materials did not vary significantly at two months after storage, the difference was significant from fourth month onwards. This is true for the beans stored during both the seasons. During first season, storing beans in T_5 (polythene lined and jute bags together with neem leaves at the rate of one kilograms per 100 kilogram of beans) and T_3 (jute bags with double lining of polythene) was found better. In these cases, the absorption of moisture by the beans was comparatively low. The increase in moisture was only 0.47 and 0.63 per cent respectively in T_5 and T_3 compared to 2.92 per cent recorded in control at ten months of storage.

During second season, the moisture level of beans was comparatively less in beans stored in HDPE bags (T_1) and jute bags with double lining of polythene (T_3) through out the intervals of the observation. The initial moisture content of 6.30

Table 28. Effect of packaging and storage on anthocyanin content of beans

Treatment	Anthocyanin (mg $100g^{-1}$)													
	1 Season (May 2003-April 2004)							II Season (October 2003-September 2004)						
	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS	Initial	2MAS	4MAS	6MAS	8MAS	10MAS	12MAS
T_1	14.67	6.59	5.75	4.81	4.31	2.64	2.71	18.97	6.51	5.56	5.12	4.34	1.42	1.07
T_2	18.74	7.81	4.59	4.61	3.41	2.55	1.72	15.47	4.92	4.87	4.43	3.64	3.62	3.44
T_3	12.30	5.65	3.44	3.58	3.59	2.46	2.67	20.31	6.71	4.64	4.15	3.99	2.52	2.32
T_4	14.17	4.57	3.74	3.46	2.69	2.63	3.14	18.66	6.42	7.81	4.56	4.85	3.42	3.41
T_5	15.39	6.91	4.54	4.56	4.61	3.75	3.16	14.89	8.56	4.94	6.89	5.48	4.98	4.43
T_6	13.41	5.88	4.42	4.64	3.57	3.16	2.61	19.60	6.76	5.44	6.21	4.63	3.62	2.81
T_7	21.43	5.91	4.82	5.82	4.67	4.44	1.85	15.65	9.45	9.84	7.24	2.42	2.51	1.48
Mean	15.73	6.19	4.47	4.50	3.83	3.09	2.55	17.65	7.05	6.15	5.57	4.19	3.16	2.70
SE	0.037													
CD	0.073													

Table 29. Effect of packaging and storage on bacterial population

Treatment	Bacteria ($x10^3$ CFU g^{-1})						
	Period of storage						
	Initial	2 MAS	4 MAS	6 MAS	8 MAS	10 MAS	12 MAS
T_1	14.33 (3.771)	14.33 (3.776)	18.00 (4.186)	18.67 (4.314)	17.00 (4.107)	27.67 (5.259)	25.33 (5.012)
T_2	10.00 (3.15)	19.67 (4.415)	18.33 (4.241)	24.33 (4.929)	20.33 (4.507)	26.33 (5.131)	27.00 (5.155)
T_3	12.00 (3.456)	12.67 (3.542)	19.00 (4.332)	19.67 (4.419)	39.00 (6.244)	20.33 (4.507)	25.33 (5.005)
T_4	22.67 (4.753)	21.33 (4.596)	30.33 (5.505)	31.33 (5.593)	33.00 (5.743)	14.67 (3.811)	26.33 (5.113)
T_5	13.67 (3.676)	18.00 (4.233)	15.67 (3.952)	19.67 (4.432)	36.67 (6.053)	30.00 (5.477)	22.00 (4.683)
T_6	21.00 (4.569)	20.67 (4.538)	28.33 (5.318)	24.33 (4.922)	20.33 (4.507)	16.00 (3.999)	30.00 (5.461)
T_7	15.67 (3.936)	52.67 (7.243)	56.33 (7.392)	56.00 (7.463)	79.00 (8.867)	75.33 (8.664)	64.67 (7.997)
SE	0.294						
CD	0.583						

per cent was increased only to 6.70 and 6.74 per cent in treatments T_3 and T_6 respectively compared to 11.06 per cent in control at ten months after storage.

4.1.3.1 pH of beans

There was significant difference in pH of beans among different packaging treatments, seasons and intervals of observation (Table 25). Mean pH of beans decreased through out the period of storage in the first season. There was significant influence for the packaging given to beans in changing their pH during storage in the first season. At final stage of observation the beans stored in jute bags with double lining of polythene (T_2) alone or together with neem leaves (T_5) retained higher pH (5.21 and 5.14 respectively) compared to other treatments except control. The pH of beans stored in jute bags with double lining of polythene (T_3) and in HDPE bags (T_1) alone or with neem leaves (T_4 and T_6) were low compared to control (5.61).

During second season the treatment effect was evident only in the later stages of storage *viz.*, eight months after storage onwards. From eighth month of storage, irrespective of packaging material all samples recorded a reduction in pH (<6.0). At the final stage of observation the beans stored in HDPE bags (T_1) and polythene lined jute bags (T_2) recorded significantly low pH (5.45 and 5.41 respectively). The pH of beans stored in T_6 was significantly high compared to other treatments except control.

4.1.3.2 Amino acid content.

The amino acid content of the beans varied significantly with respect to seasons, interval of observations and treatments (Table 26).

There was a drastic reduction in the amino acid content of beans during storage in both the seasons. The highest average amino acid content of 16.38 mg g^{-1}recorded at the initial stage was reduced to 10.23 mg g^{-1}at 6 months after

Table 30. Effect of packaging and storage on fungal population

Treatment	Fungus (x10 ^{2} CFU g^{-1})						
	Period of storage						
	Initial	2 MAS	4 MAS	6 MAS	8 MAS	10 MAS	12 MAS
T_1	3.00 (1.715)	4.33 (2.061)	5.00 (2.229)	5.00 (2.205)	5.67 (2.378)	5.00 (2.229)	4.67 (2.139)
T_2	2.00 (1.382)	4.33 (2.061)	2.33 (1.52)	3.67 (1.883)	7.00 (2.628)	5.00 (2.061)	3.00 (1.715)
T_3	3.33 (1.745)	3.00 (1.715)	3.00 (1.715)	4.67 (2.126)	5.00 (2.229)	4.33 (2.061)	4.67 (2.15)
T_4	3.33 (1.821)	2.33 (1.52)	2.67 (1.55)	3.00 (1.715)	10.33 (3.209)	4.33 (1.715)	4.67 (2.099)
T_5	5.00 (2.205)	4.00 (1.989)	4.33 (2.061)	4.33 (2.061)	5.00 (2.229)	3.00 (1.989)	4.67 (2.139)
T_6	2.33 (1.471)	3.67 (1.748)	4.00 (1.989)	4.00 (1.989)	5.00 (2.209)	4.00 (5.209)	4.67 (2.139)
T_7	4.00 (1.989)	10.33 (3.112)	7.67 (2.759)	18.00 (4.233)	33.33 (5.725)	27.33 (2.139)	29.67 (5.427)
SE	0.25						
CD	0.49						

Figures in parenthesis indicate transformed values

Table 31. Effect of alkalisation and storage on pH of bean

Treatment	I Season					II Season				
	Before alkalisation	After alkalisation				Before alkalisation	After alkalisation			
		Initial	2 MAS	4 MAS	6 MAS		Initial	2 MAS	4 MAS	6 MAS
T_1	5.51	5.52	5.48	5.49	5.40	5.47	5.54	5.52	5.47	5.32
T_2	5.51	5.52	5.55	5.45	5.40	5.47	5.81	5.79	5.60	5.42
T_3	5.51	5.76	5.61	5.52	5.42	5.47	5.80	5.62	5.68	5.46
T_4	5.51	5.99	5.67	5.72	5.66	5.47	5.91	5.89	5.79	5.51
T_5	5.51	5.64	5.61	5.60	5.57	5.47	5.55	5.49	5.55	5.51
T_6	5.51	5.68	5.83	5.67	5.51	5.47	5.91	5.89	5.79	5.54
T_7	5.51	5.86	5.79	5.83	5.88	5.47	5.86	5.81	5.78	5.61
T_8	5.51	5.91	5.84	5.84	5.83	5.47	5.90	5.89	5.80	5.73
T_9	5.51	5.51	5.41	5.41	5.32	5.47	5.46	5.44	5.42	5.36
Mean	5.51	5.71	5.65	5.61	5.56	5.47	5.75	5.70	5.65	5.50
SE	0.097									
CD	0.192									

MAS: Months after storage

storage and to 6.8 mg g^{-1}at one year after storage during first season. Thus on an average there was a loss of 9.57 mg g^{-1} in amino acid content of beans due to one year of storage. The observations were almost similar in the case of beans stored during second season. On an average the initial amino acid content of 21.47 mg g-1 was reduced to 12.3 mg g^{-1} at one year after storage. The reduction in amino acid content on an average was 9.17 mg g^{-1}.

The influence of season on amino acid content of beans varied significantly at each stage of observation during the first and second season. One year after storage higher retention of amino acid was recorded with beans stored in jute bags with neem leaves (T_5), followed by those stored in HDPE bags with neem leaves (T_4). The amino acid content in control sample was significantly lower.

4.1.3.3 Polyphenol content

The data recorded on polyphenol content of beans at bimonthly intervals upto one year of storage in different packages are given in Table 27. Significant difference in polyphenol content of beans was observed with respect to seasons of storage, intervals of observations and treatments. The polyphenol content of bean recorded a drastic reduction in response to storage during both the seasons. The polyphenol content of beans recorded at the time of storage was 38.58 mg g^{-1} during the first season and 44.89 mg g^{-1} during second season. This was reduced to 18.36 and 13.19 mg g^{-1} respectively during the course of one-year storage. It can be seen that the reduction in polyphenol was comparatively high (31.7 mg g^{-1}) in the beans stored during second season.

The effect of packaging given to beans on retention of polyphenol content varied at each stage of observation. Two months after storage retention of polyphenol was the highest in beans stored in HDPE bags (34.77 mg g^{-1}) and lowest with beans packed in jute bags with double lining of polythene (19.67 mg g^{-1}). When the storage was continued up to eight months the beans in HDPE bags with neem leaves recorded maximum polyphenol content (23.35 mg g^{-1}) and those in polythene

lined jute bags with neem leaves (T_5) recorded the minimum polyphenol (18.76 mg g^{-1}). When observed after one year of storage, the maximum polyphenol content (22.46 mg g^{-1}) was recorded in the beans in jute bags with double lining of polythene and neem leaves (T_6) followed 21.16 mg g^{-1} in HDPE bags with neem leaves (T_4). Polyphenol was very low in samples drawn from control.

During second season also, the influence of packaging material on retention of polyphenol in beans varied at each interval of observation. After two months of storage maximum polyphenol content (44.98 mg g^{-1}) was observed with beans stored in single lined jute bags with neem leaves (T_5). At fourth and sixth months after storage polyphenol content was the maximum with beans stored in HDPE bags with neem leaves (34.93 and 31.63 mg g^{-1} respectively). From eighth month onwards, the maximum polyphenol content was recorded with beans stored in HDPE bags.

4.1.3.4 Anthocyanin content

The anthocyanin content of beans varied with respect to season as well as intervals of storage and packaging treatments (Table 28). The reduction in mean anthocyanin content of beans was significant at each intervals of observation during both the season. The reduction anthocyanin content of beans was the maximum during second season compared to first season. Two months after storage reduction mean anthocyanin content of beans recorded were 9.4 and 9.54 mg $100g^{-1}$ respectively during first and second season. In the first season, after one year of storage the beans stored in polythene lined jute bags (1.72 mg $100g^{-1}$) and control (1.85 mg $100g^{-1}$) recorded minimum anthocyanin content of beans. The beans stored in HDPE with neem leaves (3.14 mg $100g^{-1}$) and polythene lined jute bags with neem leaves (3.16 mg $100g^{-1}$) recorded the maximum anthocyanin contents.

During both the seasons, the influence of the packaging materials varied significantly. The lowest anthocyanin content of beans was recorded in HDPE bags during the last two stages of observation. Beans stored in polythene lined jute

Table 32. Effect of alkalisation and storage of beans on anthocyanin content

Treatment	Anthocyanin (mg $100g^{-1}$)							
	I Season				II Season			
	Initial	2MAS	4MAS	6MAS	Initial	2MAS	4MAS	6MAS
T_1	27.19	5.56	4.89	4.36	28.03	6.42	4.81	4.92
T_2	21.55	3.11	4.56	3.88	16.44	8.91	6.71	5.81
T_3	20.98	6.41	5.22	2.66	27.77	7.81	4.91	5.62
T_4	23.43	8.43	4.52	2.45	14.56	6.44	6.65	3.76
T_5	14.92	5.61	3.78	1.52	31.83	9.62	8.91	7.42
T_6	16.59	4.56	4.89	3.85	22.18	4.81	5.92	3.41
T_7	22.02	8.64	3.56	2.66	27.29	6.99	2.88	1.22
T_8	18.32	6.41	4.52	1.62	22.49	5.89	4.11	3.33
T_9	17.43	5.81	5.89	2.45	27.19	8.95	6.54	4.22
Mean	20.27	6.06	4.65	2.83	24.20	7.32	5.72	4.41
SE	0.01							
CD	0.02							

Table 33. Effect of alkalisation and storage of beans on amino acid content

Treatment	Amino acid content (mg g^{-1})							
	I Season				II Season			
	Initial	2MAS	4MAS	6MAS	Initial	2MAS	4MAS	6MAS
T_1	21.00	21.11	11.49	9.26	15.99	9.89	7.88	5.42
T_2	21.11	22.33	11.06	13.21	16.49	9.95	9.59	5.84
T_3	21.02	25.28	8.97	14.17	15.09	17.22	14.43	5.72
T_4	22.12	20.96	11.94	14.86	15.42	15.13	9.98	7.90
T_5	21.67	19.53	10.79	9.14	17.22	8.67	6.98	6.60
T_6	21.41	23.67	13.48	10.47	13.49	7.65	4.83	7.43
T_7	22.41	21.02	11.27	9.03	15.07	17.44	12.18	10.07
T_8	21.95	18.20	8.78	8.18	16.87	19.45	18.21	8.95
T_9	22.51	26.48	5.50	10.47	15.49	19.03	16.14	15.90
Mean	21.69	22.06	10.36	10.98	15.68	13.83	11.14	8.20
SE	0.64							
CD	1.27							

bags with neem leaves recorded the highest anthocyanin content of 5.48, 4.98 and 4.43 mg $100g^{-1}$ at eighth, tenth and twelfth month after storage respectively.

In the first season, one year after storage, beans stored in polythene lined jute bags and control recorded minimum anthocyanin contents of 1.72 and 1.85 mg $100g^{-1}$ respectively.

4.1.3.5 Microbial load on cocoa beans during storage

The microbial population (bacteria and fungal count) recorded at bimonthly intervals for one year with the beans subjected to different packaging treatments are given in Tables 29 and 30.

4.1.3.5.1 Bacteria

There was significant difference with respect to bacterial population among various treatments at different stages of observation during storage. Initially, the lowest bacterial population of 10x 10^3 CFU g^{-1} was recorded with beans stored in single lined jute bags (T_2) followed by beans stored in double lined jute bag i.e. T_3 (12 x 10^3 CFU g^{-1}) and beans stored in jute bags lined with polythene and mixed with neem leaves i.e. T_5 (13.67 x 10^3 CFU g^{-1}). The maximum bacterial count was recorded with control at all storages of observation except at two months after storage. The bacterial count was the minimum in T_3 (12.67 x 10^3 CFU g^{-1}) followed by T_1 (14.33 x 10^3 CFU g^{-1}) at two months after storage. After six months of storage also, the T_1 (18.67 x 10^3 CFU g^{-1}) and T_3 (19.67 x 10^3 CFU g^{-1}) recorded lower bacterial counts. At final stage of observation, the lowest bacterial population was recorded with T_5 (22.00 x 10^3 CFU g^{-1}) followed by T_3 and T_1 (25.33 x 10^3 CFU g^{-1} each)

4.1.3.5.2 Fungus

There was significant difference with respect to the fungal population recorded with the beans under various treatments at different stages of observation.

At the initial stage of observation, fungal count was the lowest in beans stored in single lined jute bags i.e. T_2 ($2.00x10^2$CFU g^{-1}) followed by that stored in double lined jute bags with neem leaves i.e. T_6 ($2.33\ x10^2$CFU g^{-1}). At subsequent stages of observation, the fungal population was found to be varying with respect to the treatments. After a period of six months of storage, the lowest fungal population was recorded with beans stored in HDPE i.e. T_4 ($3.00\ x10^2$CFU g^{-1}) followed by T_2 ($3.67\ x10^2$CFU g^{-1}). At final stage of observation T2 recorded the lowest fungal count ($3.00\ x10^2$CFU g^{-1}) followed by T_1, T_3, T_4, T_5 and T_6 ($4.67\ x10^2$CFU g^{-1} each). The fungal population was found to increase in general with period of storage. At all stages of observation, the control recorded the maximum fungal population.

4.2 SECONDARY LEVEL PROCESSING AT SMALL SCALE LEVEL

4.2.1 Effect of Alkalisation and Storage on Quality of Beans

Observations on biochemical parameters such as anthocyanin, amino acid and polyphenol were recorded at bimonthly interval and the results are presented here under.

4.2.1.1 pH of beans

The results of the change in pH of beans with respect to alkalisation and storage are presented in Table 31.

During both the seasons, the pH increased immediately after alkalization. The pH showed a declining trend during storage. Higher pH retention was recorded during first season. There was significant difference with respect to pH of various treatments during both the seasons. In the first season, the initial pH of 5.51 rose to a maximum value of 5.99 in the case of T_4 (beans treated with 1.0 per cent alkali for four hours). This was on par with T_8 (5.91) and T_7 (5.86). Then the pH

Table 34. Effect of alkalisation and storage of beans on polyphenol content

Treatment	Polyphenol (mg g^{-1})							
	I Season				II Season			
	Initial	2MAS	4MAS	6MAS	Initial	2MAS	4MAS	6MAS
T_1	26.80	29.49	24.78	23.38	30.11	30.82	21.35	20.42
T_2	25.42	33.42	23.73	20.89	30.49	30.62	21.36	19.42
T_3	29.09	30.49	28.85	24.38	38.07	38.76	16.31	15.47
T_4	30.15	32.22	29.31	21.27	35.87	36.53	22.51	19.11
T_5	28.29	30.67	30.25	20.13	36.69	32.53	26.76	24.04
T_6	31.31	30.98	26.57	19.47	38.78	33.11	23.82	22.91
T_7	32.11	32.76	32.93	25.89	33.47	32.76	26.00	17.71
T_8	29.00	27.18	26.16	25.33	34.18	30.62	23.07	21.73
T_9	33.09	24.05	28.78	20.27	30.98	29.60	18.67	16.24
Mean	29.48	30.14	27.92	22.33	34.63	32.82	22.21	19.67
SE	0.83							
CD	1.63							

Table 35. Sensory attributes of chocolate made from alkalised and stored bean

Treatment	Sensory score				
	Colour	Taste	Flavour	Consistency	Overall acceptability
T_1	4.5	5.8	5.9	6.5	5.7
T_2	5.3	3.7	3.2	3.0	3.8
T_3	4.8	4.4	5.0	6.0	5.1
T_4	7.5	7.5	6.4	6.4	6.9
T_5	3.6	3.8	4.3	2.9	3.6
T_6	6.1	6.3	5.4	7.4	6.3
T_7	3.8	5.1	4.7	4.1	4.4
T_8	4.0	3.6	4.5	4.0	4.0
T_9	5.6	5.0	5.8	4.8	5.3

Table 36. Effect of bean size and method of roasting on quality of cocoa nibs

Bean size	pH			Non volatile organic acid (%)			Amino acid (mg g^{-1})		
	R_1	R_2	Mean	R_1	R_2	Mean	R_1	R_2	Mean
Large	6.39	6.27	6.33	0.16	0.58	0.37	3.02	6.14	4.58
Medium	6.27	6.18	6.22	0.35	0.70	0.52	7.43	11.01	9.22
Small	6.07	6.15	6.11	0.46	0.80	0.63	5.18	5.49	5.33
Mean	6.23	6.12		0.32	0.69		5.21	7.54	
SE	0.07			0.02			0.54		
CD	0.14			0.05			1.17		

R_1: Roasting in shallow pan
R_2: Roasting in small scale roaster

declined and the highest pH after six months was observed in T_7 (5.884) which was followed by T_8 (5.83) and T4 (5.66). During the second season, the initial mean pH was 5.47 which increased to 5.91 in the case of T_4 and T_6. During storage, the pH declined and after six months the highest pH was recorded in T_8 (5.73)

While considering both the seasons together, soaking of beans for four hours duration was most effective and the ideal concentration of sodium bicarbonate was 1.5 per cent in retaining higher pH of beans at the end of storage period. However the sensory test showed that soaking in one per cent alkali for four hours was most acceptable.

4.2.1.2 Anthocyanin

The anthocyanin content of alkalised beans at different intervals of storage during the first and second season is given in Table 32.There was significant difference among treatment during both the seasons with respect to anthocyanin content of beans at different intervals of storage. The mean anthocyanin content of beans decreased drastically over a period of storage for six months. During the first season, the mean anthocyanin content of 20.27 mg $100g^{-1}$ recorded at initial stage of storage was decreased to 6.06, 4.65 and 2.83 mg $100g^{-1}$ on second, fourth and sixth month after storage respectively. During second season, the initial anthocyanin content of 24.2 mg $100g^{-1}$ recorded with the beans was reduced to 7.32, 5.72 and 4.41 mg $100g^{-1}$ on second, fourth and sixth month after storage respectively.

Significant difference was observed among various treatments with respect to anthocyanin content during storage. After two months of storage T_2 recorded the lowest anthocyanin content of 3.11 mg $100g^{-1}$ and the highest was in T_7 (8.64 mg $100g^{-1}$). After four months of storage, the lowest anthocyanin content (3.56 mg $100g^{-1}$) was recorded in T_7 where as T_9 retained the maximum anthocyanin content (5.89 mg $100g^{-1}$). During sixth month of storage, T_5 (beans soaked in 1.5 % alkali for one hour) recorded the lowest anthocyanin content of

Table 37. Effect of duration of grinding on properties of cocoa mass and powder

Treatment	Cocoa mass		Powder		
	Butter recovery (%)	Powder recovery (%)	Particle size (%)	Fat (%)	Bulk density
G_1 (2 hours)	33.00	65.92	94.54	25.48	0.61
G_2 (4 hours)	30.00	68.16	96.24	30.78	0.65
G_3 (6 hours)	31.47	68.22	96.41	30.61	0.56
G_4 (8 hours)	28.17	71.52	96.60	33.64	0.69
Mean	30.67	68.46	95.94	30.13	0.63
SE	0.78	0.93	0.27	0.95	0.01
CD	2.34	2.79	0.81	2.88	0.03

Table 38. Effect of duration of grinding on sensory attributes of chocolate

Treatment	Color	Taste	Flavour	Consistency	Overall acceptability
G_1	2.2	2.05	2.2	1.65	2.03
G_2	2.25	2.45	2.4	2.35	2.36
G_3	2.15	2.2	2.55	2.5	2.35
G_4	3.1	3.3	2.85	3.5	3.19
Chi-square	8.02	7.69	2.33	14.75	
Asymptotic significance (%)	4.6	NS	NS	0.2	

Table 39. Effect of temperature on spray drying of the beverage mix

Treatment	Inlet temperature(°C)	Outlet temperature (°C)	Product characteristics
1	230	120	Charred flavour, discolouration, poor dispersibility
2	175	80	Moisture content beyond acceptable limit
3	200	100	Flavour acceptable, satisfactory dispersibility
4	190	90	Good flavour , good dispersibity and moisture content within acceptable limit

1.52 mg 100g $^{-1}$, which was followed by 1.62 mg 100g $^{-1}$ in T_8 (beans soaked in 1.5 % alkali for four hours). During the second season, T_6 (beans soaked in 1.5 % alkali for two hours) recorded the lowest anthocyanin content of 4.81 mg 100g $^{-1}$ at two months after storage. This was followed by T_8 (5.89 mg 100g $^{-1}$). The treatment T_5 recorded the maximum anthocyanin content at two, four and six months after storage. During fourth and sixth months of storage, the lowest anthocyanin content was recorded in T_7 (2.88 and 1.22 mg 100g $^{-1}$ respectively). This was followed by T_8 (5.89 mg 100g $^{-1}$).

