STUDIES ON THE FERMENTATION AND CURING OF COCOA BEANS

By

T. PREMALATHA

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Studies on the fermentation and curing of cocoa beans" is a bonafide record of research work done by me during the course of research work 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.

Premalatha
12-1-1983
T. PREMALATHA

Vellanikkara,
11th January, 1983

CERTIFICATE

Certified that this thesis entitled "Studies on the fermentation and curing of cocoa beans" is a record of research work done independently by Smt. T. Premalatha under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. N. Mohanakumaran,
Associate Director of Research (Plg.)
Kerala Agricultural University,
Vellanikkara.

Vellanikkara,
11th January, 1985

CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt. T. Premalatha, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Studies on the fermentation and curing of cocoa beans" may be submitted by Smt. T. Premalatha in partial fulfilment of the requirement for the degree.

12/1/83

Dr. N. MOHANAKUMARAN,
Advisor and Chairman.

Dr. P.C. SIVARAMAN NAIR,
Member.

Dr. K. KUMARAN,
Member.

Dr. ~~V.K. SASIDHAR~~, R VIKRAMAN NAIR
Member.

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T. PREMALATHA

CONTENTS

LIST OF TABLES

18. Seasonal variation on the shell percentage in different methods.

19. Seasonal variation on the percentage recovery in different methods.

20. Temperature development (^{o}C) in the bean mass fermented using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods.

21. Variation in pH of the pulp during fermentation using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods.

22. Variation in pH of the cotyledons during fermentation using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods.

23. Effect of ripeness of pods in the production of brown, brown + pale purple and purple beans.

24. Effect of ripeness of pods on the average bean weight, shell percentage and percentage recovery.

25. Temperature development (^{o}C) in the bean mass fermented using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days.

26. Variation in pH of the pulp during fermentation by using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days.

27. Variation in pH of the cotyledons during fermentation by using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days.

28. Effect of storing the harvested pods in the production of brown, brown + pale purple and purple beans.

29. Effect of storing the harvested pods on the average bean weight, shell percentage and percentage recovery.

30. Changes in the quality attributes of cured beans during storage.

LIST OF FIGURES

Introduction

INTRODUCTION

Cocoa ranks third among the beverage crops in the World, after tea and coffee. As a result of the launching of many development schemes, this crop gained ground in Kerala during the past decade. It is estimated that out of the total cocoa area of 20,000 ha in India, Kerala accounts for about 15,000 ha (75 per cent), followed by Karnataka and Tamil Nadu which account for 4,400 ha (22 per cent) and 600 ha (3 per cent), respectively (Anon., 1981). The production of cocoa beans in India during 1981-82 was about 3080 tonnes, of which Kerala contributed 2500 tonnes (Anon., 1981). India's requirement of cocoa has been estimated to be around 5000 tonnes by 2000 AD (Ananthakrishnan *et al*., 1979). During 1960's India imported 1135 tonnes of cocoa beans and cocoa products involving a foreign exchange drain of Rs.241 lakhs. The latter half of 1970's saw a massive expansion of cocoa cultivation and by the year 1980, India exported 1000 tonnes of cocoa products valued at Rs.10 lakhs (Anon., 1981).

In Kerala, due to the pressure on land, pure and large plantations of cocoa are not raised. Its cultivation is limited to small holdings, especially as an intercrop in the coconut and arecanut plantations where ideal situations exist.

The cocoa of commerce is the fermented and dried (or cured) bean. While different methods are being suggested for curing beans on a larger scale, techniques suitable for small quantities are yet to be standardised.

At present in Kerala, certain agencies like the Kerala State Co-operative Marketing Federation, the Cadbury Fry (India) Limited and the Central Arecanut Marketing and Processing Co-operative collect the pods from the cultivators, extract the beans at a centralised place and carry out the fermentation and drying. This has been found to be a cumbersome process. Besides, this practice does not ensure a reasonable price for the beans. If the technical know-how to cure small quantities of beans could be standardised and passed on to the cultivators, they would be in a position to dispose off their produce in cured form, thereby realising better price. This can help in transforming cocoa into a small growers' crop, ultimately paving the way for increased production.

In cognizance of the above, studies were taken up at the College of Horticulture, Kerala Agricultural University, Vellanikkara on curing small quantities of cocoa beans. The studies aimed at elucidating the following information:

1. The efficacy of different methods of fermentation of small quantities of cocoa beans.
2. The comparative efficiency of the fermentation methods during dry and wet seasons.

3. The maturity of pods at harvest in relation to fermentation of cocoa beans.

4. The effect of storing harvested pods on fermentation characteristics.

5. Quality attributes of beans in relation to storage.

Review of Literature

REVIEW OF LITERATURE

Cocoabean is the base material for the manufacture of cocoa butter, chocolate, chocolate drinks, etc. The characteristic flavour and aroma of cocoa develop only on proper fermentation/curing of cocoa beans. Fermentation of cocoa beans involves keeping the mass of cocoa beans with the mucilage well insulated so as to retain the heat, at the same time allowing air to pass through the beans for a stipulated period of time (normally lasting upto seven days) and then drying. A brief review of literature available on various aspects of fermentation and curing of cocoa is presented hereunder:

FERMENTATION METHODS

The methods of fermentation vary from country to country, grower to grower and variety to variety. Basically, there are four methods of fermentation.

Box method

For fermenting cocoa beans, various types of boxes are seen advocated. Eden (1961) devised a fermentation box measuring 1.5 m x 1.2 m x 0.90 m. He cited the height of the box as an important criterion and pointed out that height above 90 cm had an adverse effect on the quality of the beans. Maravalhas (1966) working in Bahia developed a special type of sweat box of size 1.2 m x 1.0 m x 1.0 m. The box had four compartments divided by removable vertical partitions. In this box, two lateral walls were provided with rows of holes at a spacing of 8.0 cm. A perforated lath sliding over the holes helped in regulating the passage of air. For unloading purpose, one of the walls facing the partition was made removable. It was claimed that because of the regulation of aeration at all stages of fermentation, turning of the beans could be avoided and the process of fermentation got completed in three to four and a half days. This method gave, on an average, 50 per cent fully fermented and 43 per cent partially fermented beans. Quesnel and Lopez (1975) invented a sweat box suited for fermenting small quantities (10 to 20 kg) of beans. The sweat box was made out of styrotex, a polysterene foam plastic which was found to be efficient in providing sufficient insulation thus avoiding the need for supplementation of heat from external sources. A box of size 33.5 cm x 24.0 cm x 29.5 cm could hold a maximum quantity of 18 kg of wet beans. When the box was half full, the cocoa beans were covered with banana leaves and the lid was closed. No further covering of the box was required. A temperature of 45°C to 48°C was attained inside the box in about three days and it was maintained till the completion of fermentation. The chemical analysis of the fermented cocoa indicated that the changes occurring inside the box were similar to those in normal fermentation; but the beans were slightly more aerated. By this method, quantities of six to seven kg of beans could also be fermented properly. The process involved turning of beans on alternate days. The quality of the product was good. For finding out the efficacy of sac covers and number of openings in the wooden mini boxes, Manurung <u>et</u> <u>al</u>. (1976) used wooden mini-boxes with one, three and five holes and covering with one or two layers of sacking. Comparing the results with those obtained in ordinary sweat box fermentation, they claimed that mini-boxes having three or five holes and two sac covers yielded better results in terms of weight loss and percentage of fermented beans. Kumaran <u>et</u> <u>al</u>. (1980) conducted trials during rainy season with mini-box to elucidate the effects of degree of insulation, frequency of turning, number of sluices in the box and quantity of beans on the fermentation characteristics and final quality of the cured beans. Among the four insulations provided, "straw (three cm) in two layer gunny" was found superior. With this insulation, a satisfactory temperature build-up in the ferment was observed during the rainy seasons as compared to the control with two layers of gunny. Among the four types of insulators, polythene sheet was found to be the least effective. Effect of season on fermentation was marked as it delayed curing by two to three days during rainy season. Turning the beans once daily and providing sluices 10 cm x 10 cm apart resulted in proper fermentation. Quantity of the beans did not markedly influence the extent of fermentation.

Heap method

Among the different methods of cocoa fermentation, heap method is commonly adopted in the small holdings in Ghana and other West African countries. Rohan (1958) found that quantities of 70 kg wet beans could be properly fermented using heap method. Wood (1975) described the methodology of heap fermentation. In this method, the wet beans heaped on banana leaves are covered with the leaves themselves. The leaves are held in place using small logs. The fermentation process lasts for six days during which time, the beans are turned twice at intervals of two and four days after the initial setting. Adomako et al. (1981) conducted trials on heap fermentation using samples of 50 kg, 150 kg and 450 kg beans to study the effect of heap size on temperature, pH and quality attributes of beans. It was found that the temperature fluctuations were the same in all the heap sizes, except in the 50 kg heap in which the bottom temperature was consistently lower throughout the period of fermentation. The heap size did not influence either the final pH values or the grade of the dried beans. However in the largest heap, the decrease in pH of the cotyledon was rather slow.

Basket method

Hammond (1953) and Wood (1975) reported that basket method of fermentation is generally practised in Nigeria for fermenting small quantities of beans. Kumaran et al. (1980) found that by using mini-baskets, bean lots ranging from two to six kg could be successfully fermented. Baskets made of closely woven bamboo matting with a diameter of 20 cm and height of 15 cm could hold two kg beans. For larger lots, they recommended deeper baskets. The baskets were lined with one or two layers of banana leaves which besides providing insulation could also facilitate drainage of the sweatings. Wet beans were filled, compacted and covered over with banana leaves. To allow the flow of sweatings, the baskets were placed on raised platforms. Twentyfour hours after the setting, the baskets were covered with gunny sacking. After fourtyeight and ninetysix hours, the beans were taken out, mixed and reloaded. By this method, fermentation was completed in six days and the beans were ready for drying on the seventh day.

Tray method

Tray method of fermentation was evolved by Rohan (1958) who recommended the same for small quantities of beans of Forastero variety. In this method, wooden trays of 10 cm depth with slatted split cane bottoms were used. The trays were divided into sections using wooden partitions fitting appropriate grooves provided at required distances. The capacity of the tray could be adjusted by adjusting the distance between the partition planks. A tray measuring 60 cm length and 25 cm width could hold 10 kg of beans. For successful fermentation, atleast four or five trays were used. The trays were stacked one above the other in such a manner that the cocoa-filled portions were in a single row. The topmost tray was covered with banana leaves. After twentyfour hours of initial setting, a close fitting sack cover was provided to maintain the temperature. This method did not involve any mixing or turning. Fermentation was completed within four to five days.

Laboratory methods (small scale)

Various methods have been tried for fermenting cocoa beans for laboratory studies. Maclean and Wickens (1951) evolved a method suitable for fermenting 40 to 80 beans. Their set up had a buchner funnel with aeration mechanism and temperature control. Two grammes of dextrose was added to the bean mass. The assembly was set up in an oven maintained at 37-38°C and the treatment was continued for six days. After fermentation, the beans were sun dried. Quesnel (1957) described a chemical method of fermentation. In this method, 225 g of pulp-free beans were weighed into a kilner jar to which an aqueous solution of hot acetic acid and ethenol (225 ml containing 1% volume of each constituent) was poured. The jar was sealed and incubated at 50°C for 48 hours. The beans were then rinsed and dried. Challot (1977) reported another fermentation method using desiccators for fermenting small samples of cocoa. The loaded desiccators were maintained at 37°C for 48 hours and then shifted to 50°C for four days. The beans were stirred twice a day. After six days of treatment, good quality product could be obtained.

Solar fermenting frame

Solar energy has also been used for fermenting cocoa beans. McDonald (1936) fermented small quantities of cocoa beans using a solar fermenting frame consisting of a thick walled box with a glass lid which helped to trap and retain the solar energy. Sweat boxes holding about 25 kg of wet cocoa were placed in the solar fermentary and kept in the sun. Thus, a blanket of warm air at 100°F-150°F (37.78°C-65.56°C) could be maintained around the sweat boxes for a period of eight hours a day. The other advantage of this method was that excess evaporation was prevented. The apparatus was simple and cheap. The fermented cocoa so obtained was of excellent quality possessing even appearance and quality. The beans were almost free from blue mould. Due to the maintenance of even temperature throughout the mass, turning of cocoa during fermentation was unnecessary. Rayes (1964) working in Venezuela used a basket holding 32 kg of wet cocoa and fermented the same using solar energy. Before placing the basket in the sun, it was covered with a polythene sheet. The beans were turned every 24 hours. A charge of cocoa reached a temperature of 50°C in the upper layer on the second day and in the bottom layer on the fifth day. Fermentation was completed within five days. It was found that 86 per cent of the beans was well fermented.

EFFICACY OF DIFFERENT METHODS OF FERMENTATION

Many scientists have compared the efficacy of different methods of fermentation and their variations. Knapp (1934) compared six methods of fermentation of cocoa beans (heap, pit, wooden mini-box, basket, plantain stem frame and bamboo frame) under Ghana conditions. He concluded that the best type of container was the wooden box, inspite of the fact that it lacked sufficient protection against cooling. By thorough and quick mixing of the beans every two days, considerable improvement in the quality of fermented beans could be obtained irrespective of the method employed. Laycock (1936) reported that the heap method of fermentation was superior to the pit method. It yielded a higher percentage of chocolate coloured beans against purple beans. For the production of superior first grade cocoa, two turnings in the heap were adequate. Rohan (1958) tried heap, sweat box and tray methods. From the observations made on the physico-chemical changes at different stages in the cocoa mass, he reported that when heap fermentation was used, the temperature on the surface four-inch layer rose more rapidly than in the centre, causing rapid killing of the beans. The chocolate flavour developed quickly and it was possible to obtain an acceptable product at the surface of the heap after 30 hours of fermentation. In the centre of the heap, changes occurred slowly; but once the beans died, development of chocolate flavour was rapid. There was necessity to mix the beans after the first 24 hours. In sweat boxes upto one tonne capacity, changes were slower than in the heap method owing to the lack of aeration. But by frequent mixing, this difficulty could be overcome. Plummer (1968) conducted small-scale trials using boxes and trays. He found that a product of good flavour and better uniformity could be obtained with the trays, compared to the box method. Among the different stacks of trays used, the results obtained using three to eight trays were similar to the stacks having twelve trays. On the second day, uniform temperature of 47^{o}C was recorded in all the trays. A four-day fermentation gave the best results. Kumaran et al. (1980) fermented cocoa beans using wooden mini-box, bamboo mini-basket and wooden mini-tray charged with two quantities of beans (1.5 kg and 3.0 kg each). In the case of mini-tray method, the beans were fermented for four days and in the other methods, six days. They found that for the proper fermentation of small quantities, turning the beans once in alternate days was necessary. The variation in temperature followed the same trend in all the methods, as in the conventional methods using large quantity of beans. However, among the various containers tried, wooden container was found to be better than the basket, because of better temperature retention and aeration. The quality of the beans, as judged by the cut test and pH of cured beans was satisfactory in the wooden mini-box and bamboo mini-basket methods.