4.2.1.3 Amino acid

The data recorded on amino acid content of beans in response to alkalisation and storage for a period of six months (recorded at bimonthly interval for two seasons) are given in Table 33. During both the seasons, there was not much variation in the mean amino acid content of alkalised beans when analysed during two months after storage. There after the amino acid content decreased through out the stages of observation. During first season, the mean amino acid content of 22.06 mg g $^{-1}$ recorded at two months after storage was decreased to 10.36 and 10.98 mg g $^{-1}$ at four and six months after storage respectively. During second season, the mean initial amino acid content of 15.68 mg g $^{-1}$ was decreased to 11.14 and 8.20 mg g $^{-1}$ at four and six months after storage respectively.

The treatment effect on amino acid content of beans recorded at different intervals of storage was found significant. During the first season, significantly high amino acid content (26.4 mg g $^{-1}$) was recorded in control sample and the lowest in T_8 (18.20 mg g $^{-1}$), when observed at two months after storage. On fourth month after storage, the highest amino acid content was recorded with T_6 (13.8 mg g $^{-1}$) and the lowest with the control sample (5.50 mg g $^{-1}$). At six months after storage the amino acid content retention was high in T_4 (14.86 mg g $^{-1}$) and T_3 (14.17 mg g $^{-1}$). The amino acid content was the lowest with T_8 (8.18 mg g $^{-1}$) at the same period.

During second season, higher amino acid content of 19.45 mg g^{-1} was recorded in T_8 (1.5 per cent alkali for four hours) and 19.03 mg g^{-1} in T_9 (control) at two months after storage. The lowest amino acid content of 7.65 mg g^{-1} was recorded with T_6. In all the treatments the amino acid content recorded a decrease when observed at subsequent stages of observation and at six months after storage the highest amino acid content of 15.90 mg g^{-1} was recorded with control samples, which was followed, by T_7 (10.07 mg g^{-1}) and the lowest with T_1 (5.42 mg g^{-1}).

4.2.1.4 Polyphenol content

The polyphenol content of beans in response to alkalisation and storage for a period of six months for two seasons are given in Table 34.

During both the seasons the mean polyphenol content of beans recorded a decrease with duration of storage. The rate of decrease was high (14.96 mg g^{-1}) during second season compared to first season (7.15 mg g^{-1}). The effect of alkalisation of beans was found to have significant influence on polyphenol content at different intervals of observation during storage. There was not much variation in polyphenol content of beans at two months after storage than that recorded at initial stage of storage during both the seasons. During the first season, the polyphenol content recorded was very less in T_2 (23.73 mg g^{-1}) at four months after storage. The maximum polyphenol content of 32.93 mg g^{-1} was recorded with T_7. At six months after storage the lowest polyphenol content of 19.47 mg g^{-1} was recorded with T_6 and the highest with T_7 (25.89 mg g^{-1}), which was followed by T_8 (25.33 mg g^{-1}).

During the second season, the lowest polyphenol content of beans was recorded with T_3 (16.31 mg g^{-1}) on fourth month of storage and the highest with T_5 (26.76 mg g^{-1}) which was followed by 26 mg g^{-1} in T_7. The polyphenol content of beans under all the treatments decreased at six months after storage and

Table 40. Effect of feed composition on spray drying of beverage mix

Treatment	Ingredient proportion (%)					
	Cocoa (25% fat)	Milk solids	Sugar	Gelatin	Maltodextrin	Lecithin
T_1	21	55	16	0.4	7.6	-
T_2	14	66	14	0.3	5.7	-
T_3	21*	70	-	0.3	8.7	-
T_4	14*	75	-	0.5	10.5	-
T_5	15	60	15	0.3	9	0.7
T_6	14	63	12	0.3	10.7	-
T_7	14	63	12	0.3	10.5	0.2

- Low fat cocoa powder (12% fat)

Table 41. Effect of feed composition on spray drying of beverage mix (continued)

Treatment	Properties			
	Viscosity (mPa.S)	Recovery %	Flavour/taste	Dispersibility
T_1	356	40.61	Dominant cocoa flavour	Unsatisfactory
T_2	481	41.25	Balanced flavour of cocoa and milk	Satisfactory
T_3	480	43.67	Blank and bitter taste of cocoa	Unsatisfactory
T_4	228	41.57	Slightly blank taste of cocoa	Unsatisfactory
T_5	137	43.21	Off flavour of lecithin	Very good
T_6	228	44	Balanced flavour of cocoa and milk	Good
T_7	157	41.13	Balanced flavour with slight off flavour from lecithin	Very good

Table 42. Effect of feed composition on physical properties of spray dried powder

Treatment	Properties				
	Moisture%	Fat %	Bulk density	Average particle density	% volume occupied by powder particle
T_1	3.85	5.26	0.234	0.73	32.28
T_2	4.2	5.77	0.314	0.92	34.5
T_3	4	5.3	0.25	0.87	31.97
T_4	2	6.29	0.3	0.89	34.01
T_5	1.6	7.36	0.28	0.85	35.12
T_6	1.85	3.61	0.32	0.9	30.5
T_7	1.4	4.98	0.35	0.96	28.69

the highest polyphenol content (24.04 mg g^{-1}) was recorded with T_5 and the lowest with T_3 (15.47 mg g^{-1}).

4.2.1.5 Quality of chocolate prepared with alkalised and stored beans

The mean rank for quality parameters gained by chocolate prepared using alkalised beans after a period of storage for six months are given in Table 35. During first season, there was significant difference among treatments with respect to colour, taste and consistency of chocolate. The most acceptable colour and taste was recorded in the chocolate prepared with beans alkalised for four hours using alkali at one per cent strength (T_4). The consistency of chocolate was better in T_6 (1.5 per cent for two hours). Even though, the treatment effect on quality of chocolate was prominent during first season, it was insignificant during the second season.

4.2.2 Effect of Bean size and Method of Roasting on Quality of Cocoa nibs

The data on pH, non volatile organic acid content and amino acid content of beans subjected to different methods of roasting are given in Table 36.

The mean pH of roasted nibs was high in Uruli roaster (6.23) than that in small scale roaster. (6.19). With respect to size of bean the mean pH was the highest in large beans (6.33) which was followed by medium sized beans (9.22) and small sized ones (6.11).

Non-volatile organic acid content

The mean value of non-volatile organic acids expressed as per cent acetic acid was the lowest in large beans (0.37) after roasting which was followed by medium (0.524) and small sized beans (0.627). When the method of roasting was considered, the retention of non volatile organic acids was lesser in Uruli roaster (0.323) than small scale roaster (0.691).

Amino acid content

The amino acid content retained after roasting was lower in Uruli roaster (5.21 mg g^{-1}) than small scale roaster (7.54 mg g^{-1}). With respect to size of the bean the amino acid content retention was the lowest in large sized beans (4.58 mg g^{-1}) when compared to medium (9.22 mg g^{-1}) and small (5.33 mg g^{-1}) sized beans

4.2.3 Effect of Duration of Grinding on Cocoa mass and Powder Characteristics

The data on the characteristics of cocoa mass and powder as influenced by duration of grinding are given in Table 37.There was significant difference with respect to butter recovery per cent of various treatments. The highest butter recovery was obtained when grinding was done for two hours (33.00 per cent), which was on par with that of six hours of grinding (31.47 per cent). The lowest butter recovery was obtained in case of eight hours of grinding (28.17 per cent).

In case of powder recovery, the maximum value was recorded for eight hours grinding treatment (71.5 per cent) and the lowest from beans subjected to four and six hours of grinding (68.16and 68.22 per cent respectively). The powder recovery from beans subjected to four and six hours of grinding were statistically on par with each other.

With respect to particle size (the percentage of particle that passed through 0.5 mm sieve), all the treatments except two hours of grinding was on par with each other for. The two hour grinding treatment recorded the lowest percentage of particles that passed through 0.5 mm sieve. The maximum quantity of powder particle that passed through 0.5 mm sieve was observed in eight hours' grinding treatment.

Table 43. Comparison of properties of spray dried and cabinet dried powders

Properties	Spray dried powder	Cabinet dried
Moisture (%)	2.7	2.99
Bulk density	0.245	0.314
Average particle density	0.748	0.922
Percent volume occupied by powder particles	32.8	34.05
Recovery %	42.06	43.5
TSS (%)*	16.62	16.59
pH*	6.32	6.112
Fat (%)*	5.51	4.98
Dispersibility (%)*	96.33	90.23
Flowability (Angle of repose)*	51	49

*Values recorded after dry blending of sugar

Table 44. Moisture sorption kinetics of spray dried powder

Equilibrium Relative Humidity (%)	Equilibrium moisture content (%)	Physical condition of powder
0	1.29	Free flowing , no change in flavour or colour
5	2.68	Free flowing , no change in flavour or colour
10	2.99	Free flowing , no change in flavour or colour
15	2.72	Free flowing , no change in flavour or colour
20	4.3	No change in colour or flavour
25	4.07	Free flowing , no change in flavour or colour
30	4.82	Slight caking observed
35	5.95	Caking was evident

Table 45. Moisture sorption kinetics of cabinet dried powder

Equilibrium Relative Humidity (%)	Equilibrium moisture content (%)	Physical condition of powder
0	1.96	Free flowing , no change in flavour or colour
5	2.47	Free flowing , no change in flavour or colour
10	3.51	Free flowing , no change in flavour or colour
15	3.7	Free flowing , no change in flavour or colour
20	2.99	Free flowing , no change in flavour or colour
25	4.64	Free flowing , no change in flavour or colour
30	5.57	Slight caking observed, no colour change
35	6.19	Caking was evident

The retention of fat content was the lowest (25.48 per cent) in case of beans that were subjected to the shortest duration of grinding i.e. two hours. The highest fat content was 33.64 per cent obtained from sample that was subjected to eight hours of grinding. This was on par with that of four hours of grinding (30.78 per cent).

Bulk density of the powder was the highest in case of beans subjected to eight hours of grinding (0.694) which was followed by four hours of grinding (0.653). The lowest bulk density was recorded in powder that was obtained from beans subjected to six hours of grinding.

4.2.3.1 Effect of duration of grinding on quality of chocolate

The effect of grinding given for varying duration ranging from two to eight hours on quality parameters of chocolate is given in Table 38. There was significant difference among different treatments with respect to colour and consistency of chocolate. The colour of chocolate was found most acceptable when roasted beans were ground for a period of four hours (G_2). Whereas the consistency was best when chocolate was prepared with high fat powder (G_4)

4.3 VALUE ADDITION AND PRODUCT DEVELOPMENT IN COCOA

The results of various experiments conducted to develop an instant chocolate milk beverage powder (ICBP) are presented hereunder.

4.3.1. Experiments on Spray Drying

The first part of the study consisted of standardization of ideal inlet/outlet temperature for spray drying. Development of ideal beverage composition of the feed material for production of ICBP, formed the second part of study.

4.3.1.1. Standardisation of temperature regime for spray drying

Experiments were conducted to optimize the inlet and outlet air temperatures during drying of the product in spray drier and the results are tabulated in Table 39. When the inlet and outlet temperature were maintained at 230 and 120 °C respectively, the powder obtained had dark brown colour having charred flavour and poor dispersibility. Drying the product at an inlet outlet temperature of 175 and 80°C respectively gave a product, which is under dried having moisture content above the acceptable limit. Flavour and moisture content of powder were found acceptable when the inlet and outlet air temperature were maintained at 200and 100°C. But the dispersibility of the powder was poor. Further, experiments were conducted at an inlet outlet air temperature of 190 and 90 °C. The powder obtained was found to have good flavour and dispersibility. The moisture content of the powder was also within the acceptable limit of four per cent.

4.3.1.2 Standardization of feed composition for production of spray dried ICBP

The details of the feed composition used in spray drying to produce ICBP and their quality parameters are given in Tables 40 and 41. Mainly the proportion of cocoa powder and milk solids was varied to get a desirable composition of the beverage mix. The treatment T_1 was formulated by incorporating 21 per cent and 55 per cent milk solids. The resultant product showed dominant cocoa flavour with dispersibility below satisfactory level. Thus, the proportion of cocoa powder was reduced to 14 per cent in the second trial (T_2), which included 66 per cent milk solids. Though, the product retained a balanced flavour of cocoa and milk, the powder recovery in the cyclone separator was not proper. In the case of T_3, low fat cocoa powder (12 per cent fat) was tried (21 per cent in the formulation) which resulted in a product with a blank taste of cocoa. The powder dispersibility was also poor when reconstituted. In the case of T_4 quantity of cocoa powder (low fat) was reduced to 14 per cent which gave a product still having bitterness (blankness) of cocoa and the dispersibility was not up to satisfactory level. To overcome the problem of dispersibility, 0.7 per cent lecithin was used in the next trial (T_5) and the product has shown excellent

Table 46. Cost of production of spray dried and cabinet dried powder

Sl. No	Item	Spray dried	Cabinet dried
I	Working capital		
	a. Raw material	334.900	334.900
	b. Fuel	186.000	51.000
	c. Labour	150.000	200.000
	Total	670.900	585.900
II	Interest on working capital @ 12%	0.220	0.193
III	Depreciation of machineries@ 10%	21.608	3.768
IV	Interest on fixed cost@ 12%	26.205	4.521
V	cost of production of 5 kg powder	718.930	594.380
VI	cost of 100 g powder	14.379	11.888
VII	cost of packaging	0.900	0.900
VIII	cost of 100 g unit pack	15.279	12.788

Table 47. Cost of raw materials

Item	Quantity for 5 kg powder (kg)	Unit cost (Rs /kg)	Total cost	
			Amount (Rs)	Percentage
Cocoa powder	0.3975	150	59.63	17.8
Milk	1.7898	14	208.8	62.36
Gelatin	0.0085	400	3.4	1.02
Malto dextrin	0.304	43	13.07	3.9
Sugar	2.5	20	50	14.92
Total			3344.9	100

Table 48. Sensory attributes of reconstituted ICBP

Treatment	Color	Taste	Flavour	Consistency	Overall acceptability
T_1	2.29	2.21	2.54	4	2.76
T_2	4.42	4.67	2.54	4.29	3.98
T_3	3.21	3.46	4.67	2.79	3.53
T_4	4.54	2.75	3.75	2.79	3.46
T_5	4.54	5.25	4.63	4.38	4.70
T_6	4.63	5	4.96	4.83	4.86
T_7	4.38	4.67	4.92	4.92	4.72
Chi-square	17.75	25.82	21.75	14.76	
Asymptotic significance (%)	0.70	0.01	0.10	2.20	

dispersibility. However, the reconstituted beverage had off flavour of lecithin. Hence the treatment T_6 with 63 per cent milk solids was taken up without adding lecithin. The resultant product had balanced flavour of cocoa and milk with a desirable thickness in the reconstituted beverage. Finally, in an effort to fine tune the dispersibility, T_7 was taken up with the same composition of T_6 by adding a lower level of lecithin (0.2 per cent). As the product still retained traces of off taste due to lecithin, it was rejected and the T_6 was chosen as the most acceptable feed composition.

With respect to recovery of powder T_6 was the best (44.00 per cent), which was followed by T_5 (43.21 per cent). The lowest powder recovery was registered in T_1 (40.61 per cent).

In case of viscosity of feed material, the lowest value of 137 mPa.S was recorded in T_7 (with 0.7 per cent lecithin) . Lower viscosity helped in smooth feeding of beverage mix in to the atomiser. Also, the powder recovery through cyclone separator was the best as compared to any other formulation without lecithin. The highest viscosity of 480 m Pa.S was observed in the case of T_3 which contained the highest proportion (21 per cent) of low fat cocoa powder.

4.3.1.3. Effect of ingredient proportion on physical properties of spray dried powder

The data on physical properties of spray dried powder as influenced by ingredient proportion are given in Table 42.

4.3.1.3.1 Moisture content

The lowest moisture content of 1.4 per cent was recorded in T_7 which was followed by T_5 (1.6 per cent) and T_6 (1.85 per cent) . The highest moisture content of 4.2 per cent was observed in T_3.

4.3.1.3.2 Fat

The fat content was the maximum in T_7 (7.36 per cent) containing 0.7 per cent lecithin. This was followed by 6.29 per cent in T_5. The lowest fat content was 3.61 per cent in T_8.

4.3.1.3.3 Bulk density, Average particle density and Per cent volume occupied by powder particle

The mean bulk density of spray dried powder ranged from 0.234 to 0.350 in T_1 and T_7 respectively. The average particle density varied from 0.73 in T_1 to 0.96 in T_7. Per cent volume occupied by powder particle varied from 28.69 in T_7 to 35.12 in T_5.

4.3.2 Cabinet Drying

The best beverage composition selected from spray drying trial was subjected to cabinet drying at a temperature of 60 ^{0}C and the product obtained as flakes was ground and sieved using 0.5 mm sieve. The powder properties were measured as in the case of spray dried powder.

4.3.3. Comparison of Spray dried and Cabinet dried Beverage powder

The results of analysis of physical properties with respect to spray dried powder and cabinet dried powder re given in Table 43.

4.3.3.1. Moisture

The mean moisture content of spray dried powder was 2.7 per cent and that of cabinet dried powder was 2.99 per cent.

4.3.3.2 Bulk density, average particle density and per cent volume occupied by powder particle

Cabinet dried powder had higher bulk density (0.314) than the spray dried powder (0.245). The average particle density was 0.748 and 0.922 for spray dried and cabinet dried powder respectively. The per cent volume occupied by powder particle was 32.8 and 34.05 for spray dried and cabinet dried powder respectively.

4.3.3.3 Recovery per cent

The mean powder recovery per cent of spray dried powder was 42.06 and that of cabinet dried powder was 43.5.

4.3.3.4 TSS

There was no significant difference between TSS per cent of spray dried and cabinet dried powders

4.3.3.5 Fat

The fat content was comparatively higher in spray dried powder (5.51 per cent) than that of cabinet dried powder (4.98 per cent)

4.3.3.6 Dispersibility

There was significant difference with respect to dispersibility of spray dried and cabinet dried powder. The higher dispensability was observed for spray dried powder (96.33 per cent) than cabinet dried powder (90.23 per cent)

4.3.3.7 Flowability (Angle of repose)

Flowability is inversely proportional to angle of repose. The flowability of beverage powder as revealed by the angle of repose was

comparatively better in cabinet dried powder (49 degrees) than in spray dried powder (51 degrees).

4.3.3.8 Moisture sorption kinetics

4.3.3.8.1 Spray dried powder

Moisture sorption properties of spray dried powder is given in Table 44. Up to 25 per cent ERH, (Equilibrium Relative Humidity) the powder was free flowing with no detectable change in colour or flavour. At 30 per cent ERH slight caking was observed though the colour and flavour was not affected. The equilibrium moisture content was 4.82 per cent at which the caking was evident. The sorption isotherm showed that the critical point (the point at which the caking started) was 4.82 per cent and the corresponding ERH was 30 per cent. The danger point (the moisture content corresponding to an ERH 5 per cent less than that of critical point) was found to be 4.07 per cent.

4.3.3.8.2 Cabinet dried powder

The moisture sorption properties of cabinet dried powder are given in Table 45. In case of cabinet drying the powder remained free flowing up to 25 per cent ERH. A slight caking was observed at 30 per cent ERH. The critical and danger points were 5.57 and 4.64 per cent respectively. The ERH corresponding to the critical point was 30 per cent.

4.3.3.9 Glass transition temperature (Tg)

The glass transition temperature is important in deciding the safe temperature for storage of the product. It also decides the maximum temperature to which the feed mix could be exposed while drying. The glass transition temperature measured using Differential Scanning Calorimetry. The Tg value was 180.60 ^{0}C which was 28^{0}C lower than that of cabinet dried powder (208.96 ^{0}C). In case of

spray dried powder two peaks were observed where as in cabinet dried powder only one peak was observed.

4.3.3.10 Microstructure

The scanning electron microscopy of both spray dried and cabinet dried powder revealed that there was significant difference in morphology as well as particle size.

The particle shape was spherical in case of spray dried powder whereas in cabinet dried powder it was highly irregular in shape. The particle size was almost uniform in case of spray dried powder which ranged from 20 to 50 μ m while in case of cabinet dried powder the particles were not uniform and the size varied from 10 to 100 μ m.

4.3.3.11 Cost of production

Cost of production of 5 Kg ICBP was worked out as given in Tables 46 and 47. The amount was Rs.718.73 for spray dried and Rs. 594.38 for cabinet dried powder. From these, unit cost of 100-gram powder together with cost of packaging material was worked out as Rs.15.28 and 12.89 for spray dried and cabinet dried powder respectively.

4.4 SENSORY EVALUATION

4.4.3 Quality of Reconstituted Beverage from ICBP

The quality of ICBP was judged by subjecting to sensory evaluation for colour, taste, flavour and consistency and the mean score gained by the various treatments for each quality parameter is given in Table 48. The treatments showed significant differences among themselves with respect to quality parameters. The treatment T_6 gained the highest mean score 4.63 and 4.96 for colour and flavour

Table 49. Sensory attributes of chocolate prepared from ICBP

Treatment	Color	Taste	Flavour	Consistency	Overall acceptability
T_1	2.1	2.15	2.1	1.45	1.95
T_2	2.2	2.4	2.2	2.1	2.23
T_3	1.7	1.45	1.7	2.45	1.83
Chi-square	1.70	6.26	1.70	6.87	
Asymptotic significance (%)	NS	4.4	NS	3.2	

Table 50. Sensory attributes of pudding prepared from ICBP

Treatment	Color	Taste	Flavour	Consistency	Overall acceptability
P_1	1.6	1.15	1.45	1.7	1.48
P_2	2.25	2.25	2.1	2.15	2.19
P_3	2.15	2.6	2.45	2.15	2.34
Chi-square	5.77	13.09	8.58	6.00	
Asymptotic significance (%)	NS	0.1	1.4	5	

Table 51. Sensory attributes of shake prepared from ICBP

Treatment	Color	Taste	Flavour	Consistency	Overall acceptability
S_1	2.70	2.15	2.10	2.80	2.44
S_2	3.15	2.55	3.00	2.35	2.76
S_3	2.85	3.00	3.25	2.70	2.95
S_4	4.25	4.50	3.95	4.35	4.26
S_5	3.80	4.50	4.45	4.45	4.30
S_6	4.25	4.30	4.25	4.35	4.29
Chi-square	9.20	21.27	13.59	19.20	
Asymptotic significance (%)	NS	0.10	1.80	0.20	

respectively. With respect to consistency the score for the treatment T_6 (4.86) and T_7 (4.92) were not significantly different. Regarding taste of reconstituted ICBP, T_5 was found better, followed by T_7. The overall acceptability of chocolate judged in terms of average score value (4.86) was the highest for treatment T_6 which was followed by T_7 and T_5 with mean ranks of 4.70 and 4.72 respectively.

4.4.4 Quality of Chocolate

The mean score obtained for different treatments for sensory evaluation of chocolate prepared using ICBP are given in Table 49. Only the taste and consistency of chocolate varied significantly. The treatments T_1 and T_2 were comparatively superior to other treatments with respect to these characters. The treatment T3 (ICBP containing 0.7% lecithin) was ranked inferior.

4.4.5 Quality of Pudding

The mean score gained by different treatment with respect to sensory quality are given in Table 50. There was no significant difference with respect to colour of the product. However, the taste, flavour and consistency of pudding varied significantly among treatments and P_3 was found to be the best treatment with average score of (2.34).

4.4.6 Quality of Shake

The mean score of shake prepared using varying proportions ICBP with banana (Robusta) fruits are given in Table 51. There was no significant difference among treatments with respect to acceptability of colour. The taste flavour and consistency of shake varied significantly among the treatments. Maximum score with respect to these characters were obtained for S_4 and S_5 and the lowest for S_1 in case of taste (2.15) and flavour (2.1) and S_2 for consistency (2.35).

Discussion

5. DISCUSSION

Cocoa is mainly grown in small holder sector and its processing continues to be the monopoly of multinational companies. The farmers are forced to sell their produce to multinational companies often at unrealistic prices, decided by the companies. Moreover, procurement is often ineffective which in turn leave the farmers at the mercy of such companies. In this context, development of viable technologies for processing of cocoa at small-scale level will help to realise maximum returns to the farmers. It will also guarantee additional employment including better utilization of family labour.

Based on some preliminary studies, Kerala Agricultural University has established a cocoa processing unit with a view to standardise processing for small scale units. Though the products developed are popular, their acceptability is not on par with that of commercial brands available in the market. This has necessitated further refinement in the processing of cocoa for small-scale unit. At present chocolate continues to be the popular product of small scale unit, from cocoa. If diverse products could be developed the demand for cocoa would increase. This will fetch a better price for the farmer and in turn, will come up as a viable proposition for self employment. Thus, the present study entitled 'Standardisation of technology for value addition of cocoa (*Theobroma cacao* L.)' was taken up to standardize primary and secondary processing of cocoa for small scale unit and development of cocoa based value added product.