CHANGES DURING FERMENTATION

Temperature

The temperature variations occurring during fermentation have been studied by many workers. Phillis (1946) reported that the initial temperature during fermentation rose to 37°C-38°C and remained at that level for four to five days. Phillis regarded this as the anaerobic stage. During the second stage, which was considered as the aerobic stage, the temperature rose to 52°C-54°C. It was considered that at this stage, changes associated with fermentation occurred. But when fermentation was done after storage of the pods for two weeks, the first stage was not perceptible and the temperature rose rapidly to 50°C, followed by corresponding physical changes. Hardy (1960) and Wood (1975) reported that in large scale fermentation of beans, temperature rose steadily to 40°C-44°C during the first two days. After the first mixing, temperature rose rapidly to 48°C-50°C. Thereafter, temperature fell slowly and rose again after each turning of the beans. After six days of fermentation, temperature of the mass was 45°C-48°C. They also found that over-fermentation increased the temperature to 50°C-52°C. With small quantities of cocoa beans, comparatively lower peak temperature was observed than with larger quantities. Quesnel and Lopez (1975), while fermenting small quantities of cocoa beans (10-18 kg) in "styrotex sweat boxes", observed slightly lower peak temperature in the mass compared to the mass fermented in the common sweat boxes. The maximum temperature was recorded by them on the sixth day and the temperature dropped a little on the seventh day. Adomako et al. (1981) studied the trend of variation in temperature of beans in the heap and tray methods of fermentation under Ghana conditions. They found higher peak temperature in the heaps compared to the trays. They also observed regular temperature fluctuations in the heaps compared to the tray method.

Powel (1960) and Quesnel (1968) reported that the generation of heat was due to fermentation and oxidation processes in the pulp. Only negligible contribution to the temperature variation was imparted by the bean enzyme.

Working further on the subject, Quesnel (1972) contended that fermentation and oxidation processes in the pulp caused production of acetic acid which was responsible for the liberation of heat necessary to bring the beans to the optimum temperature for effective fermentation.

Effect of temperature on colour development

Jacquemin (1957) found that in small scale-fermentation of cocoa, slaty and purple beans developed when temperature development in the mass was poor. This was not connected with the stage of maturity of the pods. Slaty and purple beans were still present after six days, when the temperature developed was below 45^{o}C. Between 45^{o}C and 50^{o}C, purple beans decreased with the elimination of slaty beans. Maintenance of temperature between 30^{o}C and 40^{o}C during the first three days and at 50^{o}C during the remaining five days of fermentation helped the production of high quality cocoa.

pH and acidity fluctuations during fermentation

Weisberger et al. (1971) and Lopez and Quesnel (1973) observed the presence of a range of both volatile and non-volatile organic acids during fermentation. These were found to contribute to the characteristic flavour to the end product. Any imbalance in the concentration of the various acids resulted in acidic, insipid and fruity tastes of the beans.

The predominant acid formed was acetic acid, which got volatalised and lost in substantial degrees through evaporation during drying. According to Couprie (1970) and Witt (1973), small amounts of acetic acid were lost during storage, leading to a reduction in the pH. Wood (1975) reported the pH of fresh pulp as 3.5 and that of the cotyledon as 6.6. He also observed production of acetic acid during fermentation. He postulated that because of the permeability of the testa, acetic acid passed into the cotyledons, killed the bean and lowered the pH to 4.8, by the third day. He could find a gradual pH increase during the remaining period of fermentation and drying. In the dried beans, a pH of 5.5 could be observed.

Said and Idrus (1976) reported that the existence of more of copper and polyphenols in the cotyledons increased the residual acidity in the beans. They opined that Malaysian cocoa beans are acidic due to the presence of more copper and polyphenols. According to Lieu (1979), Malaysian wet beans possessed more pulp and sugar and these were assumed to be the major reasons for the acidity of Malaysian beans. Greater aeration at the end of fermentation reduced the acidity considerably. Turning the beans three times a day during the last three days of fermentation promoted aeration leading to a reduction of acidity considerably.

Eden (1953) gave testimony to the views that under artificial drying the heat damage caused to the testa rendered than impermeable to acid thereby resulting in high acidity of the cotyledons. Howat et al. (1957) investigated the effect of drying process on the acidity of the cotyledons. After a sequence of tests on a through-flow tray or cabinet drier at 80°C, they showed that the average post-fermentation pH of 4.8 did not change during artificial drying as against sun drying when the samples showed a higher pH of 5.2. However, no investigation on the nature of the acids responsible for this increase was done. It was presumed that the pH variation have been due to the presence of volatile acids; but the characteristic fruity off-flavours due to the presence of volatile acids were detected only in the chocolate made out of artificially dried beans. Quesnel (1972) reported that high acid levels persisted in artificially dried cocoa. He hypothesised that the rapid high temperature during the drying did not lend sufficient time for the volatilisation of the acetic acid, thus leading to higher acidity.

FACTORS INFLUENCING FERMENTATION

Seasonal factors

Seasons have been found to exercise a great influence on the time taken for fermentation. Under Trinidad conditions fermentation took six days during the wet season and eight days during the dry season (Anon., 1957). Allison and Kenten (1963) found that the temperature rose slowly during June and July, the months of heaviest rainfall, thereby taking longer time for fermentation in the rainy months compared to that in the dry season. They reported that the ratio of cured cocoa to wet weight and the fermentation temperatures were significantly lower in the mid-crop (June-July) than in the main crop (October-November). Egbe and Owolabi (1972) found lowest bean weight, lowest butter fat and highest shell percentage for the light crop (February-May) and highest bean weight, highest butter fat and lowest shell percentage for the main crop (October-January).

Maturity of pods

Knapp (1926) found that beans of green pods with firm pulp did not ferment, the temperature having remained at 35°C after an initial rise to 40°C. Further, the loss during fermentation and drying was much higher than when ripe pods were cured. With the green pods, yield of cured beans was not more than 21 per cent of the wet weight. Further, the bean size was 1.05 g as against 1.34 g obtained when ripe pods were used. MacLean and Wickens (1951) categorised cocoa pods into over-ripe, ripe and under-ripe pods according to the colour of the pods before breaking. Beans extracted from pods of different maturity were fermented in baskets for six days with fortyeight-hour turning. Their observations on the temperature changes indicated that beans from the ripe and under-ripe pods attained higher maximum temperature, although they took two days longer to reach the maximum than the beans from overripe pods. The ratio of dry to wet weight was lower and the proportion of purple beans was higher than normal, in the case of unripe pods.

Ruinard (1961) reported that fermentation of beans from unripe pods resulted in cured beans of lesser weight and greater shell percentage. The beans were found to be disfigured with pulp residues. Further, longer fermentation time was necessary than when beans from ripe pods were used.

<u>Pre-fermentation storage of pods</u>

MacLean and Wickens (1951) stored the cocoa pods harvested during four consecutive days until the fifth day and fermented the beans in the baskets for six days with forty-eight-hour turning. Their data indicated that by storing the harvested pods for two days or more, significant temperature increase (of 2°C) could be obtained during the first 48 hours of fermentation. Compared to the beans from pods stored for only one day, the beans from pods stored for four days showed a significantly lower temperature, after 96 hours of fermentation. Increased length of storage of unbroken pods not only did not affect the percentage recovery or the bean size, but also caused a significant reduction in the percentage of both purple and wrinkled beans.