5.1 PRIMARY PROCESSING OF COCOA

Two major experiments were taken up to standardise the primary processing of cocoa for small-scale units.

The cocoa beans are embedded in a mass of mucilaginous pulp within the pod. The beans together with the pulp are removed from the pods and subject to microbial fermentation as the first step of processing. Microbial action during fermentation solublises the pulp material surrounding the beans and produces a range of metabolic end products (alcohol, organic acids etc.), which diffuses into the beans leading to their death. These changes induce an array of biochemical reactions within the beans and generate the chemical precursors of chocolate flavour, aroma and colour. The different methods of fermentation and the associated changes in cocoa beans have been well reviewed (Lehrain and Patterson, 1983; Lopez and Dimick, 1995; Thompson *et al.*, 2001).

In the present study, scientific interventions were made to make the fermentation more effective under small scale processing of cocoa. To achieve the objective, the quality of fermentation in relation to storage of pods for varying periods (0 to 6 days) and application of pectinase (0.01%) were studied. The effects of these two treatments were studied during the peak harvest season of cocoa viz. major peak (April-May) and minor peak (September-October). The merits of the treatments over the existing methods of fermentation were evaluated based on the physical, biochemical and microbial characters of beans in relation to fermentation.

The temperature profile of fermenting mass, pH of the pulp and bean, quantity of sweatings produced, change in polyphenol, anthocyanin and amino acid content of beans influence the effectiveness of fermentation which in turn govern the quality of fermented beans (Ardhana and Fleet , 2003) . In the present study, the observations recorded on the foresaid parameters during and after fermentation formed the basis for drawing valuable results.

The discussions are presented first by comparing the effect of storage of pods for varying periods (T_1 to T_4) and then the effect of pectinase application (T_5 to T_8).

5.1.1 Effect of Pod Storage

5.1.1.1 Temperature of fermenting mass

The temperature profile of the fermenting mass re corded daily in relation to pod storage have shown that maximum temperature build up happened when the beans from pods stored for four days were subjected to fermentation. The same trend was observed during both the seasons under study (Fig. 1 and 2)

The temperature increased from 38.8 to 41.5 ^{0}C when beans from pods stored for four days were subjected to fermentation (4th and 6th day after fermentation) during first season and 38.8 to 43.3 ^{0}C in second season, providing comparatively better environment for fermentation. The rise in temperature of the fermenting mass could be taken as a indication of adequate favourable biochemical reaction during fermentation and the lack of temperature development as a symptom of inadequate fermentation (Amma *et al.*, 2002). Effendi and Panji (1994) reported that pod storage and subsequent fermentation of beans resulted in a tremendous increase in temperature. They observed that fermentation of beans from pod s stored for ten days resulted in a rise in temperature of 11^o C higher than that recorded in other treatments. Bhumibhamon *et al.* (1993) reported that the temperature during fermentation reached 45 ^{0}Cwithin 24 to 28 hours in pods stored for four to seven days after harvest.

The storage of pods may precondition the pulp for better microbial activity leading to qualitative fermentation (Biehl and Voigt; 1995).

In large scale fermentation, usually the temperature rise to the range of 48 to 50^{0}C (Ardhana and Fleet, 2003) is noticed. But even with the ideal treatment, temperature rise in fermentation achieved in the present study was 5 to 6 ^{0}C lower than that reported in heap method when adopted in large scale. This could be attributed to the smaller quantity of beans used under each treatment. Only limited quantity of 50 kg

Fig. 1. Change in Temperature during Fermentation

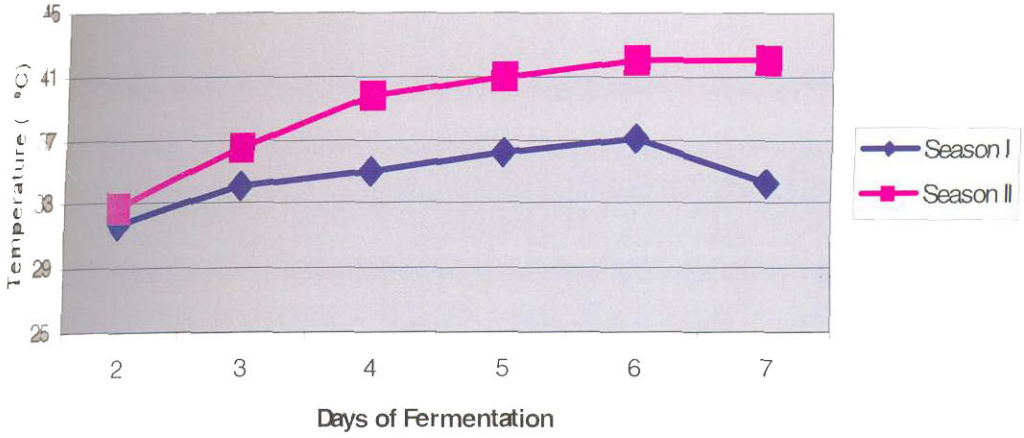


Fig. 2. Change in Temperature during Fermentation

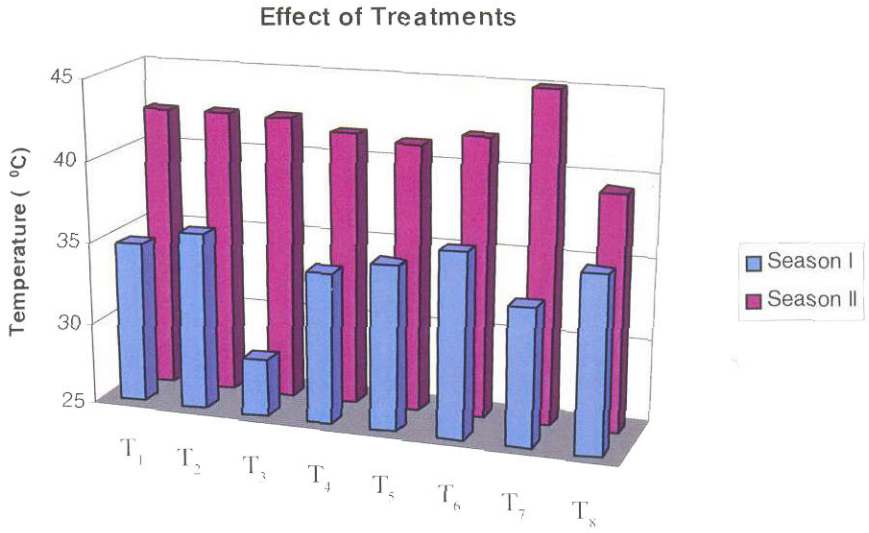
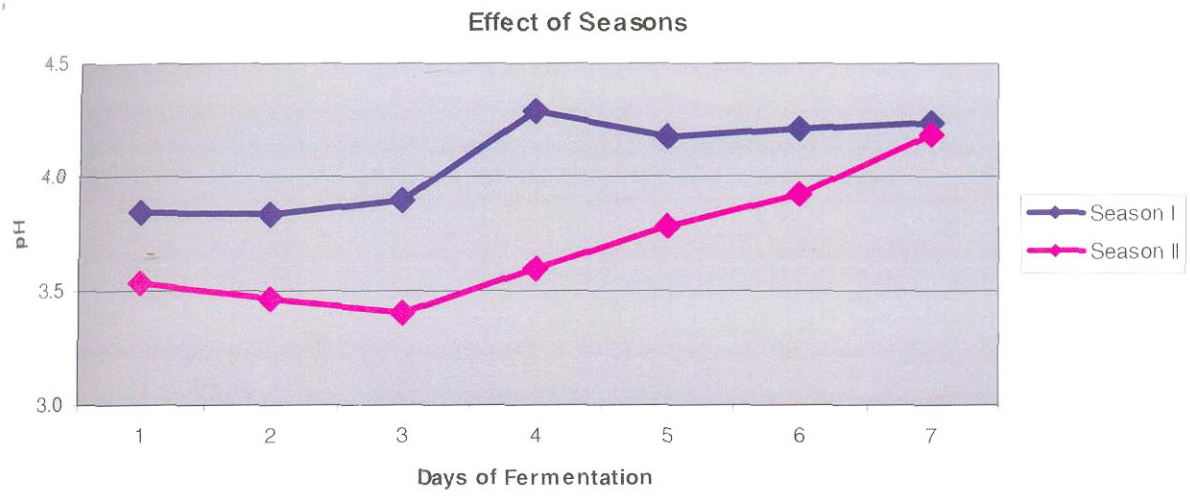


Fig. 3. Change in Pulp pH during Fermentation



beans was taken under each treatment, which is the minimum quantity required to carry out fermentation in heap method. This was done to evolve technologies, which will enhance ideal fermentation even in small-scale conditions. Moreover, the studies were carried out during April - May and September - October when there was occurrence of rain. This also might have contributed to a reduction in temperature. Considering these factors, it can be concluded that storage of pods for four days prior to fermentation could increase the temperature of fermenting mass to a high level, paving path for desirable physical and biochemical reaction to take place.

The mean daily temperature of fermenting mass was comparatively high during the second season (32.5 - 42.04^{0}C) than the first season (31.75-37.13^{0}C). The seasonal variation with respect to temperature of fermenting mass observed in the present study is in agreement with the findings of Malini (1986) under South Indian conditions. She reported that the mean daily temperature of fermenting mass varied from 32 to 46^{0}C during September and 30 to 49 ^{0}C during July. Hiiching *et al.* (2002) reported that in small holder technique of fermentation using plastic sack, the temperature increase to only around 40 ^{0}C only. The influence of seasonal variation on temperature of fermenting mass was also reported by Amma *et al.* (2002).

5.1.1.2 Quantity of sweatings

Cocoa sweating is the byproduct of fermentation of beans. The pale yellowish liquid that drains off during cocoa fermentation is the breakdown product of mucilage surrounding the fresh cocoa beans and constitutes about 10 per cent of the weight of cocoa pod. This has been shown to be a suitable raw material for production of wines, alcohol, marmalade, jam and syrup (Buamah *et al.*, 1997; Dzogbefia *et al.*, 1999). Its rapid collection in large quantity is the first step for its utilization on a commercial scale.

In the present study, maximum sweating was obtained within first 24 hours of fermentation, which accounted for 71.11 and 71.24 per cent of the total sweat collected during fermentation in the first and second seasons respectively. Further analysis on the quality of these sweatings in terms of microbial and chemical aspects is required to utilize for product development. The possibility of using the sweatings for preparation of new products is also to be explored for the benefit of small-scale units.

5.1.1.3 pH of pulp and beans.

The acidity of pulp decreased and that of beans increased during fermentation. The storage of the pods was found to exert significant influence on acidity of both pulp and beans (Figures 3, 4 and 5).

The pulp contains sugar (fructose, glucose and sucrose) and during the fermentation, the sugar get converted to ethanol, lactic acid and acetic acid. A portion of this gets to drain out from the fermenting mass as sweating. This increases the pH of the pulp. A portion of the acids intrude into the beans and this reduces the pH of beans. The bean pH usually increases from 6.3-6.5 to 5.0-5.1.

On completion of fermentation usually the pH of pulp as well as bean reaches almost same level. The observation on pH revealed that storage of pods prior to fermentation have, profound influence on pH of beans and pulp. The storage of pods for four days was found to maintain comparatively higher bean pH. After fermentation, the same beans recorded a reduced pH of 4.66 and 4.48 during first and second season respectively. This indicated the intrusion of more acids into the beans. However, the pH of pulp and beans reached to almost same level which can be considered as th indication of proper fermentation. The pH value for rest of the treatments registered lower values which is not desirable as the products from acidic beans retain detectable acidic taste.

Fig. 4. Change in bean pH during Fermentation

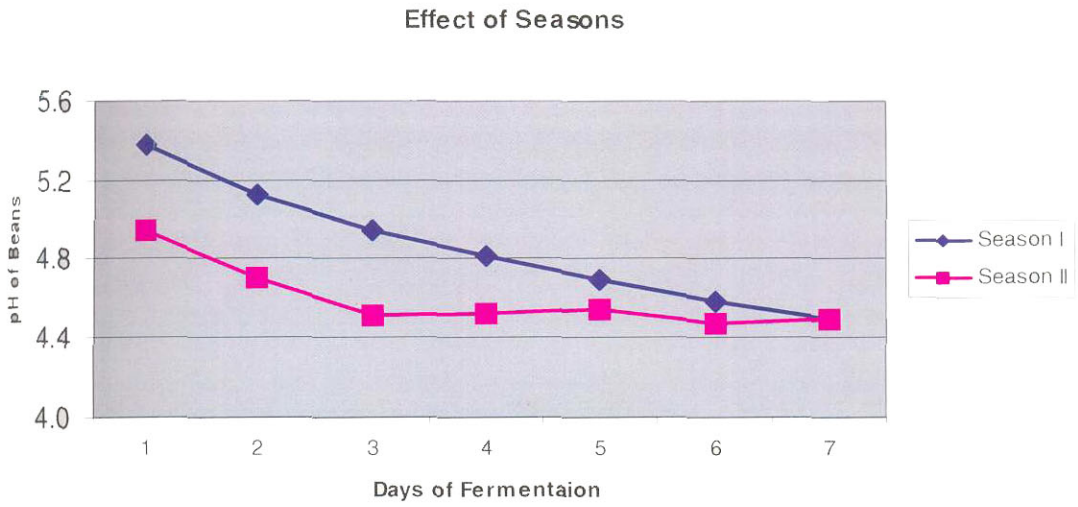
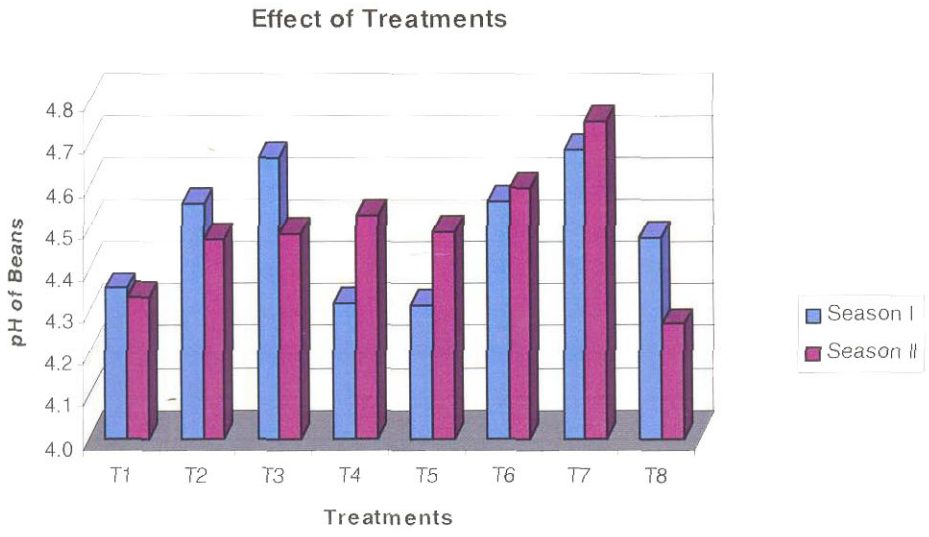


Fig. 5. Change in bean pH during Fermentation



Effendi (1993) found that pod storage for 10 to 15 days reduced the acidity of beans considerably during fermentation and produced stronger chocolate flavour. Premalatha and Mohanakumaran (1989a) recommended pod storage for two to six days to obtain desirable pH in cured beans. Increased bean pH due to pod storage has also been reported by Tomlins *et al.* (1993). However, Dias and Avila (1990) could not find any effect of pod storage on either the duration of fermentation or final acidity.

5.1.1.4 Biochemical Parameters

5.1.1.4.1 Amino acid content

The amino acid content of fermented cocoa beans is extremely important as they are the precursors of aroma compounds. The rate of production of free amino acids during fermentation has been related to the rate of flavour and aroma development. Many scientists have reported that during fermentation the amino terminals as well as that of total free amino acids increase with time.

In the present study, the mean amino acid content of beans registered a decrease during both these seasons (Fig.7). However, the beans fermented after pod storage for four days registered an increase. This specific observation highlights the importance of storage of pods for four days prior to fermentation when done on small scale. This was in agreement with the findings of Voigt *et al.* (1994a) and Hansen *et al.* (1998). They reported the beneficial effect of enzymes in improving the flavour precursors (aminoacids and oligopeptides) through disintegration of seed protein. The finding of increased amino acid in beans from stored pods in the present study is in agreement with the that of Biehl *et al.* (1993). The proteinacious material dispersed in cytoplasm get converted to amino acids during fermentation. The adequate storage of pods might be favourably supporting this conversion. Prolonged pod storage beyond four days or inadequate pod storage could not contribute to bean quality in terms of amino acids.

According to Voigt *et al.* (1994b), adequate fermentation provides the conditions for action of endoproteases that produce specific peptides and amino acids which are of extreme importance to cocoa flavour. Bhumibhamon *et al.* (1993) reported one to two per cent decrease in bean protein during fermentation. Kirchhoff *et al.* (1989) reported that seed storage proteins are exclusively degraded during fermentation. Both flavour potential and protein hydrolysis were found to depend on acidity and water uptake in seeds during fermentation.

5.1.1.4.2 Polyphenol and anthocyanin content of beans

Polyphenols are phytonutrients or they are sometimes referred to as phyto chemicals or nutraceuticals. Cocoa is rich in phytochemicals. In cocoa beans, pigment cells make up about 11 to 13 per cent of the tissues. The pigment cells contain approximately 65 to 70 per cent of poly phenols and three per cent anthocyanins by weight. Apart from anthocyanins, the polyphenols in cocoa beans consist mainly of epicatechin, with lower concentration of catechin and procyanidins. During fermentation, the polyphenols undergoes a variety of reactions including self condensation and reaction with proteins and peptides. Approximately 20 per cent of polyphenols remain at the end of fermentation process. As polyphenols are compounds responsible for astringency of cocoa and anthocyanins for color, the changes in their quantity will reflect in the quality of beans.

In the present study, storage of pods for four days prior to fermentation was found to have profound influence in reduction of polyphenol content of beans during the first season. At the end of fermentation, the beans from fresh pods registered a polyphenol content of 46.23 mg g^{-1}, whereas beans from pods stored for four days registered significantly low polyphenol content of 31.03 mg g^{-1} during first season. During the second season all the pod storage treatments were significantly superior compared to fresh pods (Fig.6). Optimally fermented cocoa beans are reported to have

Fig. 6. Change in Polyphenol during Fermentation

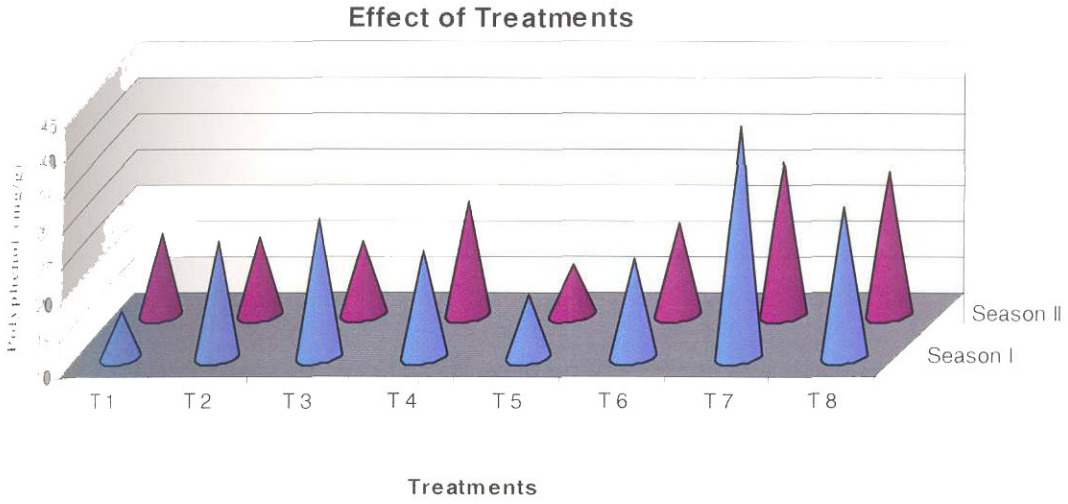


Fig. 7. Change in Amino acid during Fermentation

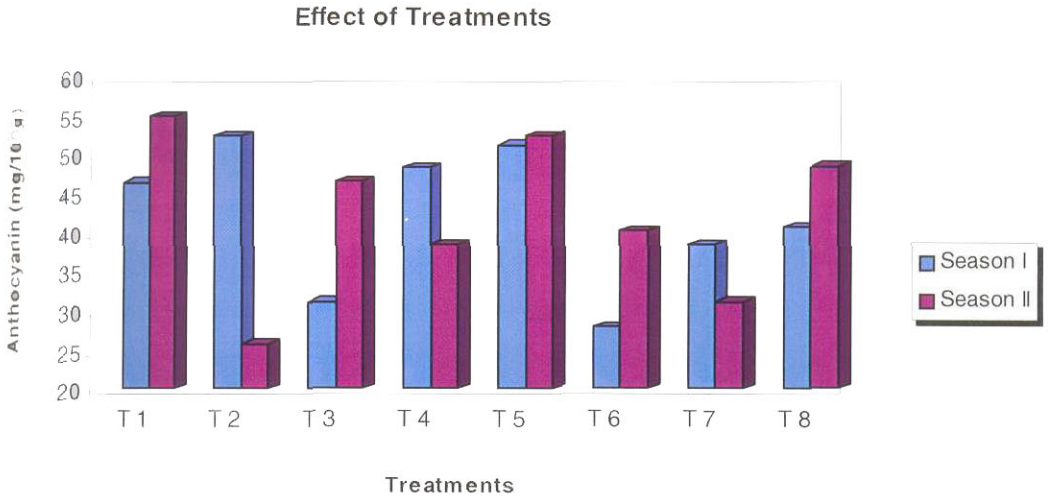
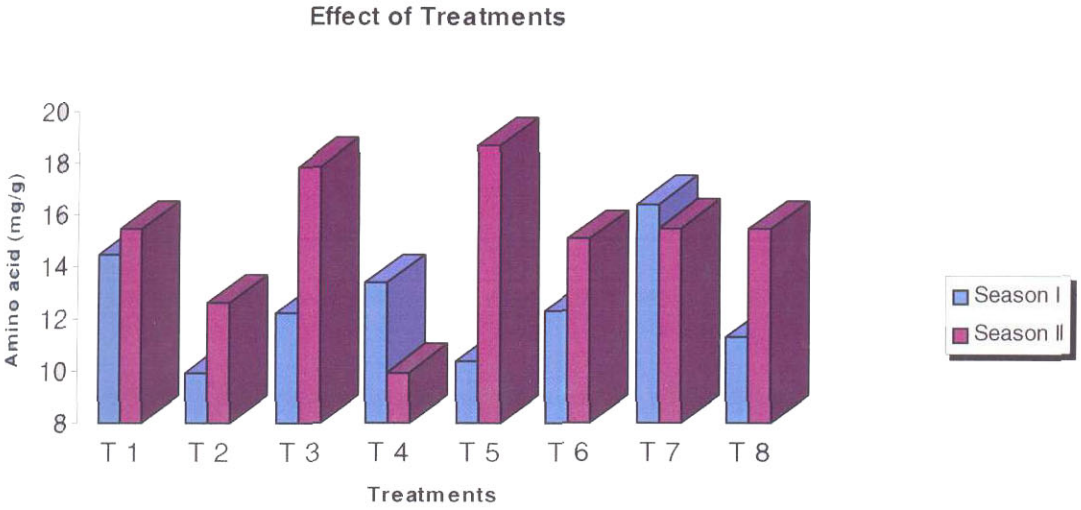


Fig. 8. Change in Anthocyanin during Fermentation



maximum polyphenol content of 58 mg g^{-1} and minimum tannin content of 31 mg g^{-1} (Bonvehi and Coll, 1997). According to Forsyth (1952), phenol transformation and loss in cocoa are due to diffusion out of cotyledons and approximately 24 per cent loss occur about 60 hours after fermentation and another 58 per cent on completion of fermentation. This view was further supported by the findings of Cros and Jeanjean (1995) wherein the reduction in polyphenol during fermentation was reported to have resulted from diffusion, tanning and thier oxidation by polyphenol oxidase (PPO).

Comparatively more reduction in polyphenol of cocoa beans from pods stored for four days reveal the superiority of this treatment over others. The oxidation, condensation and complexation of polyphenols during fermentation in general contribute to the reduction of astringency of cocoa products.

A reduction in polyphenol content was observed during fermentation during both the seasons. The magnitude of decrease was more in the second season, indicating better fermentation.

There was steep decline in the anthocyanin content of fermenting beans and the rate of decline was more in the second season (Fig.8). The reduction of anthocyanin is reported to be a desirable effect of fermentation. The results obtained in the present study are in confirmation with the findings of Wood and Lass (1985). They reported that the anaerobic conditions during the initial phase of fermentation destroy the anthocyanins by hydrolytic reactions. The resulting leucoanthocyaninins give a bleached appearance to the properly fermented beans. The reduction in anthocyanin during fermentation was also reported by Malini (1986) and Broadbent *et al.* (1997). Of the various treatments under the present study, the lowest anthocyanin content was observed for beans of pods stored for four days and treated with pectinase in the first season. During the second season also the same treatment recorded the lowest anthocyanin content at the start of fermentation. Such results underlined the beneficial effect of

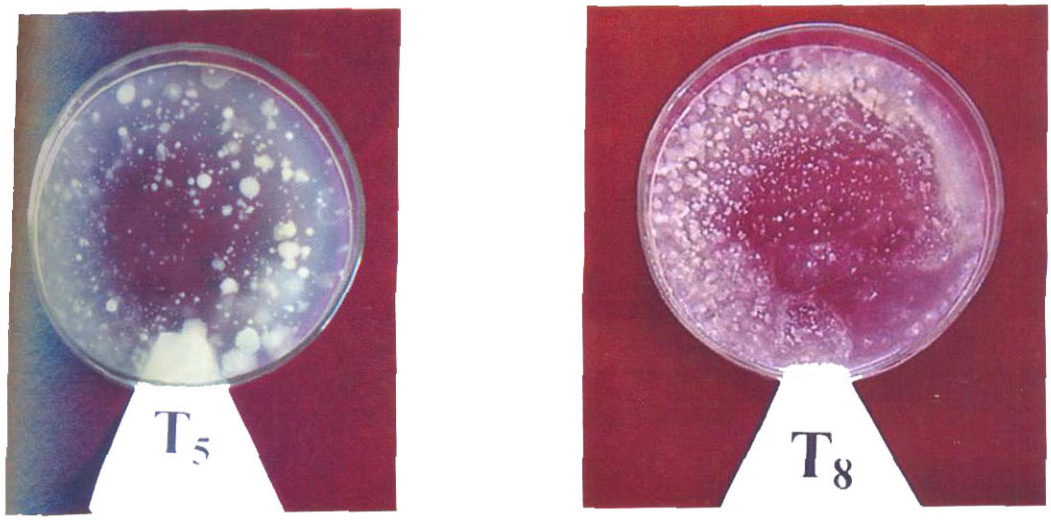
pectinase treatment in fermentation. Anthocyanins form a portion of polyphenols. The strong oxidation and condensation products of anthocyanin convert the purple color of cotyledons to brown color.

5.1.1.5 Studies on microbial population during fermentation

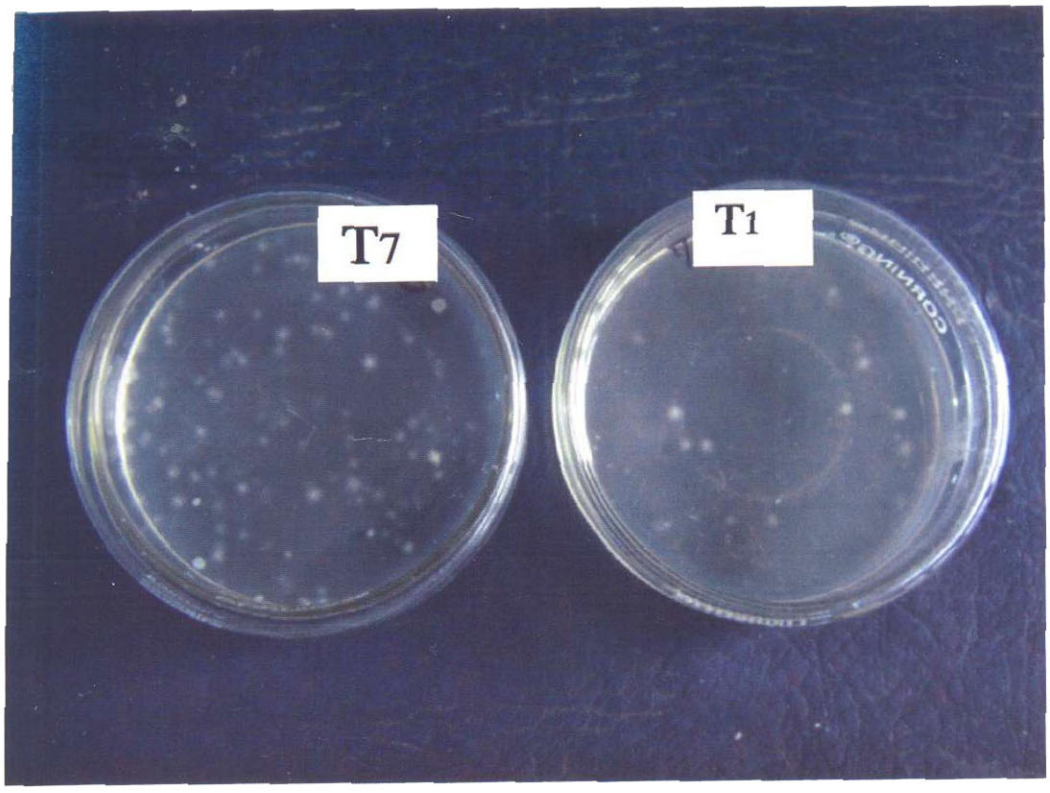
The microbial succession in the fermentation process has been clearly established (Roelofson, 1958; Ostover and Keeney, 1973; Lehrain and Patterson,1983; Schwan *et al.*,1995).Yeast dominates the fermentation during the first 24 hours. They were the briefly eclipsed by lactic acid bacteria, but as the pulp disappears, oxygen penetrates into the fermenting mass and acetic acid bacteria start to dominate and produce acetic acid. Thus, the three metabolites viz., ethanol, lactic acid and acetic acid are sequentially produced due to the activity of yeast, lactic acid and acetic acid bacteria. The presence of filamentous fungi in later stages of fermentation has also been reported by many scientists (Schwan, 1998). The build up of these microbial populations in the fermenting mass is responsible for the biochemical changes of pulp, which in turn govern the biochemical changes of the beans.

The microbial count recorded during fermentation support the selection of pod storage for four days with or without pectinase application as the best fermentation treatment (Plate 7). Higher number of yeast population during the first 24 to 48 hours of fermentation was recorded in T_3. When application of pectinase was combined with this treatment, a higher yeast count was recorded only at the first day of fermentation. Subsequently the yeast population decreased up to fourth day of fermentation. The role of yeast as discussed earlier happens during the first 24 to 36 hours of fermentation and their build up during this period will trigger the fermentation process positively. The application of pectinase might have activated the process of fermentation leading to higher yeast count during the first day of fermentation. The maximum bacterial count was recorded in beans from four days stored pods and treated with pectinase on second,

Plate 7. Microbial population on beans during fermentation



a. Yeast



b. Bacteria

third and fourth day of fermentation. The higher yeast population at initial stage and their decline in the subsequent stages, coinciding with increase in bacterial population is an indication of advancement of fermentation in a desirable manner. The beneficial yeast during the first 24 to 36 hours and bacteria during the later stages of fermentation has been reported by Schwan (1998) and Wood and Lass (1985).

5.1.2 Effect of Pectinase Application

Cocoa bean pulp is rich in pectin and composed of 70 to 86 percent of pectic substances (Adomako, 1974). This cellular component provides the pulp its integrity and serves as a protective layer to the beans. During fermentation, the disintegration of pulp occurs as a result of hydrolysis of pectin by yeast, in the presence of pectolytic enzyme known as polygalacturonase and pectin esterase. Lot of research has been carried out to speed up the process of pulp degradation to reduce the time and improve the quality of fermentation. Application of pectinase enzyme which consists of a mixture of polygalacturonase and pectin esterase is one of such efforts.

In the present study, experiment was taken up to study the effect of pectinase application at a low concentration of 0.01 percent. The application of pectinase at this level when combined with storage of pods brought out significant change in fermentation process and quality of resultant beans. Application of pectinase to the mass before fermentation was more promising during the second season than the first season. In the second season, beans from pods stored for four days and treated with pectinase recorded the highest mean temperature on all days of fermentation (Fig.1). The enhancement in temperature of pectinase treated beans could be due to the enhanced hydrolytic activity induced by the pectinase enzyme. Thus, the pectinase application helped in increasing the temperature of fermenting mass, as discussed earlier.

The positive influence of pectinase application on fermentation could be revealed through analyzing the pH of beans. The influence was more pronounced during second season. On completion of fermentation, the pH of beans from fresh pods (T_1) was 4.33. when pectinase was incorporated with these beans and fermented, the mean pH of beans raised to 4.49. Similarly, while the beans of four day stored pods recorded a pH of 4.48, the pectinase application to the same beans resulted in an increased pH to 4.75 (Fig. 5).

Same was the effect of pectinase application on amino acid content of fermented beans. During the second season, the amino acid content of fresh beans after fermentation was 15.44 mg g^{-1} while that of fresh beans treated with pectinase was 18.66 mg g^{-1}. Thus it can be concluded that application of pectinase enhanced the efficiency of fermentation of beans of freshly harvested pods.

The beneficial effect of pectinase application with ideal pod storage obtained in the present study was evident during the first season. The amino acid content of fermented beans from pods stored for four days was recorded as 12.25 mg g^{-1}. This was increase to 16.41 mg g^{-1} when beans from pods stored for four days were fermented with application of pectinase. This effect could not be observed during second season.]

As discussed earlier, lower polyphenol content is preferred in cured beans. The application of pectinase reduced the polyphenol content of beans during the second season. This positive effect was explicit only when freshly harvested pods were subjected to fermentation with and without application of pectinase. The results showed that the pectinase application when combined with pod storage actually resulted in marginal increase in polyphenol content of fermented beans. It can be presumed that under accelerated fermentation, the diffusion of polyphenol from beans is comparatively low. However under all the fermentation treatments tried, the polyphenol content reached to a level lower than that reported earlier (31 mg g^{-1}). A definite relation could

not be observed on the influence of pectinase application with respect to reduction on anthocyanin content after fermentation.

5.1.3 Effect of Method of Drying on Quality of Cured Beans

The fermented beans will have a moisture content of 53 to 55 per cent. Such a high moisture content is unsuitable for storage of beans as putrefaction may set in. The moisture content has to be brought down to about six per cent for safe storage and transportation. This necessitates drying of beans, which should commence immediately after fermentation. Unless the beans are skin-dry within 24 hours of fermentation, moulds set in and damage the beans. Many times, the farmers encounter the difficulty of drying fermented cocoa samples due to the occurrence of intermittent rain during May and September under Kerala condition, as experienced during the present study. Thus, there exist the necessity of developing alternate methods to sun drying which continue to be the most simplest and popular methods of drying in major cocoa producing countries.

The purpose of this experiment was to analyze the feasibility of resorting to artificial drying under small scale processing especially during adverse climatic conditions. Several artificial driers have been developed and are in use in different cocoa growing countries. Cunha *et al.* (1998) designed a plat form drier to make artificial drying of cocoa more economical and efficient.

In the present study, the cocoa beans from varying fermentation treatments were subjected to sun and oven drying. As the quality of cured beans is dependent on the efficiency of the fermentation and drying, the results of present experiment are discussed considering these two aspects.

To analyze the effectiveness of fermentation and drying, the moisture content, pH, polyphenol, anthocyanin and amino acid content of beans were monitored during

and after drying. Finally the recovery percentage was worked out and cut test was performed.

5.1.3.1 Moisture content of beans

Study on the rate of removal of moisture in different methods of drying showed that there was rapid moisture removal in oven than in sun drying. In oven drying, the initial moisture content of beans was reduced to safe level of below seven per cent within four days. However in sun drying, it took nine days to bring down the moisture to safe storage level. The merit and demerits of these two treatments are further evaluated through analyzing the pH and other biochemical changes associated with the beans undergoing drying.

5.1.3.2 pH of beans

During drying the oxidation of excess acetic acid in the beans take place which reduces the acidity of beans. The reaction, being enzymatic, can proceed only when the seeds are still moist and when the temperature is below which degradation of enzymes occur. The non-acid beans generally have a pH around 5.2 – 5.5. The results on the analysis of pH of beans subjected to sun and oven drying have shown that desirable pH is achieved within four days in oven drying and nine days in sun drying. The pH of oven dried and sun dried beans did not show any significant difference. As the oven drying was carried out at a temperature of 60^0 C, it can be presumed that enzymatic degradation did not takes place. However, the effect of fermentation treatments was evident. The beans of four day stored pods without pectinase in the first season and with pectinase in the second season registered comparatively higher pH. Therefore it is better to dry the beans following fermentation with pod storage and pectinase application.

5.1.3.3 Polyphenol and anthocyanin content

The total polyphenol content of beans decreased during sun and oven drying during both these seasons (Figures 9 and 11). It could be observed that the reduction in polyphenol was more when the samples were sun dried. This result is in agreement with the findings of Almeida *et al.* (1998) and Brito *et al.* (2000). They reported that sun dried beans contained lower polyphenols compared to artificially dried beans. The lower phenolic content in sun dried beans could be attributed to the slow removal of moisture in sun drying that too under low temperature. Together with removal of moisture, small quantities of phenols also get diffused out of testa in a phased manner. Also, the oxidation of polyphenols by polyphenol oxidase (PPO) takes place. In oven drying, rapid removal of moisture occurs and drying is completed within short period and the chance for escape of phenols is also less. The PPO also gets inactivated easily under the higher temperature to which beans are subjected in the oven. It was encouraging to observe that the least polyphenol was present when the beans of four days stored pods were subjected to fermentation and sun drying in the first season. The beans from pods of same storage period and fermented with pectinase treatment recorded the lowest polyphenol under sun drying during the second season. These observations under line the importance of adopting selected pod storage and pectinase treatment technique to get better quality cured beans.

The anthocyanin content of beans registered drastic decline in response to drying. The intensity of reduction was more in sun dried samples compared to oven dried samples. The oxidation and condensation products of anthocyanin generated during drying are responsible for producing characteristic brown color and the merit of this reaction could be judged through cut test, which has been explained elsewhere in this section.

Fig. 9. Change in Polyphenol during Sun drying

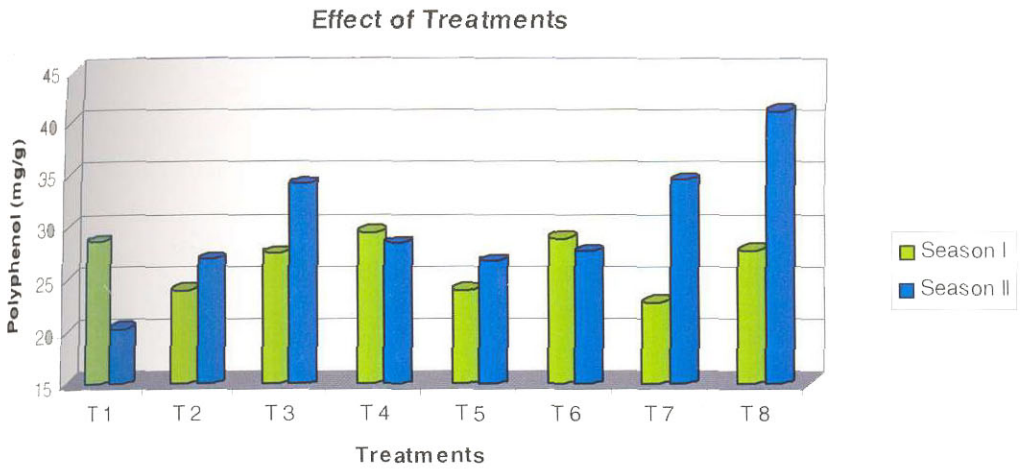


Fig. 10. Change in Amino acid during Sun drying

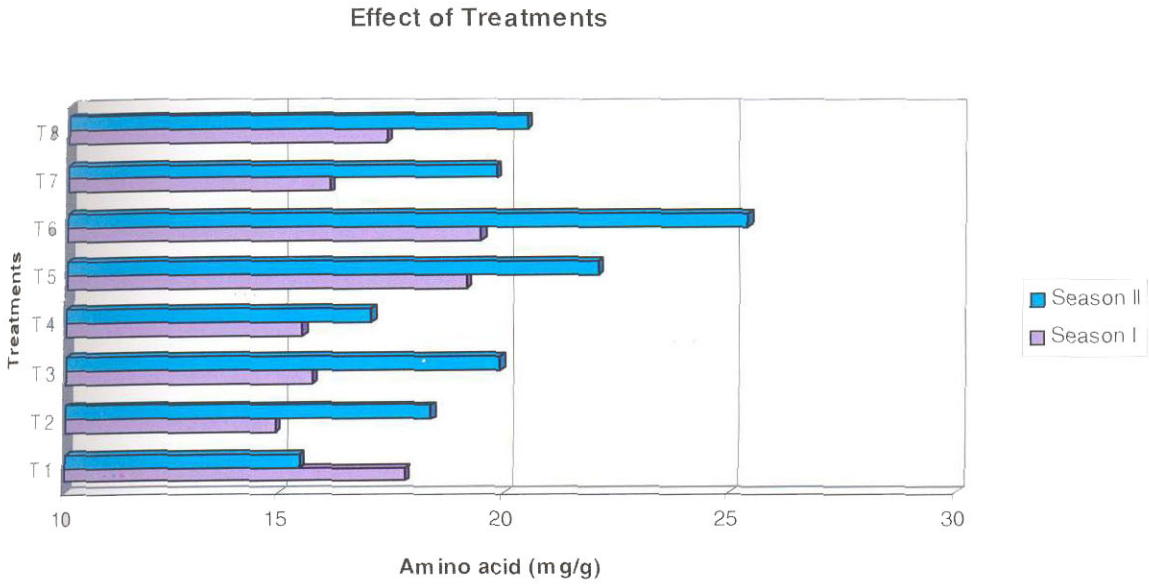
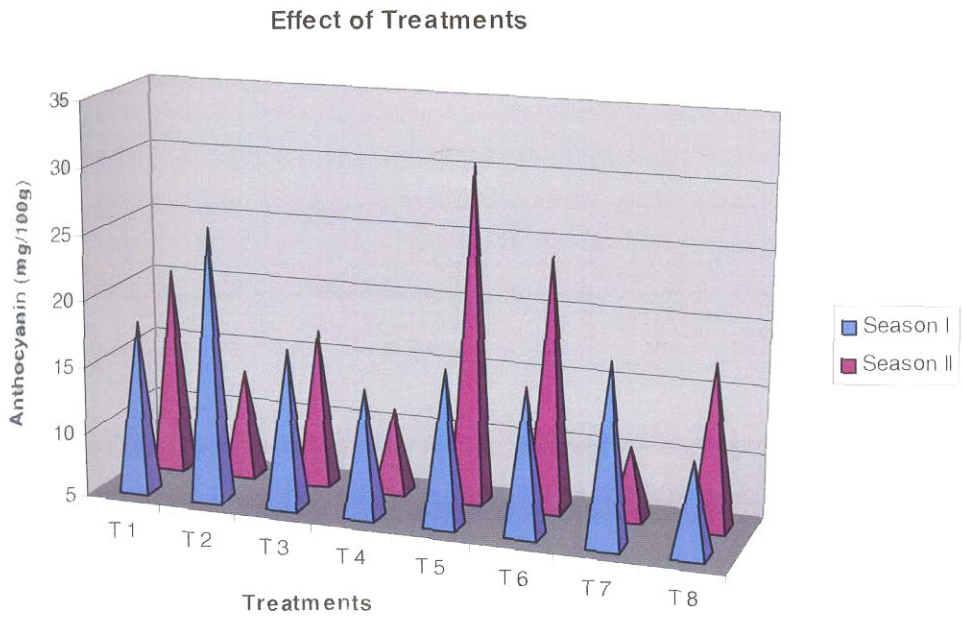


Fig. 11. Change in Anthocyanin during Sun drying



5.1.3.4 Amino acid content

The two important reactions responsible for production of flavour precursors are the hydrolytic reaction during fermentation and the oxidative reactions during drying (Brito *et al.*, 2002). The amino acid content of beans registered an increase when the beans were subjected to sun as well as oven drying method, irrespective of the season. However, the increase in amino acid content was more in first season compared to second season (Fig.10). There was not much difference in the magnitude of increase with respect o method of drying. Similarly, the method of drying adopted did not have a definite relation with amino acid content of dried beans.

5.1.3.5 Recovery percentage

On an average, the recovery percentage of beans subjected to sun drying was more compared to oven dried samples (Fig.12 and 13). This could be attributed to the higher moisture level retained in the sun dried samples (6.63 – 6.57 per cent) compared to oven dried sample (5.49-6.28 per cent), although, both were within the safe moisture level. A definite effect of fermentation treatments combined with drying methods was not found with respect to recovery of dried beans.

5.1.3.6 Cut test

The cut test is described as the tool for judgment of the final quality of cured beans (Wood and Lass, 1985). The cut test index was worked out based on the different categories of fermented beans under each fermentation and drying treatments Appendix-II. The results of the cut test threw light on the superiority of sun dried samples over the oven dried ones. Yusianto *et al.* (1995) also reported a maximum cut test score for sun dried beans compared to artificially dried beans. This could be attributed to the desirable biochemical changes (phenols and anthocyanin) in the sun dried beans as discussed

Fig. 12. Recovery per cent of Dried beans

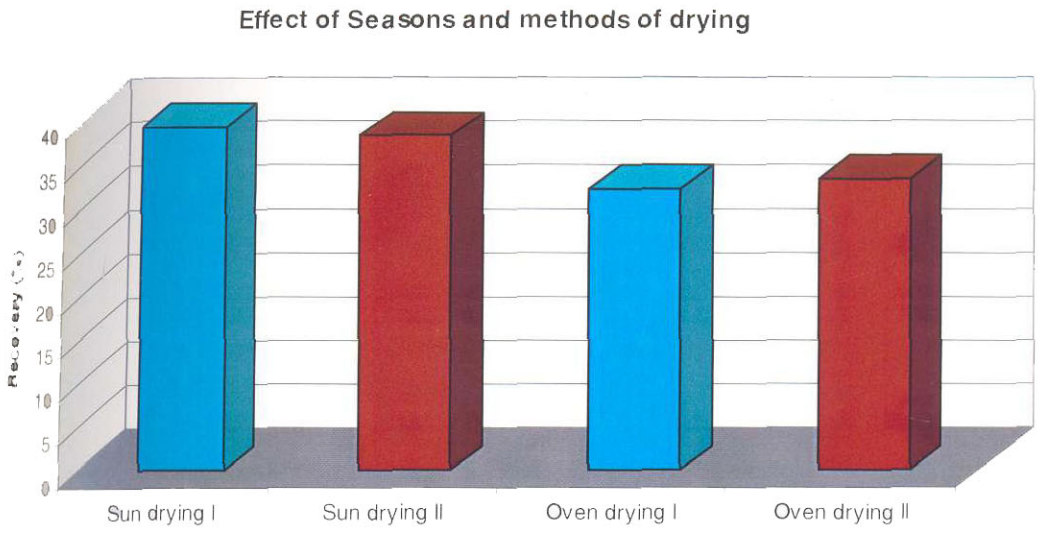
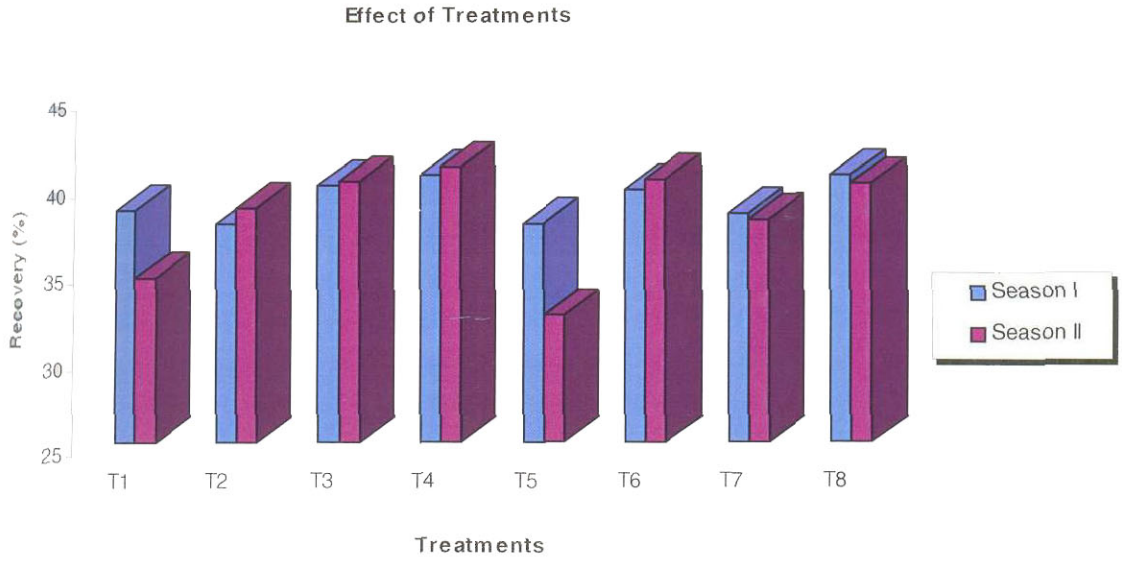


Fig. 13. Recovery per cent of Dried beans



earlier compared to the oven dried samples. The rapid removal of moisture in artificial methods of drying is not beneficial. Augier *et al.* (1998) reported the gentle drying of cocoa for longer period compared to fast or shorter periods of drying. They reported that this is important to get desirable pH and acidity of cured beans. This might have been achieved through sun drying of beans in the present study compared to oven dried beans.