DRYING

According to Knapp (1937), complex biochemical changes occur during drying of the beans, which decide the quality of the end product. The factors considered indicative of good drying were (i) good storage properties, (ii) crisp and plump bean with shell neither broken nor fragile, (iii) well oxidised interior with adequate brown colour and low bitterness, and (iv) good flavour without excessive acidity or smoky flavour. He also found that drying the beans to a moisture level of less than eight per cent was necessary to prevent mouldiness of the beans during storage.

Sun drying

Sun drying is popularly adopted by the cocoa growers. Knapp (1937) and Palma (1951) have reported that concrete platforms were used for drying cocoa beans in northern South America, parts of the Far East and Nigeria. Rohan (1963) reported on the use of platforms made out of bamboo mats for drying cocoa in West Africa.

The common problem confronted with the above methods was the difficulty in providing protection to the beans during rainy periods. Van Hall (1932) used the method of heaping the beans during rains and covering them with canvas. Rohan (1963) found it advantageous to cover the cocoa beans on bamboo mats using palm fronds during light showers and to roll up of the drying mats and storing them indoors during heavier rains. Wood (1975) preferred placing of corrugated iron sheets or PVC sheets over the beans during rains.

Thickness of the cocoa bean layer has been known to influence the duration of drying as well as the quality of the end product. Hudson (1913) advocated spreading of cocoa beans to a thickness of not more than 5.0 cm for drying. Wood (1975) and Sorbal (1981) stipulated that a quantity of 18 kg of dried beans per square metre area of drying yard facilitated completion of drying process within seven days.

According to Ghosh and Cunha (1975) drying under rainy conditions took about 22 days.

Artificial drying

Artificial drying, though involves higher expenditure, may become necessary during the rainy season when sun drying is difficult. The economics and efficiency of artificial drying depend on the depth of the beans, the rate of air flow and the air temperature. Through a series of small scale experiments, Shelton (1967) indicated that a 25 cm layer allowing an air flow of three metres per minute at a moderate temperature of 65°C was the most economic conditions for drying.

Salz (1972) observed that high air flows of 50-60 ft/minute (1.5 m-1.8 m/minute) at a low temperature during the pre-drying stage and low air flows of 30-35 ft/minute (0.9 m-1.05 m) at high temperature during the final stages of curing gave the best results. A "Samoan drier" developed by Cadbury Brothers (Anon., 1963) was found to be a low investment installation useful for the smaller farmer. Nair (1980) developed an electric cocoa drier. It was a wooden box size 90 x 60 x 60 cm with three trays placed one over the other. A temperature range of 47°C-51°C could be maintained using four bulbs of 100 Watt each. Drying could be completed within 24-72 hours. The capacity of the drier was approximately 10-25 kg wet beans.

EFFECT OF STORAGE OF CURED BEANS ON BEAN pH AND PERCENTAGE OF BROWN, PALE PURPLE, PURPLE AND SLATY BEANS

Couprie (1970) conducted trials to find out the effect of storage of cured beans on their acidity and other characteristics. He reported that aroma of the cured beans developed during the first three months of storage and acidity during the following three months.

MacLean and Wickens (1951) studied the rate of change of the purple bean count during storage of Amelonado and a 50:50 mixture of Amelonado and Upper Amazon cocoa. They observed that purple bean percentage fell from 80 to 20 during a period of 36 weeks of storage.

Materials and Methods

MATERIALS AND METHODS

The investigations reported in this thesis were carried out during 1979-'81 in the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara. The following aspects were studied:

The efficacy of different methods of fermentation of small quantities of cocoa beans,

The comparative efficiency of the fermentation methods during dry and wet seasons,

The maturity of pods in relation to fermentation of cocoa beans,

The effect of storing harvested pods on fermentation characteristics, and

Quality attributes of beans in relation to storage.

THE EFFICACY OF DIFFERENT METHODS OF FERMENTATION OF SMALL QUANTITIES OF COCOA BEANS

Mini basket lined with banana leaves

Small bamboo baskets of size 20 cm diameter and 15 cm, 30 cm and 45 cm height to contain two kg, four kg and six kg wet beans, respectively were made. The bamboo baskets were closely woven ones with sufficient strength. Lining with two layers of banana leaves was given. In all the three sets cocoa pods of uniform maturity were used, three days after harvest. The pods were broken and the wet weight of beans with the mucilage was recorded. After filling the beans into the baskets, the surface of the beans was levelled with palm and covered with a layer of banana leaves. A small brick was placed on the top of it and the mass was set for fermentation for six, seven and eight days. The baskets were placed on the ground over bricks for 24 hours to permit drainage of the sweatings. On the second day, the baskets were covered with a single layer of gunny which was weighted down by placing bricks. Mixing and resetting were done after 48 and 96 hours of initial loading. The end point of fermentation was judged by cutting the beans crosswise through the middle portion and observing the reddish brown coloured exudate, pale-centered cotyledon with a brownish ring around the outside, plumpy nature of the beans and loosened testa over the cotyledons. The beans were finally taken out for drying on the seventh, eighth and nineth days. In the dry season, the beans were dried in the sun by spreading them over bamboo mats at a thickness of five cm and stirring frequently to ensure uniformity in drying. At night, the beans were kept in the mat itself in folded condition to protect them from dew, dust and other foreign particles. Drying was done for five to six days. Completion of drying was judged by the characteristic crackling noise of the dried bean when pressed in the palm. In the wet season, the cured beans were dried in a cocoa drier developed by the Kerala Agricultural University. It was of size 90 cm x 60 cm x 60 cm with three trays placed one over the other. A temperature range of 47°C to 51°C could be maintained using four 100 W bulbs. Drying was completed in two days. After cleaning off the split and flat beans, the good ones were filled in double polythene bags (150 gauge), labelled and the bags stored at room temperature and humidity.

<u>Mini basket lined with polythene sheet</u>

The baskets mentioned as above holding two kg, four kg and six kg wet beans were used. The baskets were lined with one layer of 150 gauge polythene sheet. Charging of the wet beans, methodology of fermentation, judgement of the end point of fermentation, drying and storage were done as mentioned in the previous method.

<u>Mini box</u>

Wooden boxes of size 25 x 15 x 12 cm, 32 x 20 x 12 cm and 41 x 25 x 12 cm were used to hold two kg, four kg and six kg wet beans, respectively. The boxes were made with hard wood planks of 1.5 cm thickness. Holes of about five mm were provided at all the sides of the box to facilitate aeration and drainage. The top of the boxes were kept open. Charging of the wet beans, methodology of fermentation, judgement of the endpoint of fermentation, drying and storage were done as mentioned in the above methods.

Small heap using banana leaves

A layer of bamboo splits were placed on the ground in a radial manner. On the bamboo layer, two layers of banana leaves were spread. Samples of two kg, four kg and six kg wet beans were heaped on the banana leaves. The heaps were covered with projected portions of the banana leaves and a small brick piece was placed on the top of the banana leaves to keep them in position. Methodology of fermentation, judgement of the endpoint of fermentation, drying and storage were done as mentioned in the previous methods.

Small heap with polythene sheet

A layer of bamboo splints were placed on the ground in a radial manner. On this, one layer of 150 gauge polythene sheet having 5 mm holes at a spacing of 10 cm were spread and the wet cocoa beans cured as in the case of small heap with banana leaves.

Tray (Single trays and stacks of trays)

Wooden trays of size 25 x 15 x 12 cm; 32 x 20 x 12 cm and 41 x 25 x 12 cm were made to hold two kg, four kg and six kg wet beans, respectively. Wooden reepers of 1.5 cm width were fixed to the bottom of the trays at a spacing of 0.5 cm. The beans were set for fermentation for four, five and six days. The trays were assessed singly and after stacking five trays one over the other. The beans were not mixed after the initial charging. The beans were taken out for drying on the fifth, sixth and seventh day of initial loading. Drying and storage were done as in other methods. The methods were tried twice.