The cut test confirmed the superiority of selected fermentation treatments over others in producing quality cured beans. Among the treatments, the highest cut test index was obtained in beans of four day stored pods and treated with pectinase before fermentation in both sun drying and oven drying during both the seasons. The next best treatment was pod storage for four days and fermentation without pectinase. As discussed earlier, the beneficial effect of pod storage for a period of four days, pectinase application and drying in sun reflected totally upon the quality of cured beans.

It can be seen that fermentation of beans after storage of pods for four days (T_3) was beneficial during both the seasons. The effect was more manifested when pectinase application is combined with this treatment especially during second season. However, further studies are required to standardize the fermentation with the aid of pectinase in terms of its quantity and time of application to make the technology more efficient.

5.1.3.7 Selection of ideal drying method

Many enzymatic reactions started during fermentation continue during drying and are important to the flavour quality of the product. In the past, these reactions were guaranteed on the sun drying floors. The artificial driers dry the fermented beans as fast as possible and is evident in the results of present study. Under this circumstance, there is a likelihood of enzyme inactivation by high temperature or lack of moisture. Hence it is very important to standardize the temperature regime, duration of drying, rate of air flow and number of racking to be given in artificial drying systems. Based on the results

in small scale processing, we can recommend oven drying (at temperature below 60^0 C) under adverse climatic conditions when the availability of sun light becoming a limiting factor for effective drying. Care is to be taken to drain the beans adequately before loading to oven. Methods which dry cocoa beans in a gentle manner at low temperature can only be selected. The present study only utilized the oven method and further standardization of artificial drying of beans for small-scale units is needed.

5.1.4 Storage of Cured Beans

The relative humidity in Kerala is above 85 per cent and the long term storage of cocoa beans at this environment is difficult. This is because of the fact that cocoa beans absorb moisture from the surrounding atmosphere and this in turn attract contamination by micro organism which make it unsuitable for further processing (Amma *et al.*, 2004). As sun drying is the only practical method in small scale sector and pattern of rain fall being continuous for four to six months, use of cocoa beans at farm level necessitates their storage for at least six months for year round processing. Hence in the present study, the effectiveness of different packaging methods on extending storage life of cocoa beans was studied with and without incorporating neem leaves (Plate 8). The effect of packaging methods studied in relation to increase in moisture content of beans, change in pH, amino acid, polyphenol and anthocyanin content of beans yielded valuable results (Figures 14 to 19). The microbial load on cocoa beans were also analysed at bimonthly intervals showed significant variation with respect to the packaging methods (Plate 10).

The moisture content of beans increased during the course of storage and crossed the safe level at six months after storage in both the seasons in almost all treatments. How ever, the beans packed in jute bags with double lining of polythene remained within safe level up to 10 months of storage during both the seasons. The packing material had profound influence on moisture absorption by beans.

Plate 8. Cured beans after one year of storage

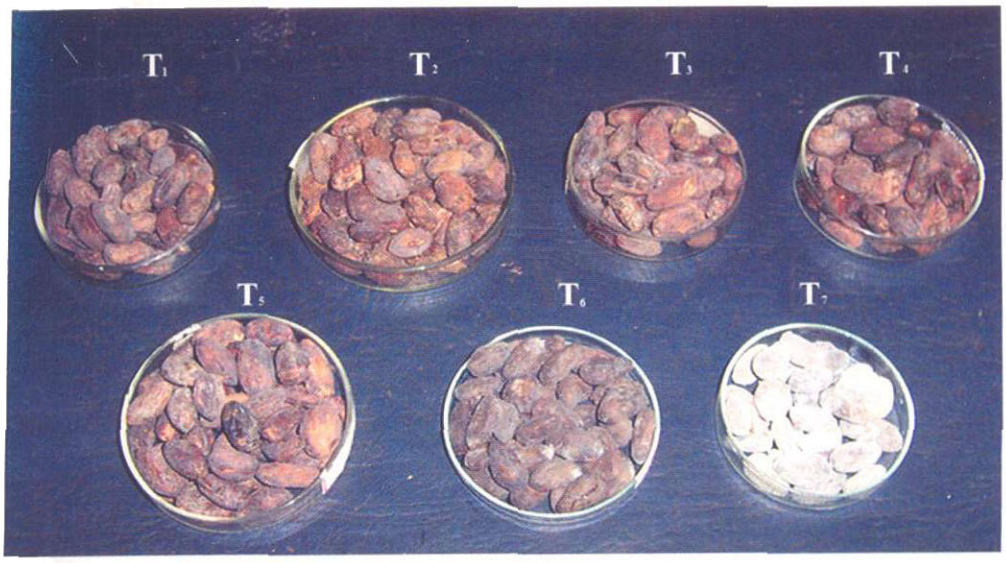


Plate 9. Cured and alkalised beans after six months of storage

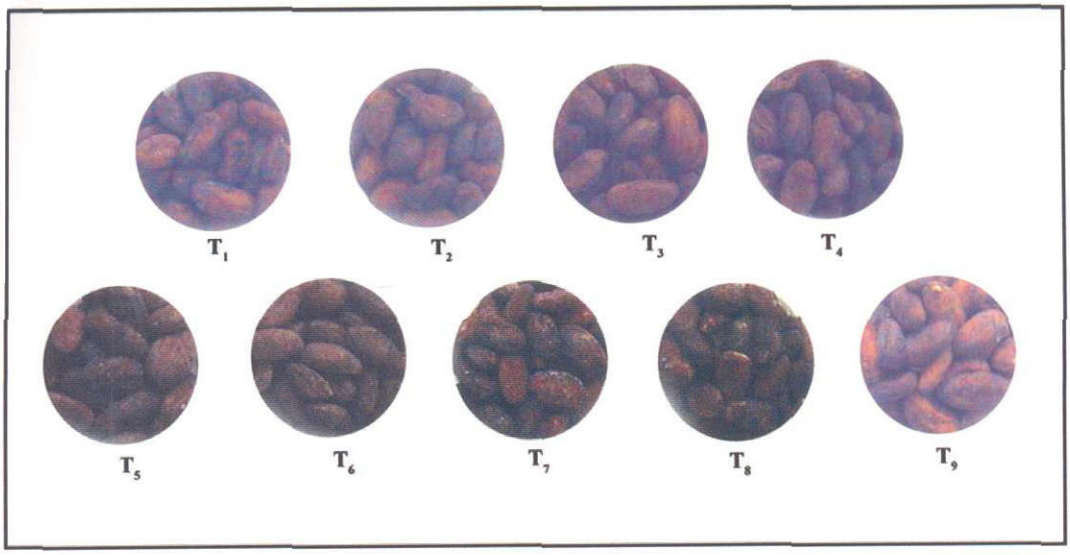
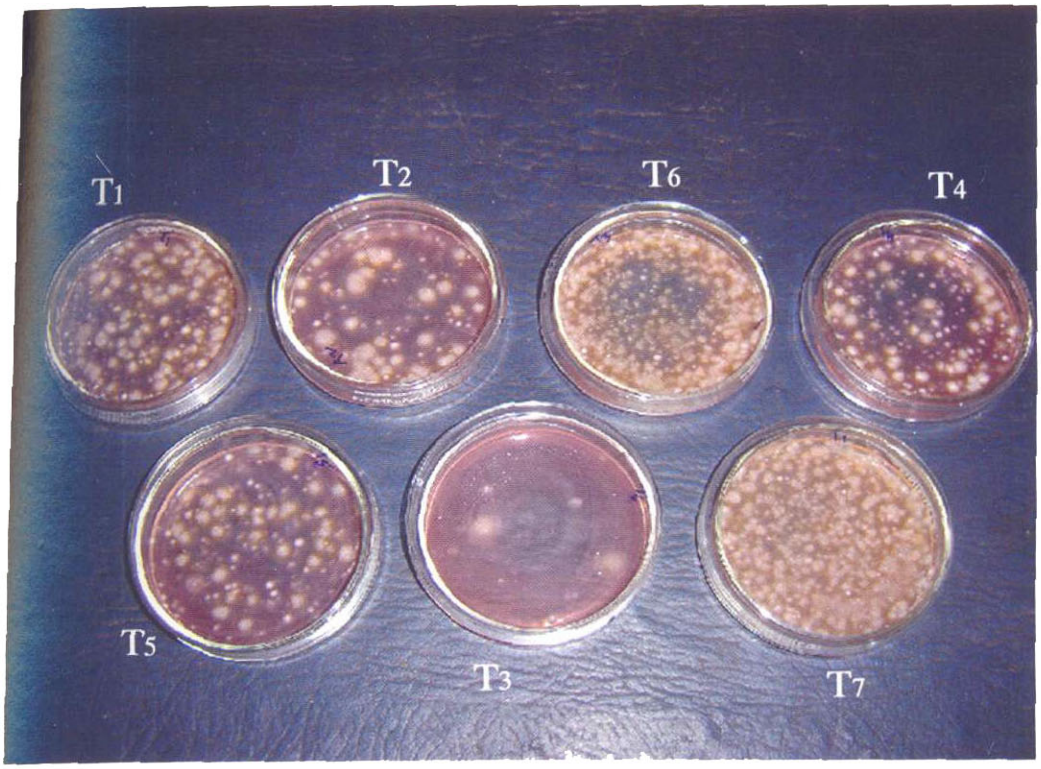
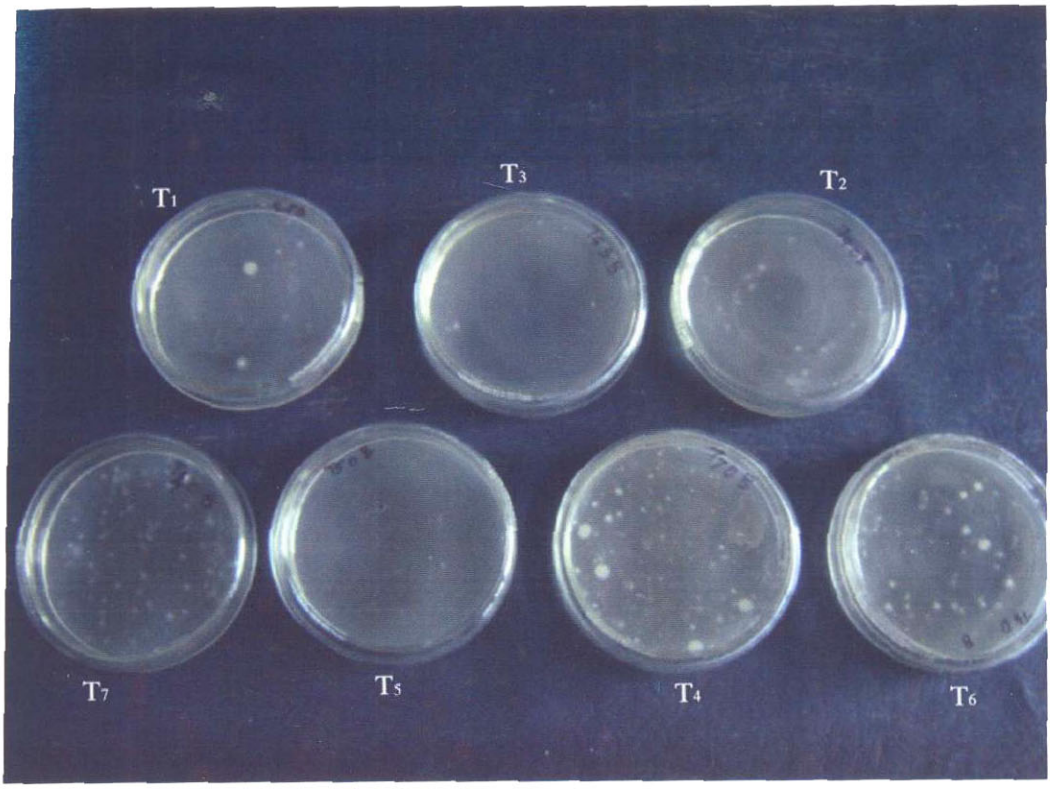


Plate 10. Effect of packaging on microbial population of stored beans



a. Fungal population



b. Bacterial population

Fig. 14. Change in pH of Beans during Storage

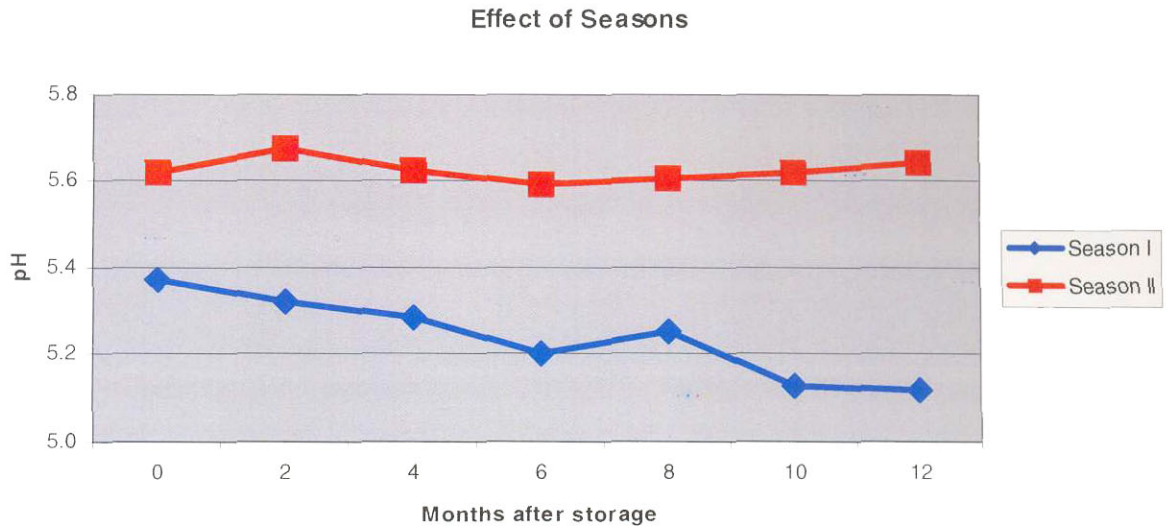


Fig. 15. Change in Moisture content of Beans during Storage

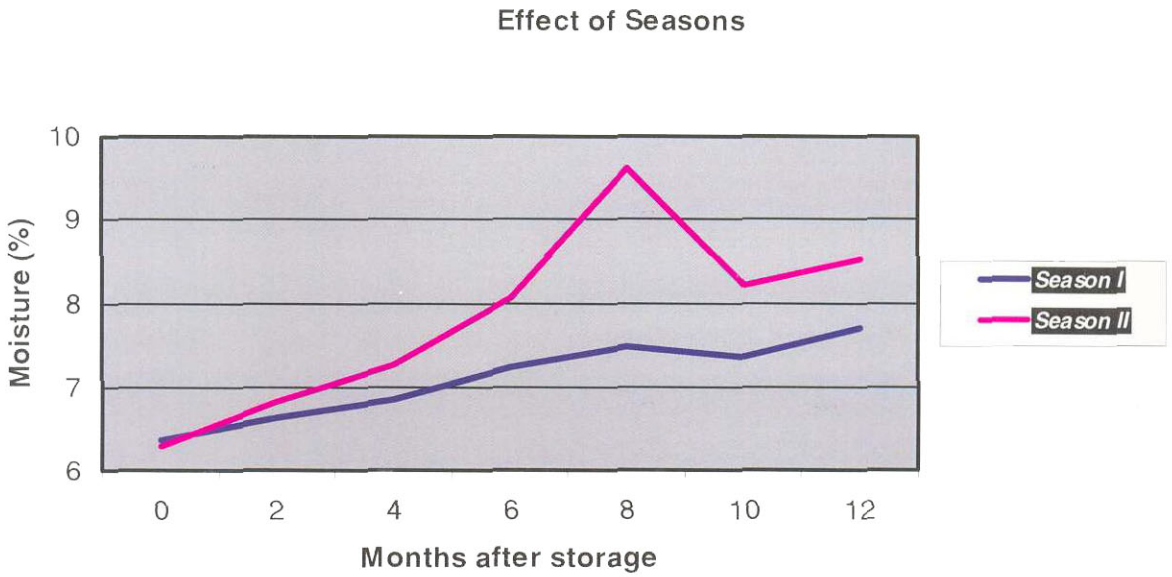


Fig. 16. Change in Moisture content of Beans during Storage

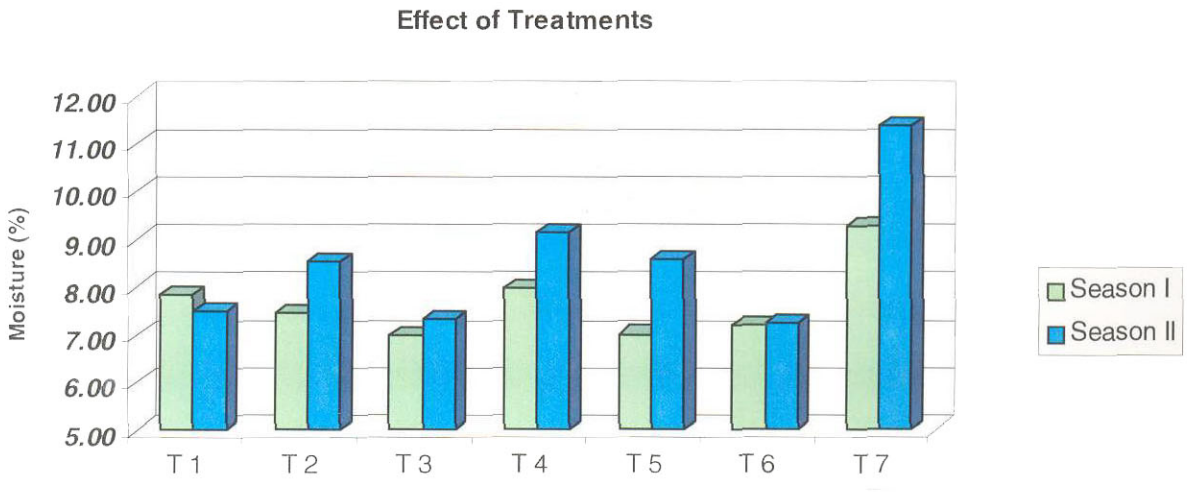


Fig. 17. Change in Anthocyanin content of Beans during Storage

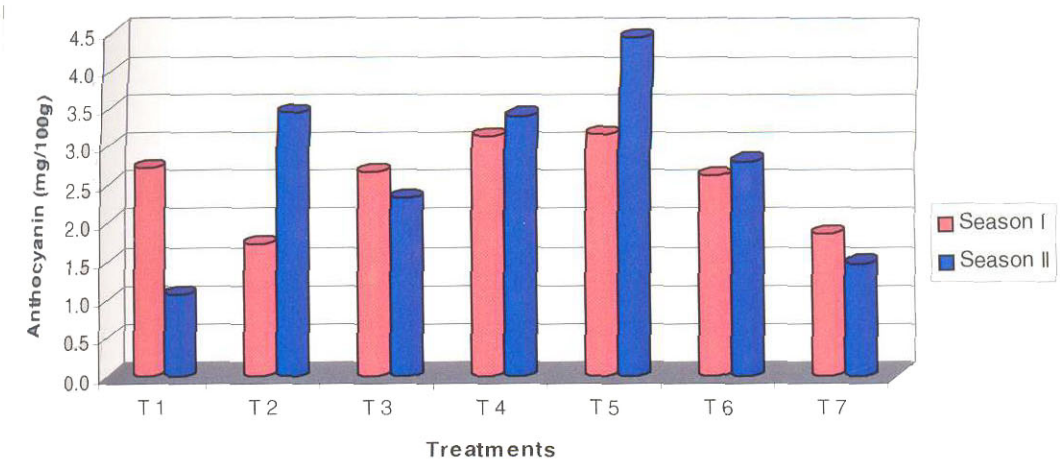


Fig. 18. Change in Polyphenol content of Beans during Storage

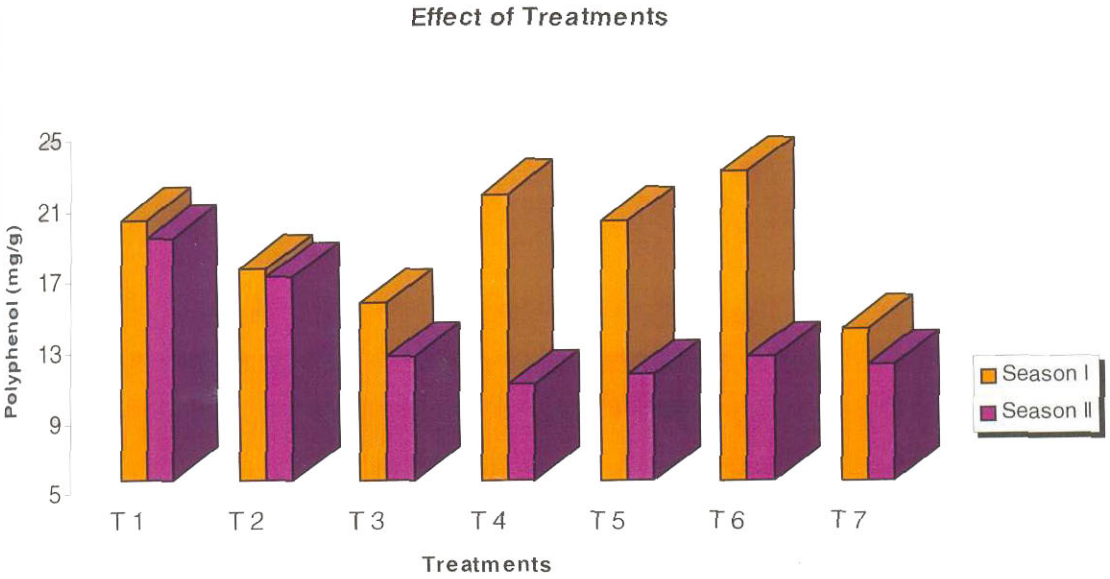
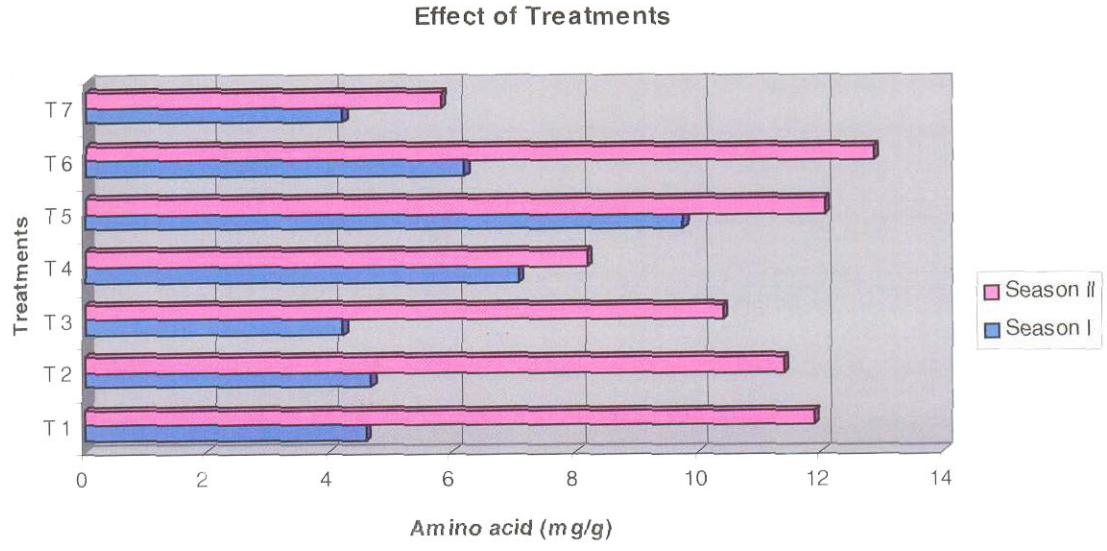


Fig. 19. Change in Amino acid content of Beans during Storage



Wood and Lass (1985) recommended storage of beans in jute bags with double lining of polythene to prevent quality deterioration due to mould and insect attack as well as moisture uptake. Bopaiah (1992) could store the cured beans in jute bags upto 36 months under South Indian conditions without quality deterioration. Amma *et al.* (2004) achieved storage of beans at acceptable moisture level upto six months using jute bag with double lining of polythene.

The seasons had influenced the moisture content of beans during storage. During first season, the rate of increase in moisture content was low compared to that in the second season. The cured beans of first season (April -May) got comparatively long dry spell during storage after a period of rain from June to August. Hence the absorption of moisture would be comparatively less. In case of second season (September - October) the dry spell is lesser during the storage period of one year. It coincides with South – West as well as North – East monsoons under south Indian conditions. Hence the possibility of moisture absorption is more. Another important factor governing the storability of cured beans is pH. The pH of beans decreased substantially during the period of storage. This could be due to the enhanced hydrolytic reaction taking place inside the bean due to increased moisture content. However, a definite relation could not be drawn with respect to the influence of packaging methods in relation to change in pH of beans.

Similarly, the polyphenol and anthocyanin content of the beans reduced during the period of storage. This threw light on the fact that biochemical reactions like hydrolysis and oxidation take place during storage.

5.2 SECONDARY PROCESSING

5.2.1 Alkalisation and Storage of Beans

The manufacturers of chocolate generally alkalise the beans before roasting or at the nib stage or at chocolate liquor stage. This is to increase the pH of beans or nibs or

chocolate liquor as such to overcome the acid taste that may affect the acceptability of chocolate in many instances.

The process of nib alkalization involves soaking in warm alkali solution until complete penetration to the nib was achieved. Both the quality of the alkali and its concentration had a profound effect on the quality of final cocoa. In the present study effect of alkalization of cured beans with sodium bicarbonate at one and 1.5 percent concentration for four different durations (one to four hours) were evaluated (Plate.9). The parameters analysed were the change in pH, anthocyanin, polyphenol and amino acid content of beans after alkalization and during its storage for a period of six months.

The immediate effect of alkalization was an increase in the pH of beans (Fig.20 and 21). The highest pH was noted in beans soaked in one percent alkali for four hours in the first season. During the second season pH of beans was higher when soaked in 1.5 percent alkali for four hours. The rise of pH from 5.1-5.47 to the range of 5.91-5.99 due to alkalisation of beans has been reported by Minifie (1989). When the cured beans are used immediately after alkalization with one to 1.5 percent sodium bicarbonate for four hours, good quality chocolate can be expected.

The effect of alkalization on retention of quality of cured beans during storage was analysed. The result was almost same as that observed with storage of non-alkalised beans. The pH, anthocyanin, polyphenol and amino acid content of beans decreased progressively during storage. This can be attributed to the effect of storage rather than the effect of alkalisation. Hence the effect of storage of beans alkalized with varying concentration of sodium bicarbonate for different duration was judged based on the quality of chocolate through sensory evaluation.

The alkalisation process produced significant influence on quality of chocolate during first season. As discussed earlier, the pH of bean obtained during first season is

Fig. 20. Effect of Alkalisation and Storage on pH of beans

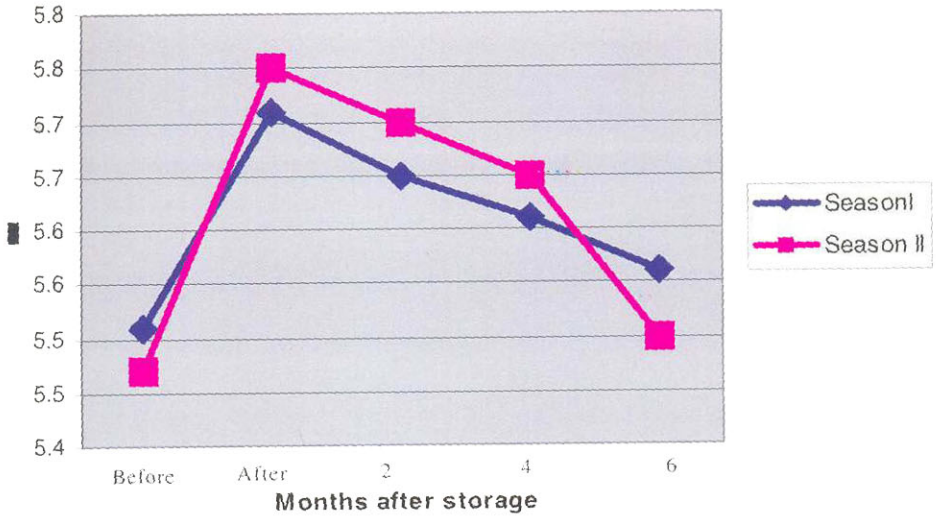
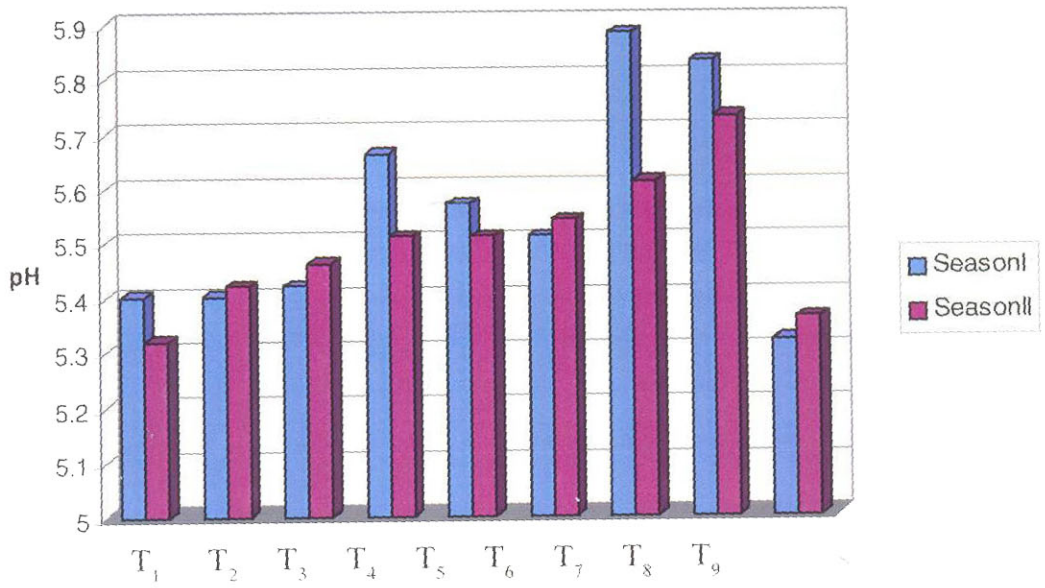


Fig. 21. Effect of Alkalisation and Storage on pH of beans



comparatively low and this could be increased to the desired level by alkalization. Chocolate prepared with beans soaked in sodium bicarbonate at one percent for four hours got the highest score with respect to color and taste (Fig.22). The penetration of alkali into the beans at this level may be sufficient to bring up the pH to near neutrality, which in term is desirable for development of better color and flavour in the finished chocolate. There are several reports on improvement of chocolate quality through alkalization process (Minifie, 1989 and Amma *et al.*, 2004).

5.2.2 Bean Size and Method of Roasting on Quality of Nibs

The purpose of roasting of cocoa bean is to develop flavour, loosening of shell and removal of excess moisture. It brings down the moisture content to 1.5 to two percent .The factors governing the quality of roasted beans are the method employed as well as the temperature and duration of roasting. Whatever be the method employed, it should ensure uniform roasting of beans. The uniformity could not be achieved when the cocoa beans of different sizes were roasted together. Hence in the present study, the beans were graded into three categories based on size and subjected to roasting by two different methods.

The results of the present study revealed the importance of grading of beans prior to roasting and enabled to suggest a viable method for small scale processing of cocoa. Among the different methods of roasting tried, roasting in shallow pan (the conventional method) was found better than roasting in small scale roaster. The beans roasted in shallow pan got higher pH, lower organic acid and residual amino acid compared to those roasted in small scale roaster. As opined by Riedel (1977), the loosening of shell and removal of undesirable volatile acids take place in a better way when the beans are roasted in shallow pans. The reduction in volatile acids, in turn, increases the pH of beans. The superiority of roasting in shallow pan could be attributed to the effective control possible with the duration and temperature of roasting and controlled removal of

moisture together with acids. The lowest amino acid content in beans that were roasted in shallow pan could be attributed to their effective utilization in the formation of amadori compounds as suggested by Heinzler and Eichner (1991). The amadori compounds formed by the reaction of reducing sugars (aldoses) and amino acids in roasted beans are the precursors of Maillard reactions leading to the formation of aroma compounds. The rapid roasting in small scale roaster may not be favourable. However, considering the feasibility for handling more quantity of beans, the small scale roaster could be recommended.

The experiment also highlighted the influence of bean size on quality of roasted beans. The big sized beans were superior to medium and small sized ones. The large beans recorded higher pH, less organic acids and amino acids. As discussed earlier, due to the desirable biochemical composition, bigger sized beans yielded better quality chocolate. so when the beans are graded based on size and subjected to roasting , uniform roasting as well as good quality chocolate could be achieved. The influence of bean size on quality was reported by John (1980). Nobesney and Rutkowski (1998) observed reduction of total and volatile acidity when beans were roasted at 110 t0 150°C. The reduction in the free amino acid content after roasting was also reported by Brito *et al.* (2000). Amma *et al.* (2004) studied the quality of beans roasted in microwave oven, shallow pan and *Uruli* roaster and found that the uniformity in size of the bean was important in achieving proper quality. Thus grading of beans before roasting has become necessary. Misnawi *et al.* (2004) observed that a higher concentration of polyphenol reduced the development of flavour compound (Pyrazines) which could result from the increased binding of free amino acids with polyphenols and their reduced availability for pyrazine formation.

5.2.4 Effect of Duration of Grinding on Quality of Butter, Powder and Chocolate.

The most important factor which influences the quality of chocolate is the particle size of cocoa. Smaller the particle size better the mouth feel in addition to better

integrity of the constituents in chocolate. The important factor which governs the particle size of cocoa powder is the method and duration of grinding. In large factories, the beans are ground for durations upto 72 hours. However in small scale units grinding for such long duration is not practical.

Hence, in the present study, wet grinder of three litre capacity (SHANTA model) was used to standardize the duration of grinding at small scale level. The effect of duration was studied with respect to particle size, bulk density and powder recovery.

In the present study, the highest butter recovery was obtained when beans were ground for two hours compared to longer durations of grinding tried. The butter recovery from cocoa mass is reported to vary with bean size, type of grinder used and duration of grinding (John, 1980 and Amma *et al.*, 2004). The cocoa butter, which constitutes 55 to 58 percent of the nib by weight, gets melted due to the temperature generated during the process of grinding. Pressing the mass immediately after grinding may result in higher butter recovery. On prolonged grinding the cocoa mass become more viscous and particles become finer resulting in decreased butter extraction as reported by Minifie (1989). This could be the reason for lowest butter recovery recorded in the present study with longer duration of grinding. When the butter recovery is decreased, powder recovery will be higher as a result of more butter retention in the powder.

The particle size of powder, the single most important factor governing the quality of chocolate (Amma *et al.*, 2004), was very fine when the nibs were ground for four to eight hours. The proportion of powder particles that passed through 0.5 mm sieve was above 96 per cent in all these treatments. Minifie (1989) reported that for production of quality chocolate the particle size of cocoa powder should be such that more than 96 per cent should pass through 0.5 mm sieve. The bulk density of powder was the highest in case of eight hours grinding due to the retention of more butter in the powder as

evidenced by the present study. The sensory attributes of chocolate revealed the importance of duration of grinding in producing better consistency and colour Thus, it can be concluded that grinding for 4 to 6 hours duration would result in quality chocolate when done in small grinder at small scale level (Fig.23).

5.3 VALUE ADDITION AND PRODUCT DEVELOPMENT

Value addition is the most important method to reduce the post harvest loss as well as to get maximum returns for the farmers. This is achieved through development of processed products with enhanced shelf life and nutritional value and reduced cost.

Dehydration or drying is the oldest and most important method of food processing and dehydrated foods are convenient, versatile and incur less handling cost (Loesecke, 1998; Hayashi,2003).

5.3.1 Spray Drying

Loesecke (1998) reported spray drying as one of the widely adopted dehydration techniques for preparation of value added products especially powder formulation. Spray drying helps to produce a powder of specific moisture content and particle size. In a continuous operation spray drying delivers a highly controlled powder quality with relatively easy manipulation. The objective of spray drying is to produce a spray of high surface to mass ratio droplets and then to evaporate the water uniformly and quickly. Evaporation keeps the product temperature to a minimum, which in turn reduces the chance of high temperature deterioration of the product. Further, spray drying minimises the loss of volatile flavours as against other dehydration techniques

5.3.1.1 Standardisation of temperature regime for spray drying

Four different combinations of inlet/ outlet temperature for spray drying the instant chocolate beverage mix were tried. At an inlet/ outlet temperature of 230/ 120^{0}C, the resultant powder had charred flavour, discoloration and poor dispersibility. Increased drying air temperature resulted in lower bulk density, due to increased particle size and greater tendency for the particles to be hollow. When the temperature was reduced to 175/ 80^0 C, the drying was not proper as revealed by the high moisture content in the finished powder. The optimum temperature was standardised as 190/ 90^0 C for spray drying of beverage mix. Al-Kahtani and Hassen (1990) observed that the moisture content , solubility and bulk density of spray dried Roselle powder decreased with an increase in drying temperature.

Mango- milk shake powder with 2.5 per cent moisture was developed by Sharma *et al.*, (1974) by spray drying the mix at an inlet and outlet temperatures of 170-175^0 C and 98-160^{0}C respectively. Jayaraman *et al.* (1976) successfully spray dried mango pulp mixed with skim milk powder or double strength fresh whole milk at 160 – 180^0 C and 60-70^0 C inlet and outlet temperature respectively. The inlet and outlet temperature for spray drying of milk-shake mix was standardized as 180 and 95^{0}C respectively (Sharma and Gupta, 1978).

5.3.1.2 Standardisation of feed composition

Formulation of the feed mix is the most important factor in developing a new product through spray drying. In the present study, the milk and cocoa content were varied and seven different beverage compositions were formulated and subjected to spray drying in a laboratory scale spray drier (ANHYDRO, Denmark) with rotary atomizer and co-current air flow (Plate 11a.). The cocoa powder content was varied between 14 and 21 per cent (25 per cent fat). In two of the formulations, cocoa powder

with reduced fat of 12 per cent was tried and the resultant powder gave a blank taste of cocoa on reconstitution and the dispersibility also was affected. Hence, the formulation containing 14 per cent cocoa of 25 per cent fat was selected. Similar result of reduced dispersibility with increase in cocoa content was reported by Hla and Hogekamp (1999). The quantity of milk solids in the present study was varied from 55 to 75 per cent and the most acceptable combination in terms of balanced flavour and dispersion was achieved with 63 per cent milk solids.

Once the cocoa and milk solids proportion were finalised the aim was to improve the dispersibility of the powder upon reconstitution. As the product contained fairly high amount of fat, fine tuning of dispersion has become necessary. For this purpose, soy lecithin of 0.2 and 0.7 per cent were incorporated in the selected beverage formulation and the resultant powder had very good dispersibility. The viscosity of the feed material could also be reduced by adding lecithin which in turn helped in smooth feeding of the mix into the atomizer as well as in getting maximum powder recovery through cyclone separator.

El-Shibiny *et al.* (1994) developed a spray dried beverage powder from 1:3 mixture of carrot juice and ultra-filtration permeate of whole milk along with 0.2 per cent stabilizer. Concentration of the mix under vacuum to 25 per cent total solid and homogenization at 200 kg cm^{-2} pressure were found satisfactory to obtain quality powder. Deis (1997) suggested spray drying of skim milk after concentrating about 50 per cent solids in evaporator to obtain finished product of 3.1 per cent moisture. A ready to use banana milk shake powder (RBMSP) through spray drying was developed by Laxminarayana *et al.* (1997) by blending cow milk with 'Musa cavendishi' banana in 5:1 proportion along with 0.015 per cent Carboxy Methyl Cellulose (CMC). Ground sugar was then blended with the powder to obtain a final sugar content of 42.5 per cent in RBMSP.

Addition of lecithin was suggested as one of the methods of improving dispersibility of instant cocoa powder (Kneil, 1993). Fang *et al.* (1995) reported that addition of 0.63 per cent of lecithin reduced viscosity of cocoa dispersions due to lesser number of flocs in the suspension. Hofstaetter (1996) could improve wettability of cocoa beverage powder containing lecithin through microwave treatment. Agglomeration of powder and coating with lecithin were the methods suggested by Deis (1997) to overcome the problem of dispersibility encountered in the case of whole milk powder (due to high fat content).

Brennan *et al.* (1971) reported that liquid glucose (39-43 DE) was the most effective additive as spray drying aid for concentrated orange juice. Highest feed rate and recovery were obtained using this additive. Dacosta and Cal-vidal (1988) attempted spray drying of coconut milk by adding corn starch at 15-20 per cent w/v surfactant and anti-caking agents.

Among various formulation of beverage mix tried in the present study, the one with 14 per cent cocoa, 63 per cent milk solids and 23 per cent additives (gelatin, maltodextrin and sugar) was found to be superior to other combinations. Sharma *et al.* (1974) standardized the feed mix for mango milk shake powder as 36 per cent fruit, 10.8 per cent sugar, 52.6 per cent concentrated skim milk, 14 per cent cream and 0.4 per cent stabilizer.

With respect to powder recovery, maximum value of 44 per cent was obtained in the aforesaid formulation and the viscosity of feed material was the lowest in the formulation containing 0.7 per cent l lecithin followed by that with 0.2 per cent lecithin. However, feed combination containing the highest proportion of low fat cocoa powder (21 per cent) was having the highest viscosity of 480 mPa.S. The process flow chart for preparation of instant chocolate beverage powder through spray drying is given in Figure 31.

5.3.1.3 Physical properties of spray dried powder

In the present study, the moisture content of the spray dried powder ranged powder between 1.4 per cent and 4.2 per cent in different formulations.

The fat content of the powder (ICBP) after dry blending of sugar ranged between 3.61 per cent and 7.36 per cent. The bulk density varied between 0.23 and 0.35, the average particle density varied between 0.73 and 0.96 and the per cent volume occupied by powder particles ranged between 28.69 and 35.12 in different formulations.

5.3.2 Cabinet Drying

As a cost effective alternative for drying of the beverage mix, cabinet drying was attempted using the best formulation of the beverage mix selected and the powder obtained was compared with spray dried powder for various properties. Loesecke (1998) suggested cabinet drying for dehydration at small-scale units. Maya (2004) reported successful cabinet drying of sapota –milk beverage at optimum temperature of 80^0 C for 4.5 hours.

5.3.3 Comparison of Spray and Cabinet dried Beverage Powder

The mean moisture content of spray dried powder was 2.7 per cent and that of cabinet dried powder was 2.99 per cent. The bulk density, average particle density and per cent volume occupied by powder particles were higher in case of cabinet dried powder than spray dried powder. Reineccius (2004) reported that bulk density is important in packaging and transporting considerations, which gives an idea of how much material by weight will fit into a pack or container. The mean powder recovery was 42.06 per cent in spray drying and 43.5 per cent in cabinet drying method. This could be because of the slightly higher moisture content in the cabinet dried powder and

the loss of some quantity of feed material in the spray drier chamber as experienced during the study. This was supported by the findings of Loesecke (1998) that during spray drying (of banana pulp) two major types of powder losses occur viz. wall losses and entrainment losses.

With respect to the TSS, there was no significant difference between spray dried and cabinet dried powders. The dispersibility on reconstitution was higher in spray dried powder (96.33 per cent) and lower in cabinet dried powder (90.23 per cent). As the product is meant for beverage purpose, the dispersibility is very important and spray drying was far superior to cabinet drying in this aspect. According to Reineccius (2004) dispersibility is primarily influenced by particle size, density and the carrier matrix used (maltodextrin in the present study). Generally small, low density particles are difficult to disperse.

5.3.3.1 *Flowability*

Powder flow properties are very important in handling and processing operations. It was measured in different ways such as the angle of repose, friability angle, flow index etc. The angle of repose and flowability are inversely related whereas the flow index is directly related. In the present study flowability of beverage powder was measured in terms of angle of repose. The flowability was slightly higher for cabinet dried than spray dried powder. Fitzpatrick *et al.* (2003) reported the flow index of cocoa powder and non fat milk powder as 1.5 and 3.8 respectively and the flowability increased with increase in flow index. According to Reh *et al.* (2003) the friability angle of a free flowing powder generally falls below 90 degrees.

5.3.3.2 *Moisture sorption kinetics*

Mathlouthi and Roge (2003) reported that the behaviour of dehydrated food products during storage towards humid air to which it is exposed is described by the

water vapour sorption isotherm. It gives the relationship between water content and water activity at a given temperature. This is used to predict caking behaviour of food powders. Depending on the nature of food powder (crystalline or amorphous) the shape of isotherm varies. The temperature together with the water activity (or water content) influences the process of plasticization which leads to agglomeration/ caking of food powders.

Lan and Fang (2003) suggested that moisture adsorption-desorption kinetics are important physical properties to be examined for designing the storage behaviour of dehydrated agricultural commodities.

The results of the present study indicated that caking started at about 30 per cent ERH for both spray dried and cabinet dried powders (Fig.25). In case of spray dried powder the critical point (the equilibrium moisture content at which caking started) was 4.82 and the danger point (the equilibrium moisture content at ERH 5 per cent less than that of critical point) was 4.07. With respect to cabinet dried powder, the critical and danger points were slightly higher ie. 5.57 and 4.64. Maya (2004) reported that the critical point of spray dried and cabinet dried sapota milk beverage powder was 4.98 and 5.08 per cent respectively at 33 per cent ERH.

5.3.3.3 *Glass transition temperature (Tg)*

The glass transition temperature decides the safe storage temperature for the product. It is the temperature at which there is physical change from hard solid glossy state to the soft rubbery liquid state in amorphous solids. It is measured using differential scanning calorimetry (DSC). It also decides the flavour stability of product during storage.

The present study revealed that the Tg value of spray dried and cabinet dried powders were 180.60^0 C and 208.96^0 C respectively (Figures 26 and 27). The value of sticky point temperature (Ts) normally lays 10 to 50^{0}C above the Tg value (Roos and Karel, 1991). In order to reduce sticking of powder to each other and to the drier wall it is necessary that the temperature of drying should remain below sticky point temperature. In the present study we got Tg as 180.6 ^{0}C. So Ts would be above 190 ^{0}C and hence the selected inlet air temperature is safe to prevent stickiness of the powder.

Ozmen and Langrish (2002) reported that the Tg value of skim milk powder decreased with increase in moisture content. The Tg was 87.7^{0}C at moisture content of 1.65g 100g^{-1} of dry powder and 46.7^{0}C at moisture content of 4.52g 100g^{-1}. They also reported that the Tg of skim milk powder was virtually the same as sticky point temperature (Ts). Wauters *et al.* (2002) and Hashimoto *et al.* (2003) recommended storage of food powders at temperature below Tg value to prevent viscous flow and increased potential of caking.

5.3.3.4 Microstructure

A proper understanding of the behaviour of a food product requires knowledge about its structure such as size, shape, spatial arrangements and their interaction. The interaction forces determine the consistency and physical stability of the products (Heertje, 1993). In the present study, scanning electron microscopy (SEM) was employed to understand the structure of beverage powder at microscopic level. In case of spray dried powder, the particles were spherical with uniform size of 20-50 μm, whereas the cabinet dried powder particles were irregular in shape with less uniform size (10-100μm). Uniformity in size and shape of the particle is necessary to have good dispersion during reconstitution of the powder.