Out of the seven methods of fermentation, mini basket lined with banana leaves and mini box (with six kg beans, six days fermentation) were selected for further studies based on the temperature development and on the results of the cut test. In the case of tray method, the stack of five trays (each tray holding two kg beans, four days fermentation) was selected for further studies.

THE COMPARATIVE EFFICIENCY OF THE FERMENTATION METHODS DURING DRY AND WET SEASONS

Three methods, namely, mini basket lined with banana leaves, mini box and set of five small trays were tried during the dry and wet seasons using six kg of beans. The beans were subjected to turning on alternate days. Observations on temperature development, pH changes of the pulp and the cotyledons, pH of the dried bean, cut test, average bean weight, shell percentage and percentage recovery of the cured and dried beans were recorded for the different treatments.

MATURITY OF PODS IN RELATION TO FERMENTATION OF COCOA BEANS

Pods were harvested at different stages of maturity and classified as green (unripe with firm pulp), furrow yellow (with furrows turned yellow and the rest of the pods green), yellow/ripe (completely yellow pods) and over-ripe (completely yellow with disintegrated pulp).

Six kg samples of wet beans from pods of different maturity were fermented in baskets lined with two layers of banana leaves for a period of six days, subjecting the beans to turning on alternate days. The experiment was repeated five times and observations on the temperature development, pH changes of the pulp and cotyledons, pH of the dried beans, cut test, average bean weight, shell percentage and percentage recovery of the cured beans were recorded.

EFFECT OF STORING HARVESTED PODS ON FERMENTATION CHARACTERISTICS

Uniformly yellow pods were harvested on a single day and stored in gunny bags for a period of seven days. Out of the lot, pods were taken for fermentation at different stages, namely, on the day of harvest, two days after harvest, four days after harvest and six days after harvest. The beans were fermented in mini basket lined with banana leaves, the duration of fermentation being six days. The beans were turned on alternate days. Observations on the temperature development, pH, changes of the pulp and cotyledons, cut test, average bean weight, shell percentage and percentage recovery were recorded in this experiment also for the different treatments.

QUALITY ATTRIBUTES OF BEANS FERMENTED BY THE DIFFERENT METHODS IN RELATION TO STORAGE

In order to gather information on the changes in the quality attributes of cured beans during storage, six to ten kg beans were sealed in double polythene bags and stored for a period of ten months. Bean samples were drawn every month for observations on the percentage of brown, brown+pale purple and purple beans as well as on the pH of the cotyledons.

OBSERVATIONS RECORDED

Temperature

The temperatures were recorded at two levels, namely, top and bottom, twice daily at 9 am and 5 pm for the different methods of fermentation tried. In the case of tray method, temperatures were recorded at the middle portion of the top, middle and bottom trays.

pH

The pH of the pulp and the cotyledons were recorded adopting the method recommended by the Cocoa Research Institute, Ghana (Anon., 1978).

For determination of the pH of the pulp and the cotyledons, bean samples were drawn everyday from the middle portion of the basket and the box. In the case of tray method, samples were taken from the centre of the top and middle trays. Samples were left out from the bottom trays since the temperature development will be low in the bottom trays and satisfactory fermentation will not take place in them (Rohan, 1958).

A sample of 10 beans was made and the pulp portion removed by a scalpel. The pulp was then transferred into a 100 ml beaker and 90 ml of boiling water poured into it with stirring. The mass was then cooled to 20.0°C to 25.0°C and the pH was determined with the help of a pH meter.

For estimating the pH of the cotyledons, the cotyledons from 10 beans were taken and finely ground using mortar and pestle. From the ground mass, 10 g samples were taken for determining the pH, as described for the pulp.

Cut test

Properly dried beans were subjected to the cut test for determining the efficiency of fermentation.

Samples of beans were taken, thoroughly mixed and quartered to give a heap of more than 100 beans. One hundred beans were then taken at random for the cut test. Each bean was cut lengthwise through the middle with a sharp scalpel and one half of the cotyledon was examined for its colour in good day light. The beans were classified into brown, pale purple, purple, slaty and over-fermented beans. The percentage of the beans in each category was then worked out.

Average bean weight

Weight of 100 beans was recorded and averaged.

Shell percentage

From a sample, 100 beans were counted, irrespective of their size and shape. After recording the weight, the beans were shelled and the weight of the shell recorded. From these data, the shell percentage was calculated.

Percentage recovery of cured beans

Based on the weight of beans before fermentation and the weight of cured (fermented and dried) beans, the percentage recovery was worked out.

Statistical analysis

All the data collected were analysed statistically as per the methods suggested by Panse and Sukhatme (1978).

Results

RESULTS

EFFICACY OF DIFFERENT METHODS OF FERMENTATION

The efficacy of seven methods of fermentation was assessed based on the development of temperature during fermentation and on the cut test. The results are presented below:

Temperature development

Mini basket lined with banana leaves

Temperature development in the top 1/3 portion and bottom 1/3 portion have been recorded at the time of initial loading and thereafter at 9 am and 5 pm each day. The data are presented in Table 1 and Fig.1. By the second day (40 hrs), the temperature in the top 1/3 portion rose from the initial 27.0°C-27.5°C to 37.0°C, 34.0°C and 32.5°C in the six-four-and two-kg bean lo ts, respectively. On the fourth day (88 hrs), peak temperatures of 48.5°C and 45.0°C were attained, which dropped to 39.0°C, 37.5°C and 37.0°C by the fifth day (112 hrs). Temperature again rose on the sixth day (136 hrs) to 45.5°C, 44.5°C and 44.0°C. From the sixth day onwards, there was a steady drop, the temperature ultimately reaching 37.0°C, 35.5°C and 33.0°C, respectively on the nineth day (192 hrs) in the three lots.

Table 1.- Temperature development (^{o}C) in the bean mass fermented using the mini-baskets lined with banana leaves.

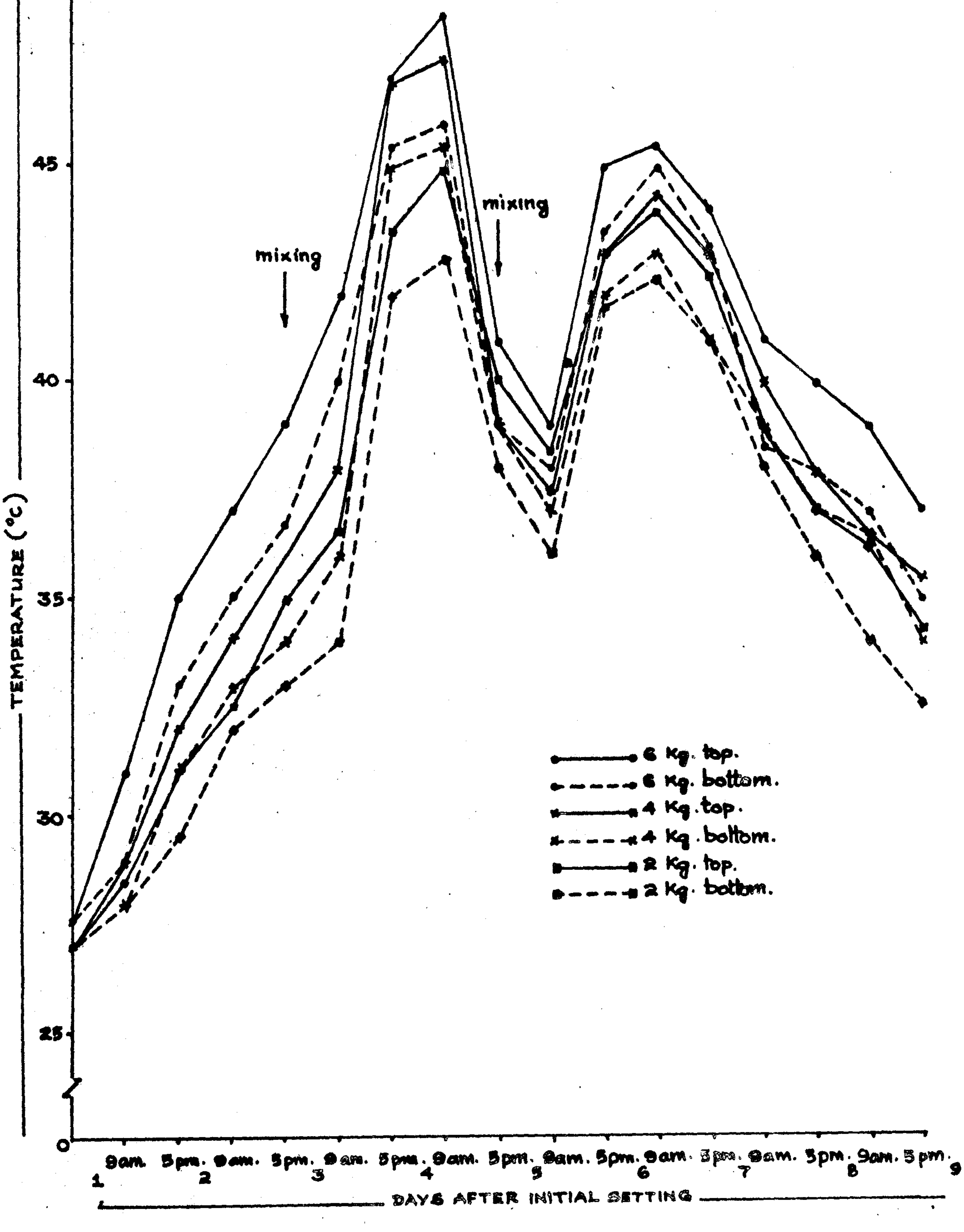
Temperature recorded at	Days after setting@								
	1	2	3	4	5	6	7	8	9
	6 kg lots								
Top 1/3	27.5*	35.0	39.0	47.0	41.0	45.0	44.0	40.0	37.0
	31.0**	37.0	42.0	48.5	39.0	45.5	41.0	39.0	-
Bottom 1/3	27.5	33.0	36.5	45.5	39.0	43.5	43.0	38.0	35.0
	29.0	35.0	40.0	46.0	38.0	45.0	38.5	37.0	
	4 kg lots								
Top 1/3	27.0	32.0	36.0	47.0	39.0	43.0	43.0	38.0	35.5
	29.0	34.0	38.0	47.5	37.5	44.5	40.0	37.5	-
Bottom 1/3	27.0	31.0	34.0	45.0	39.0	42.0	41.0	37.0	34.0
	28.0	33.0	36.0	45.0	37.0	43.0	39.0	36.5	-
	2 kg lots								
Top 1/3	27.0	31.0	35.0	43.5	40.0	43.0	42.5	37.0	33.0
	28.5	32.5	36.5	45.0	37.0	44.0	39.0	35.0	-
Bottom 1/3	27.0	29.5	33.0	42.0	38.0	42.0	41.0	36.0	32.5
	28.0	32.0	34.0	43.0	36.0	42.5	38.0	34.0	-

@ The beans were mixed at 9 am in the third and fifth days

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

Fig. 1 - VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING MINI BASKET LINED WITH BANANA LEAVES



The bottom 1/3 portion also recorded similar trends.

Mini basket lined with polythene sheet

Under this method, the temperature in the top 1/3 portion rose from the initial 27.0°C-27.5°C to 33.5°C, 32.0°C and 30.0°C by the second day (40 hrs) in the six-four-and two-kg bean lots. On the fourth day (88 hrs), the temperature rose to 43.5°C, 43.0°C and 40.0°C. The temperature dropped to 39.0°C, 37.0°C and 36.0°C by the fifth day (112 hrs) and again rose to 47.5°C, 44.0°C and 42.0°C by the sixth day (136 hrs). From the sixth day onwards, steady drop could be observed, the temperature reaching 38.0°C, 35.5°C and 33.5°C, respectively in the three lots by the nineth day morning (192 hrs).

The bottom 1/3 portion also showed the same trend in the temperature development (Table 2 and Fig.2).

Mini box

In mini box, the temperatures attained were 36.0°C, 36.5°C and 35.5°C on the second day (40 hrs) in the six-four- and two-kg bean lots, respectively. On the fourth day (88 hrs), the temperature rose to 47.5°C, 48.0°C and 47.0°C. The temperature dropped to 39.0°C, 38.0°C and 37.5°C on the fifth day (112 hrs). Temperature of the fermenting bean mass which was 45.5°C, 44.5°C and 43.5°C on the sixth day (136 hrs), dropped to 37.5°C, 36.0°C and 35.0°C by the nineth day (192 hrs).

Table 2.- Temperature development (°C) in the bean mass fermented using the mini-baskets lined with polythene sheet

Temperature recorded at	Days after setting@								
	1	2	3	4	5	6	7	8	9
	6 kg lots								
Top 1/3	27.5*	32.0	36.0	43.0	39.0	46.5	46.0	43.0	38.0
	28.0**	33.5	41.0	43.5	42.0	47.5	44.5	41.0	
Bottom 1/3	27.5	31.0	34.0	41.0	38.0	44.0	45.0	41.0	36.0
	28.0	31.5	39.0	42.5	40.5	46.0	43.0	40.0	
	4 kg lots								
Top 1/3	27.5	31.0	36.5	42.0	37.0	43.5	43.0	41.5	35.5
	28.0	32.0	39.0	43.0	41.0	44.0	42.5	37.0	
Bottom 1/3	27.5	30.5	33.5	40.0	36.0	42.0	42.0	39.0	33.0
	28.0	31.0	36.0	41.0	40.0	43.0	41.0	37.0	
	2 kg lots								
Top. 1/3	27.0	29.0	33.0	38.5	36.0	41.0	42.5	37.5	33.5
	27.5	30.0	35.0	40.0	37.5	42.0	40.0	36.0	
Bottom 1/3	27.0	28.0	32.0	37.0	35.0	40.0	41.5	36.0	33.0
	27.5	39.0	33.0	37.5	36.0	41.0	39.0	34.0	

@ Beans were mixed at 9 am on the third and fifth days

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

Fig. 2 - VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING MINI BASKET LINED WITH POLYTHENE SHEET.