Fig. 22. Sensory attributes of chocolate made from alkalised beans

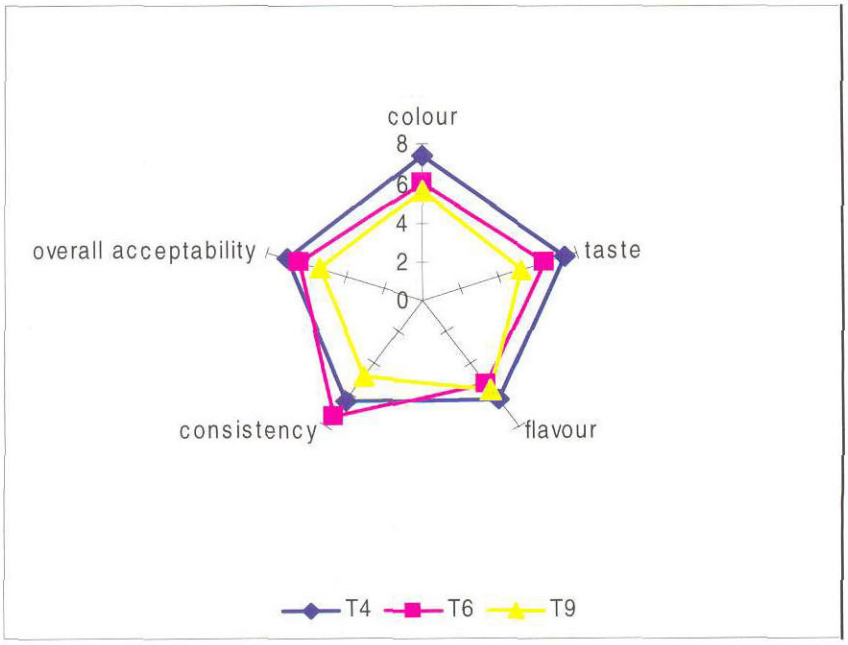


Fig. 23. Effect of duration of grinding on sensory attributes of chocolate

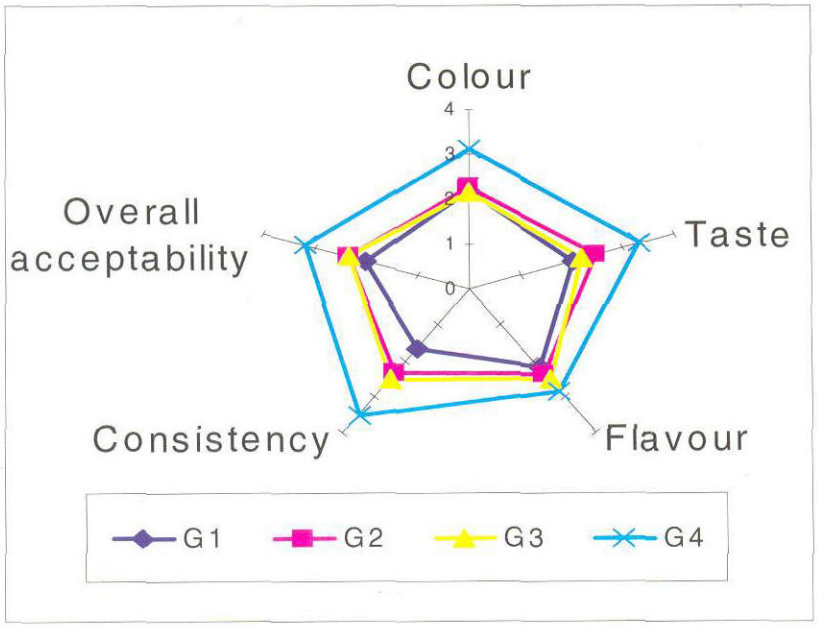


Fig. 24. Sensory attributes of reconstituted beverage (ICBP)

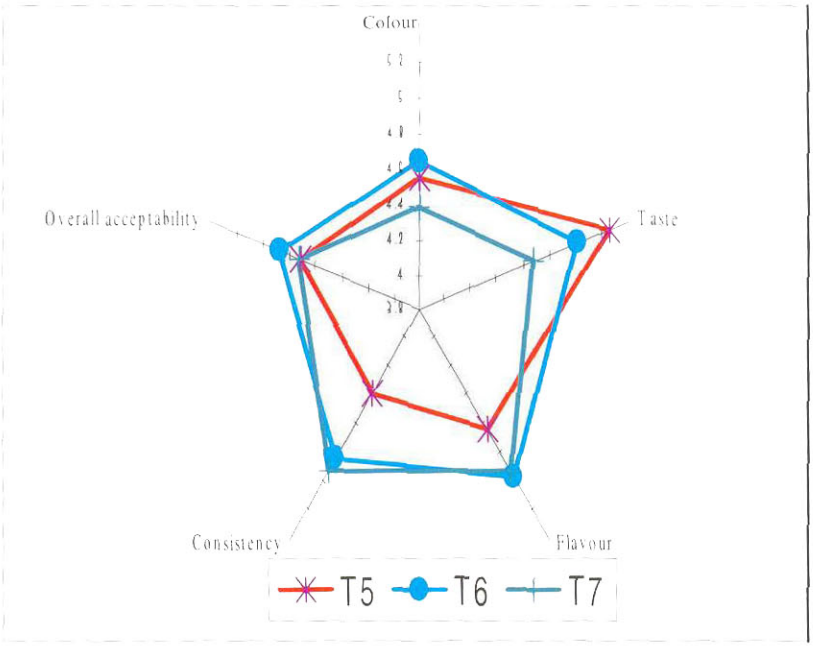
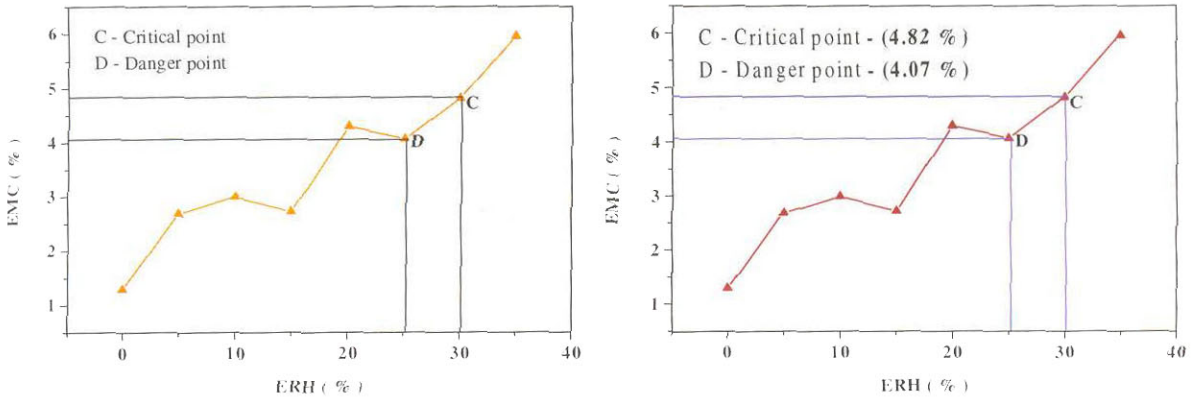


Fig. 25. Sorption Isotherm of beverage powder



Spray dried **Cabinet dried**

Ganesan and Gothandapani (1999) reported the shape of spray dried coconut skim milk powder as almost spherical or oval. El-salam (2000) observed excessive indentation of spray dried emulsion of Whey Protein Concentrate and skim milk when high protein WPC was used. When low protein WPC was used, almost spherical particles were obtained, irrespective of the fat content in powder. Aryana and Haque (2002) found that dehydration of cheddar whey protein concentrate through spray drying preceded by vacuum evaporation caused formation of aggregates, improved packing density and improved gel elasticity of the product.

Groot (2001) suggested the particle size (fineness) as one of the important criteria for selection of cocoa powder for bakery applications. The particle size, shape, surface area and density were the physical properties of dehydrated agricultural products to be studied (Lan and Fang, 2003). The effect of particle size of spray dried powder on properties of chocolates was reported by Keogh *et al.* (2004). The particle size suitable for chocolate making was found to be 132-162μm.

5.3.4 Sensory Evaluation

5.3.4.1 Sensory attributes of reconstituted beverage (ICBP)

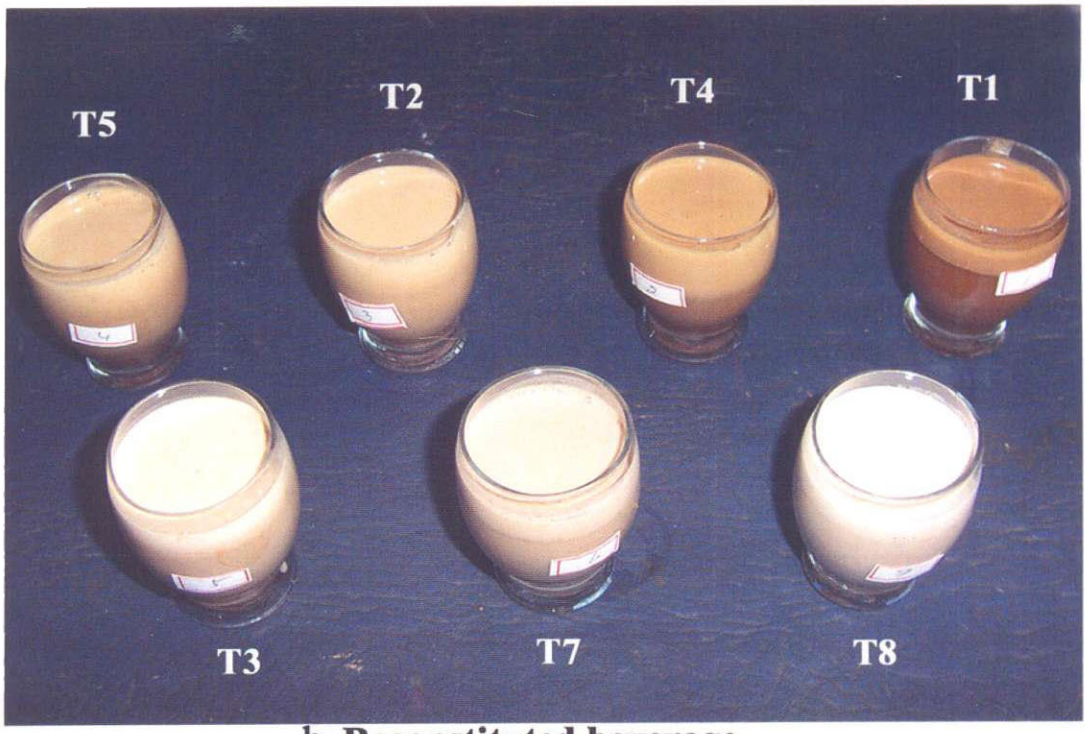
There was significant difference with respect to sensory quality of different formulations developed (Fig.24 and Plate 11b.). The formulation containing 14 per cent cocoa, 63 per cent milk solids and 23 per cent additives (T_6) got maximum score for color, flavour and overall acceptability which was followed by the same formulation with 0.2 per cent lecithin (with improved dispersibility).

5.3.4.2 Sensory attributes of other products prepared from ICBP

Various products were prepared using ICBP as base material such as chocolate, shake and pudding (Plate 13).

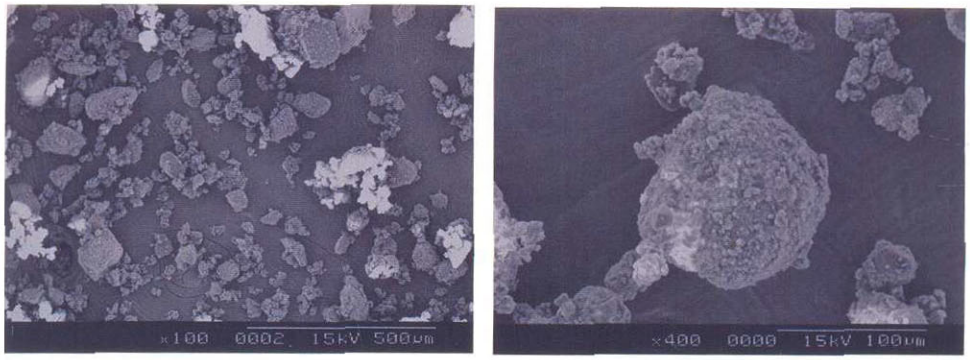
Plate 11. Effect of feed composition on spray dried ICBP

a. Spray dried beverage powder

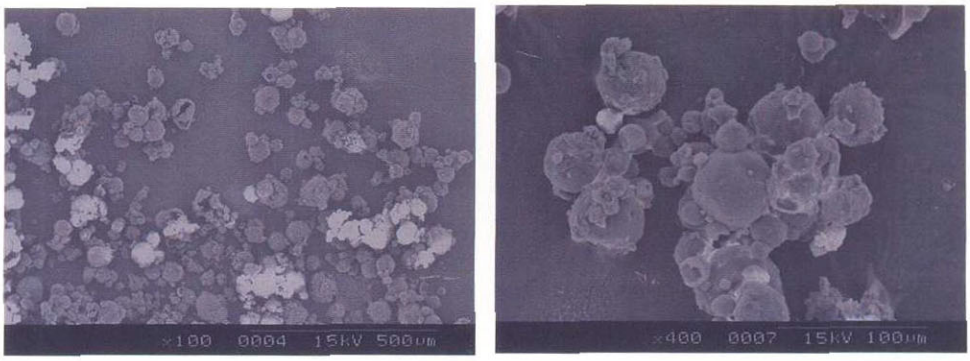


b. Reconstituted beverage

Plate 12. Scaning Electron Microseopy of ICBP

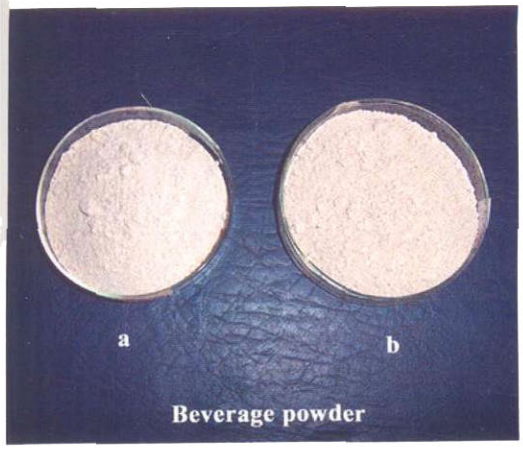


a. Microstructure of cabinet dried powder

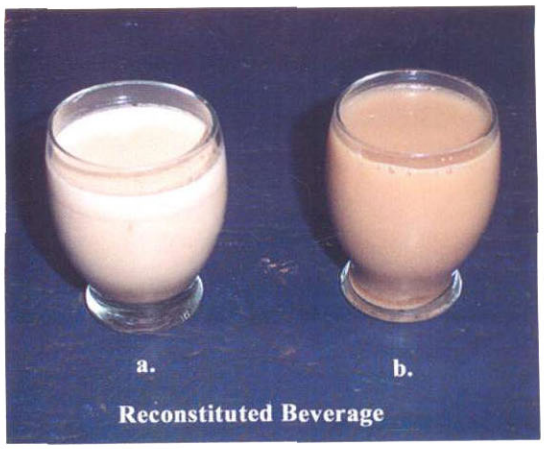


b. Microstructure of spray dried powder

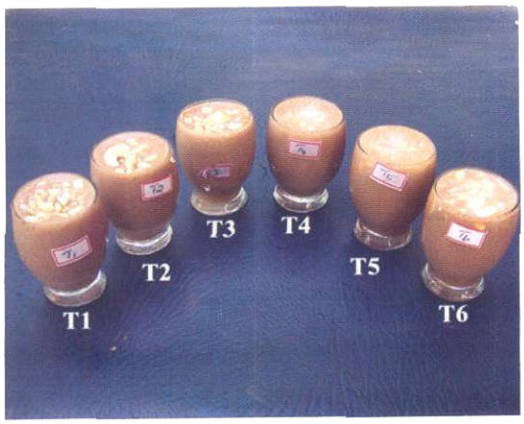
Plate 13. Value added products



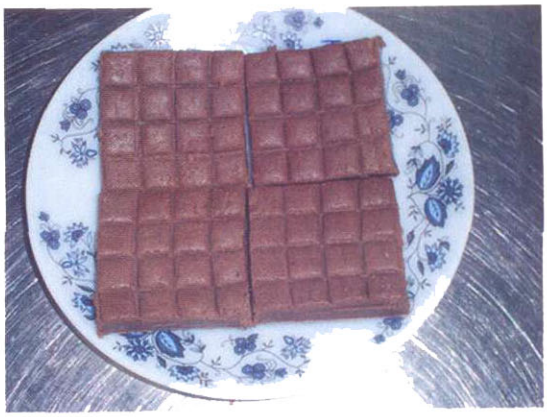
a. Spray dried b. Cabinet dried



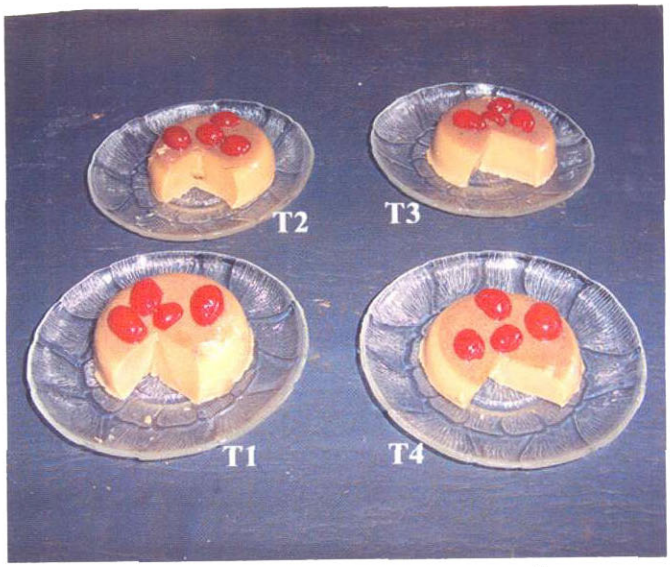
a. Spray dried b. Cabinet dried



Shake from beverage powder



Chocolate



Pudding from beverage powder

5.3.4.2.1 Chocolate

The chocolate prepared by substituting the ICBP in standard recipe (developed by Amma *et al.*, 2004) showed variations with respect to taste and consistency. The best formulation was that used 330g powder, 30g butter and 75 ml water in respect of color, taste flavour and overall acceptability. The consistency was best when lecithinised beverage powder was used in chocolate preparation and the product was on par with the commercial brands in the market (Fig.28).

5.3.4.2.2 Pudding

The taste, flavour, consistency and overall acceptability varied among different formulations and the one using 25g powder, 10g sugar and 2g china grass was found to be the best (Fig. 29).

5.3.4.2.3 Shake

Shake was prepared using ICBP by incorporating varying quantities of banana (cv. Robusta), sugar and the ICBP. The taste, flavour, consistency and overall acceptability varied significantly. The shake formulation containing 50g powder, 50g banana, 5g sugar and 100 ml water was the best as indicated by sensory evaluation (Fig.30).

Planovskii and Golovach (1988) developed a spray dried of apple juice blended with skim milk and recommended the same for use in the manufacture of ice creams, beverages and other confectioneries.

Fig.26 Glass transition temperature of spray dried beverage powder

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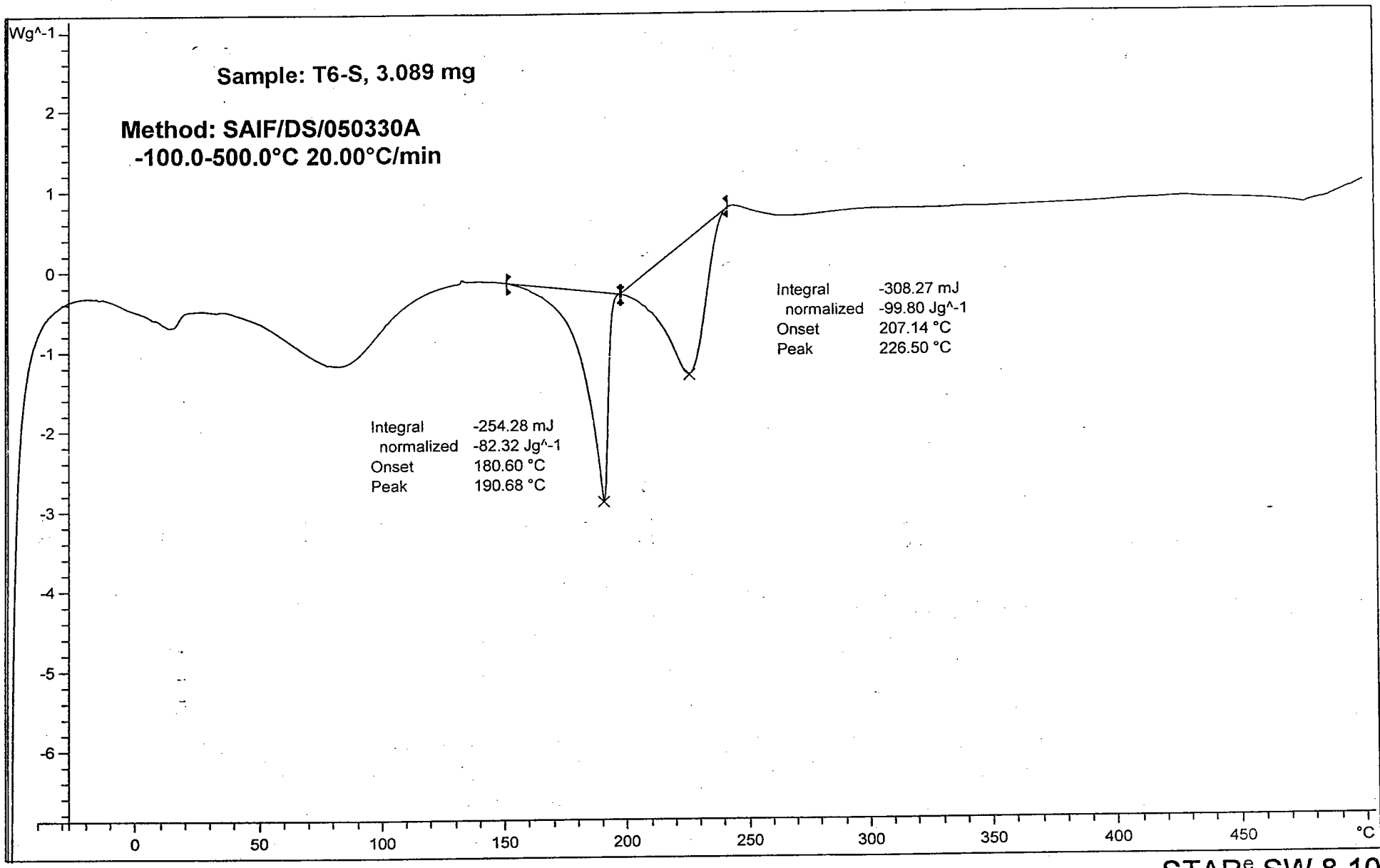