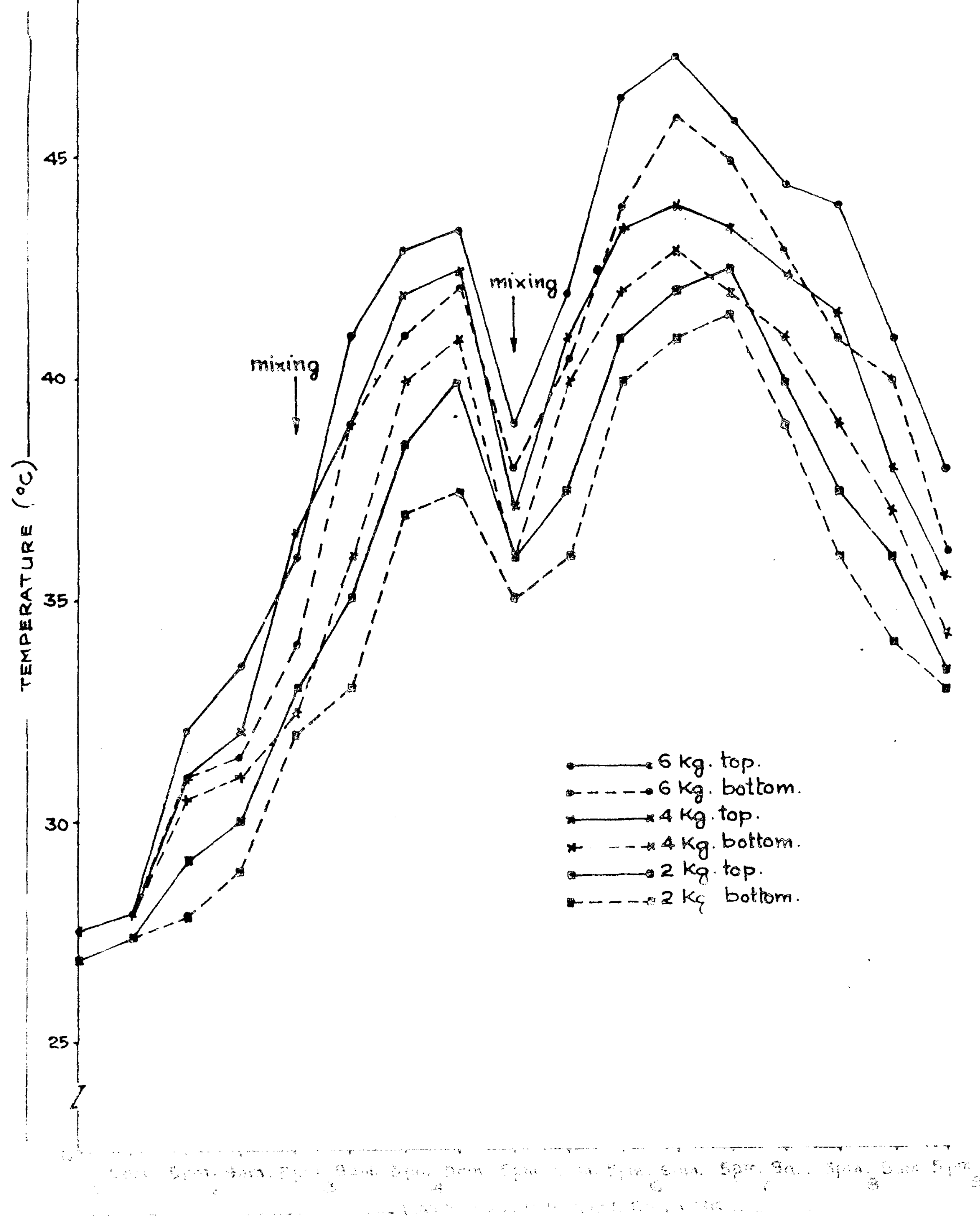


Table 3.- Temperature development (°C) in the bean mass fermented using the mini-boxes

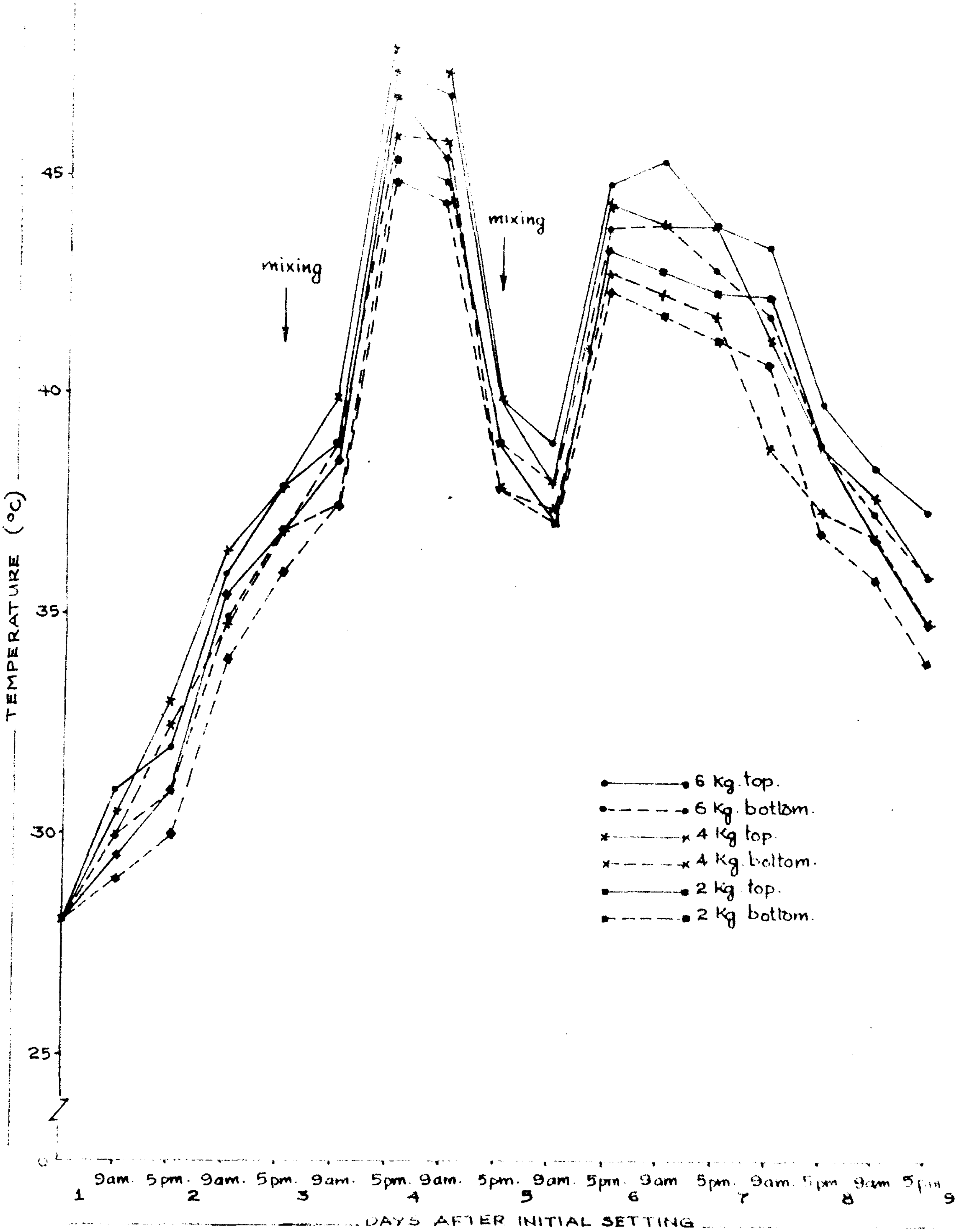
Temperature recorded at	Days after setting[@]								
	1	2	3	4	5	6	7	8	9
	<u>6 kg lots</u>								
Top 1/3	28.0*	32.0	38.0	47.5	40.0	45.0	44.0	40.0	37.5
	31,0**	36.0	39.0	47.0	39.0	45.5	43.5	38.5	
Bottom 1/3	28.0	31.0	37.0	45.5	39.0	44.0	43.0	39.0	36.0
	30.0	35.0	37.5	45.0	38.0	44.0	42.0	37.5	
	<u>4 kg lots</u>								
Top 1/3	28.0	33.0	38.0	48.0	40.0	44.0	44.0	39.0	36.0
	30.5	36.5	40.0	47.5	38.0	44.5	41.5	38.0	
Bottom 1/3	28.0	32.5	37.0	46.0	38.0	43.0	42.0	37.5	35.0
	30.0	35.0	39.0	46.0	37.5	42.5	39.0	37.0	
	<u>2 kg lots</u>								
Top 1/3	28.0	31.0	37.0	47.0	39.0	43.0	42.5	39.0	35.0
	29.5	35.5	38.5	45.5	37.5	43.5	42.5	37.0	
Bottom 1/3	28.0	30.0	36.0	45.0	38.0	42.5	41.5	38.0	34.0
	29.0	34.0	37.5	44.5	39.0	42.0	41.0	36.0	

@ Beans were mixed at 9 am on the third and fifth days

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

Fig 3- VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING MINI BOX



The data revealed that the bottom 1/3 portion of the fermenting bean mass also showed the same trend in the temperature development (Table 3 and Fig.3).