Fig.27 Glass transition temperature of cabinet dried beverage powder

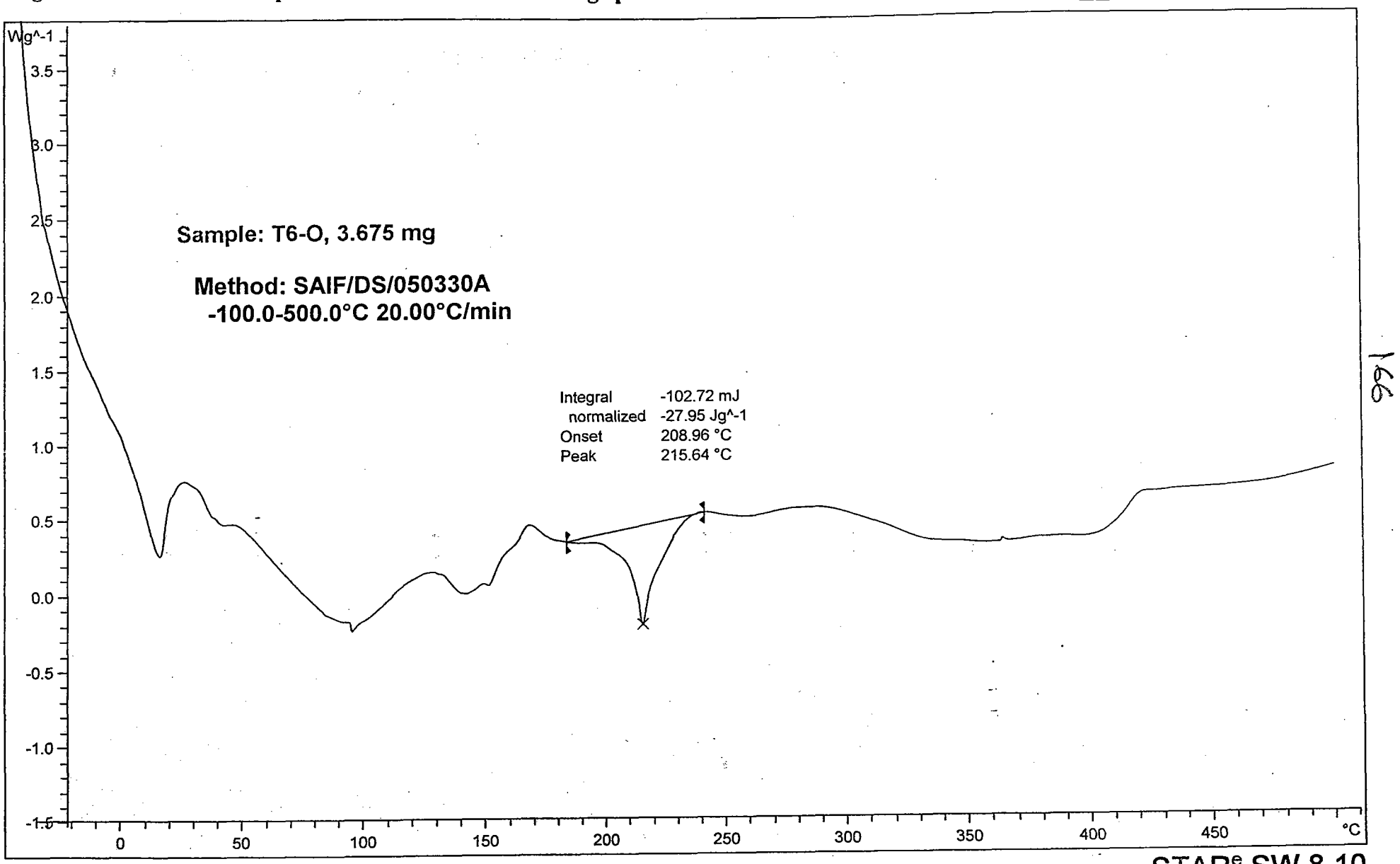


Fig. 28. Sensory attributes of pudding prepared with ICBP

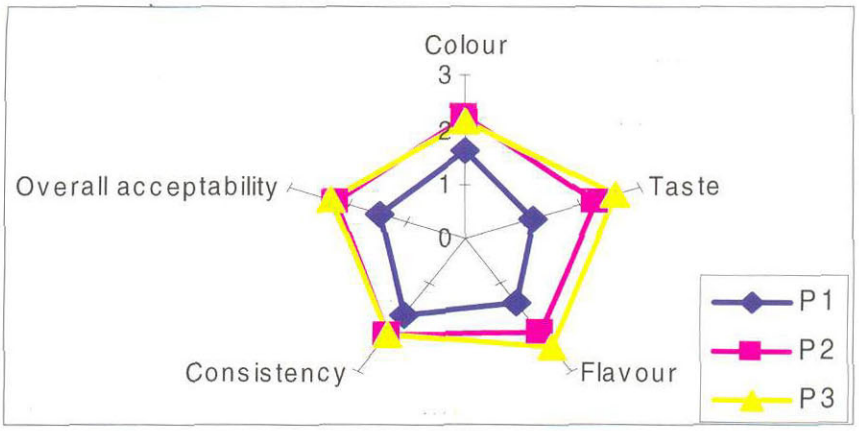


Fig.29. Sensory attributes of shake prepared with ICBP

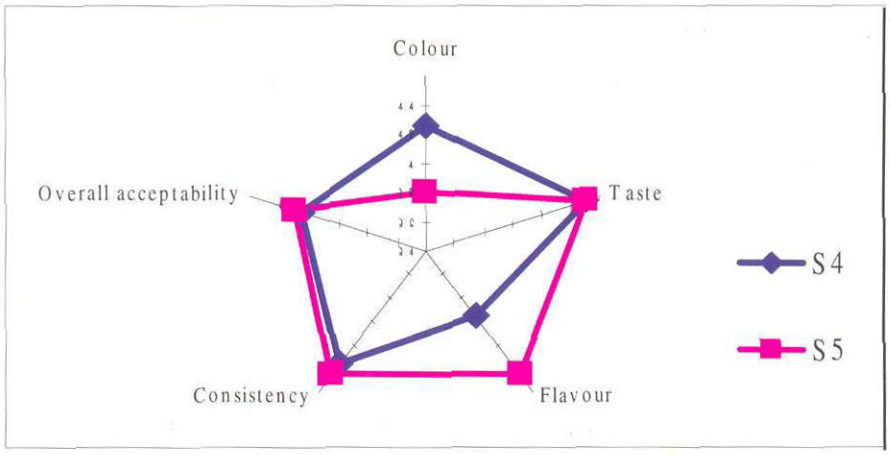


Fig. 30. Sensory attributes of chocolate prepared with ICBP

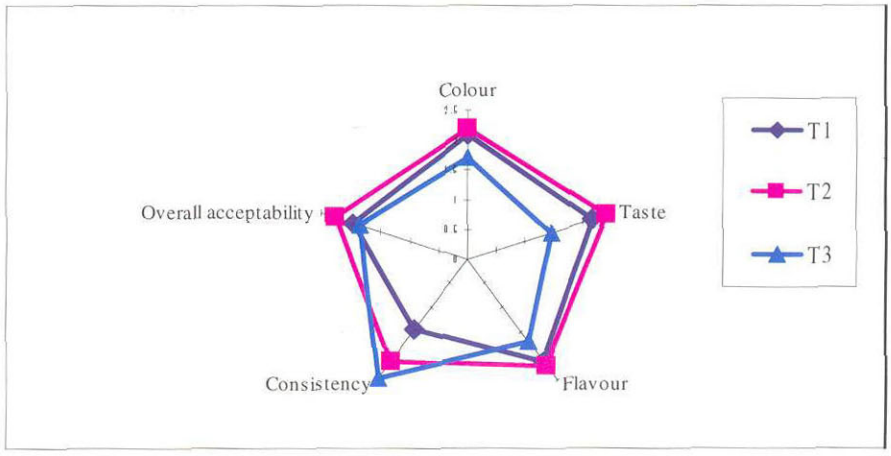
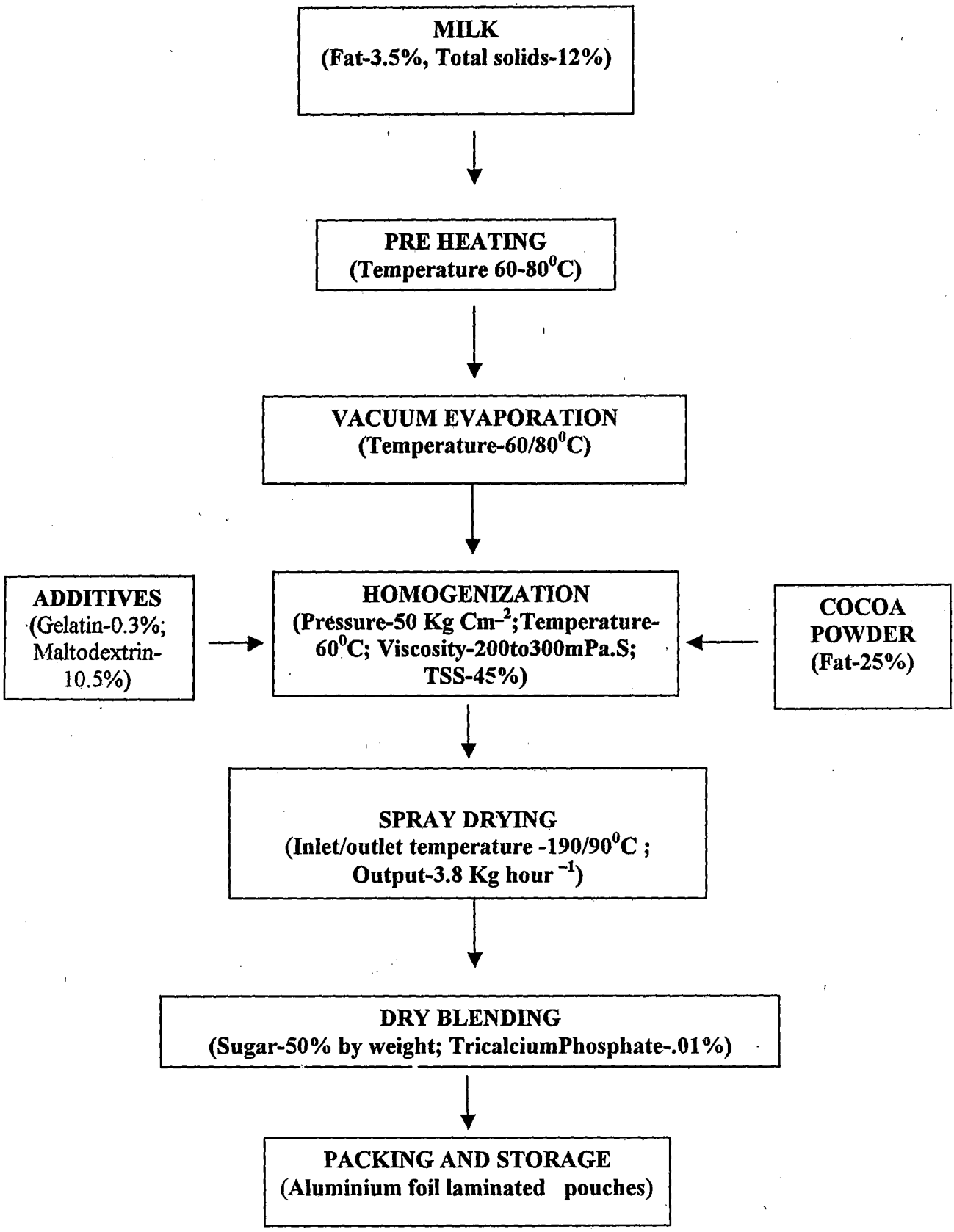


Fig.31 Process flow chart for preparation of spray dried Instant Chocolate Beverage Powder



5.3.5 Cost of Production

The cost of production of 100g unit pack of ICBP was worked out as Rs. 15.28 for spray drying and Rs. 12.89 for cabinet drying. Fifty gram of the powder is sufficient to give 200 ml beverage on reconstitution and the cost works out to be Rs. 7.64 and 6.45 for spray dried and cabinet dried powders respectively. Though the cost of spray dried beverage is slightly higher, considering the quality on reconstitution, it was far superior to that of cabinet dried beverage.

Summary

SUMMARY

The project entitled standardisation of technology for value addition of cocoa (*Theobroma cacao* L.) was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 2002-2005. The major objectives were to refine the technologies of small scale primary and secondary processing of cocoa and to develop an instant chocolate beverage powder (ICBP) which will serve as a basic material for preparing various products like shake, pudding, chocolate etc.

Harvesting and storing of pods for four days and subjecting to fermentation with (T_7) or with out (T_3) application of pectinase was found to improve the quality of cured beans. Application of pectinase was found to have more effectiveness during the second season i.e, September -October. The temperature of fermenting mass increased substantially during the critical period fermentation (3-6 days) and the temperature build up at this period was high (38.8 -41.5^{0}C) in T_3 during first season and T_7 (38.8 to 43.3^{0}C) in the second season. Maximum quantity of sweating was produced with in the first 24 hours of fermentation which could be utilised for production of jam, vinegar, beverages etc.

The pH of the pulp increased and that of bean decreased in response to fermentation during both seasons. After fermentation, the highest bean pH (4.66-4.68) during April- May was recorded with T_3 and T_7 and the bean pH reached to a maximum level of 4.75 in T_7 during September- October. The population build up of yeast and bacteria, which are responsible for bringing biochemical changes during fermentation, were maximum in T_7.

The quality analysis carried out in terms of moisture content, pH, anthocyanin, polyphenol, amino acid, index of cut test and dry bean recovery percent of sun dried and oven dried beans revealed that the sun dried beans are better compared to oven dried beans. The pH of beans increased to a level of 5.82-5.84 when the beans extracted from pods stored for four days were fermented with (T_7) or

with out addition of pectinase (T_3) and dried in the sun. The beans having a pH of this range are expected to produce quality products without acidic taste. Oven drying brought down the moisture content of beans to safe level within four days whereas it took nine days in the case of sun drying to bring the moisture to safe level. Though sun drying is cumbersome, it is easier as well as cost effective. When occurrence of intermittent rain, impair the quality of beans during second season, oven drying alone or together with sun drying could be resorted to.

In case of primary processing, fermentation of beans after four days of pod storage (T_3) in the first season and fermentation of beans after four days pod storage along with application of 0.01 percent pectinase (T_7)followed by sun drying was selected as the best package. The total polyphenol, anthocyanin and amino acid content of beans were found assembled in a desirable manner in T_3 and T_7 as revealed by cut test. These treatments got the highest indices of cut test viz., 75 and 74.6 during the first and second season respectively.

The quality of beans subjected to different packaging methods and stored were analysed at bimonthly intervals for pH, amino acid, polyphenol and anthocyanin content of beans and found that the retention of quality was better when the cured beans were packed in jute bag with double lining of polythene. Incorporation of neem leaves and packing in single polythene lined jute bags was equally effective except for microbial load. The microbial load viz., fungus and bacterial were low in beans packed in double lined jute bag with out neem leaves (T_3).

The alkalisation of beans with Sodium bicarbonate at varying concentration of one and 1.5 percent for different duration of one to four hours yielded valuable results. Alkalisation of beans increased the pH from 5.57 to 5.99 during the first season and 5.47 to 5.91 in the second season. The increase in pH was higher for beans treated with one percent alkali for four hours. The quality of chocolate as revealed by sensory evaluation was good for this treatment. The anthocyanin, amino acid and polyphenol content of alkalised beans decreased during storage. The pH also reduced during storage, but the intensity was less compared to

control. The pH was retained at a desirable level of 5.88 in T_7 (1.5 percent alkali for three hours) and 5.73 in T_9 during sixth month of storage in the first and second season respectively.

The quality of large, medium and small sized beans after roasting was evaluated for pH, presence of non-volatile organic acids and amino acid contents. The results revealed the superiority of large beans over the others. The pH of the large beans was high (6.33) compared to small and medium beans. The non- volatile organic acids and amino acid content reduced in response to roasting. This indicated the conversion of amino acids to flavour compound (alkyl pyrazines) during roasting. These two desirable effects of roasting take place in large sized beans in a better way.

Comparison of roasting methods revealed that roasting in shallow pan roaster gave good quality beans in terms of pH, amino acid etc than small scale roaster. Studies on the effect of duration of grinding on quality of cocoa mass and powder characteristics have shown that grinding for 8 hours result in maximum recovery of powder which in turn resulted from high fat content (33.69%) and bulk density (0.69). the fat content of powder was very less (25.48%) when ground for two hours. The particle size of the powder was fine with respect to four to eight hours of grinding and the corresponding fat content ranged between 30.61 to 30.68. For high fat products, grinding for eight hours can be recommended and for powder with medium fat content, four to six hours grinding would be sufficient.

A value added product viz., Instant chocolate beverage powder (ICBP) was developed adopting the technology of spray drying and cabinet drying. The ideal inlet/ outlet temperature for production of quality ICBP was standardised as $190/90^0$ C for spray drying. Among the seven different feed combinations tried, T_6 containing 14 percent cocoa, 63 percent milk solids and 23 percent additives (maltodextrin, gelatin and sugar) was found to be the ideal composition. Compared to cabinet dreid ICBP, the spray dried material had better dispersibility, particle size and shape. The

cost of production of 100 g ICBP by spray drying amounted to Rs. 15.30 where as that of cabinet dried powder was Rs. 12.80.

The moisture sorption kinetics of spray-dried powder has shown that upto 25 percent ERH, the qualities of the powder was not affected. When the ERH was raised to 30 percent, caking of the powder started. The equilibrium moisture content of the powder for safe storage was determined as 4.82 and for cabinet dried powder it was 5.7 percent. The danger point (moisture content corresponding to and ERH less by five percent from critical point) was determined as 4.07 and 4.64 percent for spray dried and oven dried powder respectively. The glass transition temperature (Tg) was 180.6^0C and 208.96^0C for spary and cabinet dried powders respectively. The particle shape was uniform, spherical and ranged between 20-50 μm for spray dried powder and it was irregular with wide range of sizes from 10 to 100μm for cabinet dried powder.

In addition to the suitability of ICBP for production of beverage, it formed the base material for value added products like chocolate, pudding, cake etc. The ideal composition for preparation of chocolate using ICBP was identified as 330 g powder + 40 g butter + 75 ml water. For pudding it was better to mix 25 g powder with 10 g powder and 2 g china grass. Most acceptable shake could be prepared with 50 g powder, 100 ml water and 100 ml banana with or with out addition of sugar.

The findings of the present study could be concluded as follows,

- Storing the pods for 4 days prior to fermentation was advantageous
- Application of pectinase 0.01 % enhanced effectiveness of fermentation
- Maximum sweat collection of more than 70 percent was obtained within the first 24 hours of fermentation during both the seasons
- Sun drying produced better quality beans compared to oven drying
- Packaging and storage of beans in jute bags with double lining of polythene retained acceptable quality up to 10 months of storage

- Alaklisation of beans with 1 % Sodium bicarbonate for 4 hours was effective in improving the quality
- Large sized beans (≥1.2 g) produced better quality chocolate than medium or small sized beans
- Roasting the beans in shallow pan was more effective than small scale roaster
- Grinding the beans for 4-6 hours can be recommended for small scale units for production of quality powder
- Developed an Instant Chocolate Beverage Powder (ICBP) through spray and cabinet drying
- Standardised the inlet/ outlet temperature (190/90 ^{0}C) and feed composition (14 percent cocoa ,63 percent milk solids and 23 percent additives) for ICBP
- The ICBP was suitable for production of value added products like chocolate, pudding, shake *etc.*

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* Originals not seen

Appendices

Appendix I

Media for enumeration of microbial population

1. Martin's Rose Bengal Agar

Dextrose	-	10 g
Peptone	-	5 g
Potassium dihydrogen phosphate	-	0.5 g
Rose Bengal	-	1 part in 30000 parts of the medium
Agar	-	20 g
Streptomycin	-	30 mg
Distilled water	-	1000 ml

2. Nutrient Agar

Peptone	-	5g
Beef extract	-	3g
NaCl	-	5g
Distilled water	-	1000 ml

3. Sabouraud's (modified) Dextrose Agar

Dextrose	-	20g
Peptone/ Neopeptone	-	10g
Agar	-	20g
Distilled water	-	1000 ml

Appendix-II

Cut test scores

Sun dried beans												
Treatment	Season I						Season II					
	Brown	Partly purple	Purple	Slaty	Total	Index	Brown	Partly purple	Purple	Slaty	Total	Index
T_1	96	82	122	5	300	46.6 (7)	78	31	55	2	164	40.8 (8)
T_2	134	54	90	3	278	71.4 (3)	129	6	75	7	210	59.4 (5)
T_3	136	59	85	5	280	70.0 (2)	148	10	68	2	226	76.0 (2)
T_4	100	70	129	4	299	45.8 (8)	127	15	88	2	230	60.4 (4)
T_5	112	53	135	2	300	49.6 (6)	87	40	62	2	189	46.6 (7)
T_6	112	72	65	6	249	65.0 (5)	117	19	86	4	222	54.4 (6)
T_7	135	68	94	2	297	74.6 (1)	171	53	46	3	270	102.2 (1)
T_8	120	80	100	3	300	66.2 (4)	139	27	86	3	252	69.8 (3)

Oven dried beans												
Treatment	Season-I						Season-II					
	Brown	Partly purple	Purple	Slaty	Total	Index	Brown	Partly purple	Purple	Slaty	Total	Index
T_1	111	62	123	4	300	37.0 (6)	141	45	79	4	269	75.4 (5)
T_2	120	80	97	3	300	40.0 (3)	155	45	94	8	302	78.4 (4)
T_3	85	100	115	0	300	40.5 (2)	81	52	49	7	189	79.1 (3)
T_4	105	80	115	0	300	35.0 (7)	83	47	80	12	222	36.0 (8)
T_5	78	34	88	0	200	39.0 (4)	96	28	62	2	188	49.6 (7)
T_6	104	88	108	0	300	34.6(8)	121	76	26	2	225	81.4 (2)
T_7	125	74	101	0	300	41.6(1)	150	31	47	5	233	83.8 (1)
T_8	115	90	95	0	300	38.8(5)	111	64	109	8	292	52.8 (6)

Appendix III

Score card for sensory evaluation

Name of scorer……. Date……

Product. ……

Please score the given products using the following 5 point hedonic scale

Score	Inference
5	Like very much
4	Like
3	Neither like or dislike
2	Dislike
1	Dislike very much

Product code	Colour	Taste	Flavour	Consistency/Texture	Over all acceptability
1					
2					
3					
4					

Remarks……
(Please write which flavour is dominating, whether you find the colour appealing etc.)

Signature……

Appendix IV

Machineries used in the production of spray and cabinet dried ICBP

1. Spray drying

Sl. No.	Machinery	Cost (Rs)	Working time (minutes)	Depreciation (@10%)	Interest (@12%)
1	Spray drier (15 kg H_2O/h)	15 lakhs	60	17.127	20.5524
2	Vacuum evaporator	2.5 lakhs	20	0.9515	1.418
3	Homogeniser	26000	20	0.0990	0.1188
4	Cream separator	35000	15	0.0999	0.1999
5	Steam processing vats	30000	30	0.1713	0.2055
6	Steam boiler	2.5 lakhs	60	2.8545	3.425
7	Packaging machine	1.5 lakhs	20	0.2855	0.3425
8	Mini pulveriser	10000	10	0.0190	0.0228
Total				21.6077	26.2049

2. Cabinet drying

Sl. No.	Machinery	Cost (Rs)	Working time (minutes)	Depreciation (@10%)	Interest (@12%)
1	Cabinet drier	50000	360	3.4254	4.1100
2	Mini pulveriser	10000	30	0.0571	0.0685
3	Packing machine	1.5 lakhs	10	0.2855	0.3425
Total				3.7680	4.5210

STANDARDISATION OF TECHNOLOGY FOR VALUE ADDITION OF COCOA

(Theobroma cacao L.)

By

K. SUNILKUMAR

ABSTRACT OF THESIS
Submitted in partial fulfilment of the requirement for the degree of

DOCTOR OF PHILOSOPHY IN HORTICULTURE

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ABSTRACT

Cocoa is the sole source for chocolate and its manufacture continued to be the monopoly of multinational companies. Even though, cocoa is mainly grown in small-holder sector, the growers are forced to sell their produce at a price decided by the multinational companies. The growers are facing acute problem due to ineffective procurement system of the companies and the unrealistic price offered by them. In this context, development of viable technologies for small-scale processing and value addition of cocoa will help a long way to safe guard the interest of farmers (Amma *et al.*, 2004). Hence the present study was taken up with the objectives of standardization of primary and secondary processing of cocoa for small scale unit and the development of an Instant Chocolate Beverage Powder (ICBP) and studying its suitability for preparation of value added products.

The primary processing technology for cocoa was standardised in terms of fermentation, drying and storage of cured beans. Pod storage for four days was found to produce quality beans during the major (April- May) as well as minor (Sept- Oct.) harvest seasons of cocoa. The application of pectinase (0.01per cent) enhanced the effectiveness of fermentation as reported by Bhumibhamon and Jinda (1997). The quality analysis of sun dried and oven dried beans revealed the superiority of sun dried beans over the other. The most desirable pH (5.82-5.84) of the beans was achieved in sun dried samples. The effectiveness of fermentation and drying as judged by the cut test (Wood and Lass, 1985) revealed the superiority of selected fermentation and drying treatments. Packaging and storing the beans in jute bag with double lining of polythene was found to retain quality of beans to an acceptable level upto ten months during both the seasons.

The secondary processing of cocoa (alkalisation, roasting and grinding) was standardised for small scale units. Alkalising the cured beans with one per cent Sodium carbonate for four hours was found beneficial. The chocolate prepared using alkalised

beans was ranked superior with respect to pH and sensory attributes. Grading the beans based on size before roasting is to be done to get good quality powder and butter. Large sized beans (≥1.2 g) gave better quality powder compared to that of small and medium sized beans. The quality of beans roasted in shallow pans was superior compared to that roasted in small scale roaster. The ideal duration for grinding the roasted beans was identified as four to six hours when a table top grinder of two litre capacity (suitable for small scale unit) was used.

A value added product *viz.*, ICBP was developed adopting the technology of spray and cabinet drying. The ideal inlet/ outlet temperature for production of quality ICBP was standardized as $190/90^0$ C for spray drying and the feed composition formulated with 14 per cent cocoa, 63 per cent milk solids and 23 per cent additives produced the best quality ICBP. The quality of the spray dried powder was better than that of cabinet dried samples. In addition to the suitability for preparation of beverage, the ICBP was found useful as a base material for preparation of chocolate, shake and pudding.