Small heap with banana leaves

In this method, temperature in the top 1/3 portion of the heap rose from the initial 27.0°C-28.0°C to 31.0°C, 31.0°C and 30.0°C by the second day (40 hrs) in the six-four and two-kg lots. On the fourth day (88 hrs), temperature rose to 41.0°C, 37.0°C and 35.5°C. A drop to 37.0°C, 35.0°C and 34.0°C was observed on the fifth day (112 hrs). Temperature again rose to 38.0°C in the six-kg bean lot. In the four-and two-kg bean lots temperatures of 35.0°C and 32.5°C was recorded on the sixth day (136 hrs). From the sixth day onwards, a steady drop was observed, the temperature ultimately reaching 30.0°C, 28.5°C and 28.0°C on the nineth day (192 hrs).

The bottom 1/3 portion also revealed similar trends (Table 4 and Fig.4).

Small heap with polythene sheet

In small heap with polythene sheet, temperature rose from the initial 27.0°C to 30.0°C, 30.5°C and 29.0°C by the second day (40 hrs) with six-four-and two-kg heaps. The temperature rose to 40.0°C, 39.0°C and 36.5°C on the fourth

Table 4.- Temperature development (°C) in the bean mass fermented in the small heaps with banana leaves

Temperature recorded at	Days after setting@								
	1	2	3	4	5	6	7	8	9
	6 kg lots								
Top 1/3	27.0*	30.0	31.5	39.0	38.0	36.0	36.0	33.5	30.0
	29.0**	31.0	35.0	41.0	37.0	36.5	35.0	32.5	
Bottom 1/3	27.0	29.0	31.0	37.0	36.0	36.5	35.0	33.0	29.5
	28.0	30.0	33.0	39.0	35.0	36.0	34.0	32.0	
	4 kg lots								
Top 1/3	27.0	30.0	32.0	36.0	36.0	35.0	33.0	31.0	28.5
	28.5	31.0	33.0	37.0	35.0	34.0	32.0	30.0	
Bottom 1/3	27.0	28.5	30.0	35.5	35.0	33.5	32.5	30.5	28.0
	28.0	29.0	32.0	35.0	34.0	32.5	31.5	29.0	
	2 kg lots								
Top 1/3	27.0	28.0	31.0	35.0	35.0	32.5	32.0	29.5	28.0
	27.0	30.0	35.0	35.5	34.0	32.5	31.5	29.0	

@ Beans were mixed at 9 am on the third and fifth days

* Temperature recorded at 9 am

** Temperature recorded at 5 pm.

Fig. 4 VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING SMALL HEAP WITH BANANA LEAVES

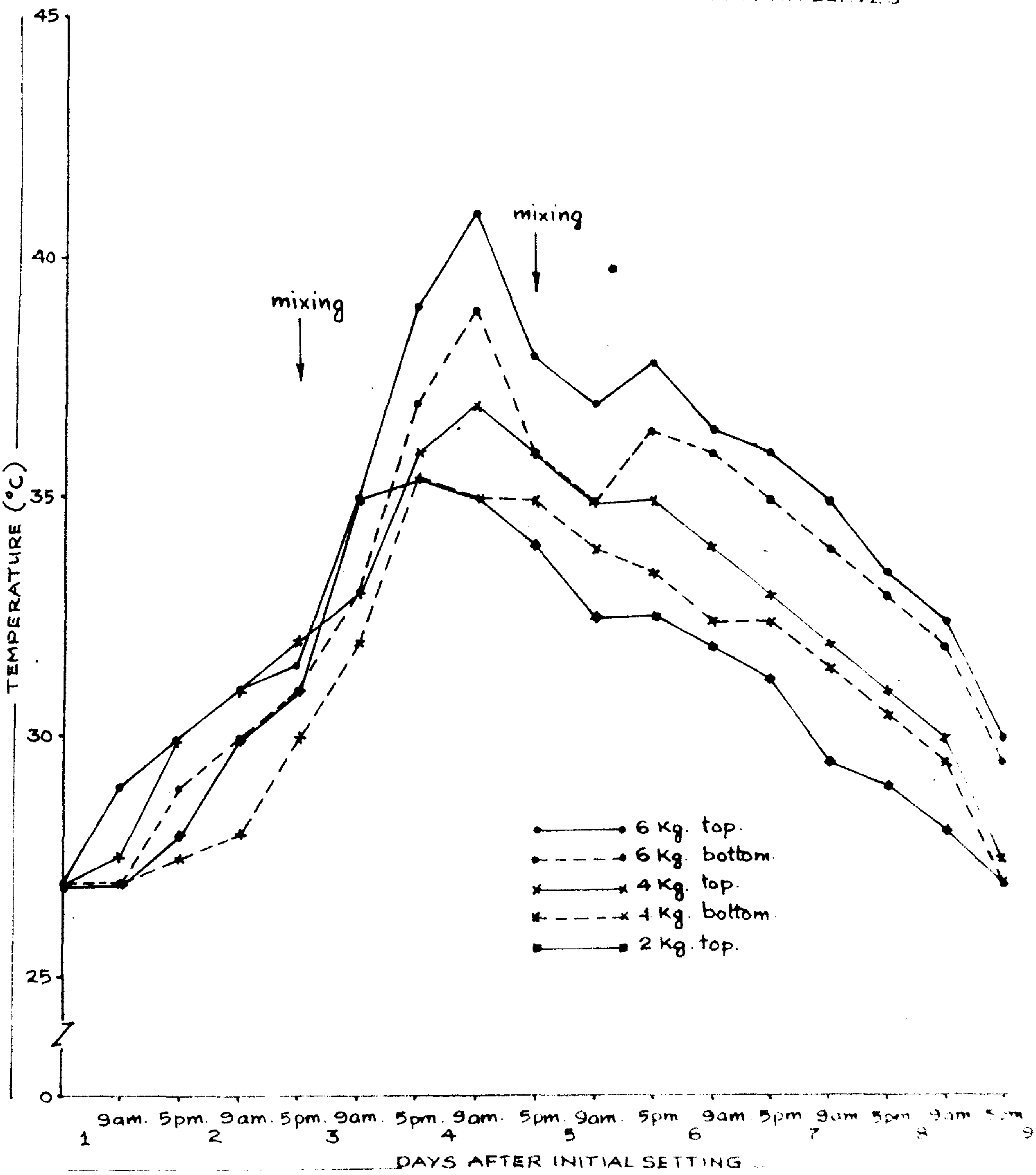


Table 5.- Temperature development (^{o}C) in the bean mass fermented in the small heaps with polythene sheet

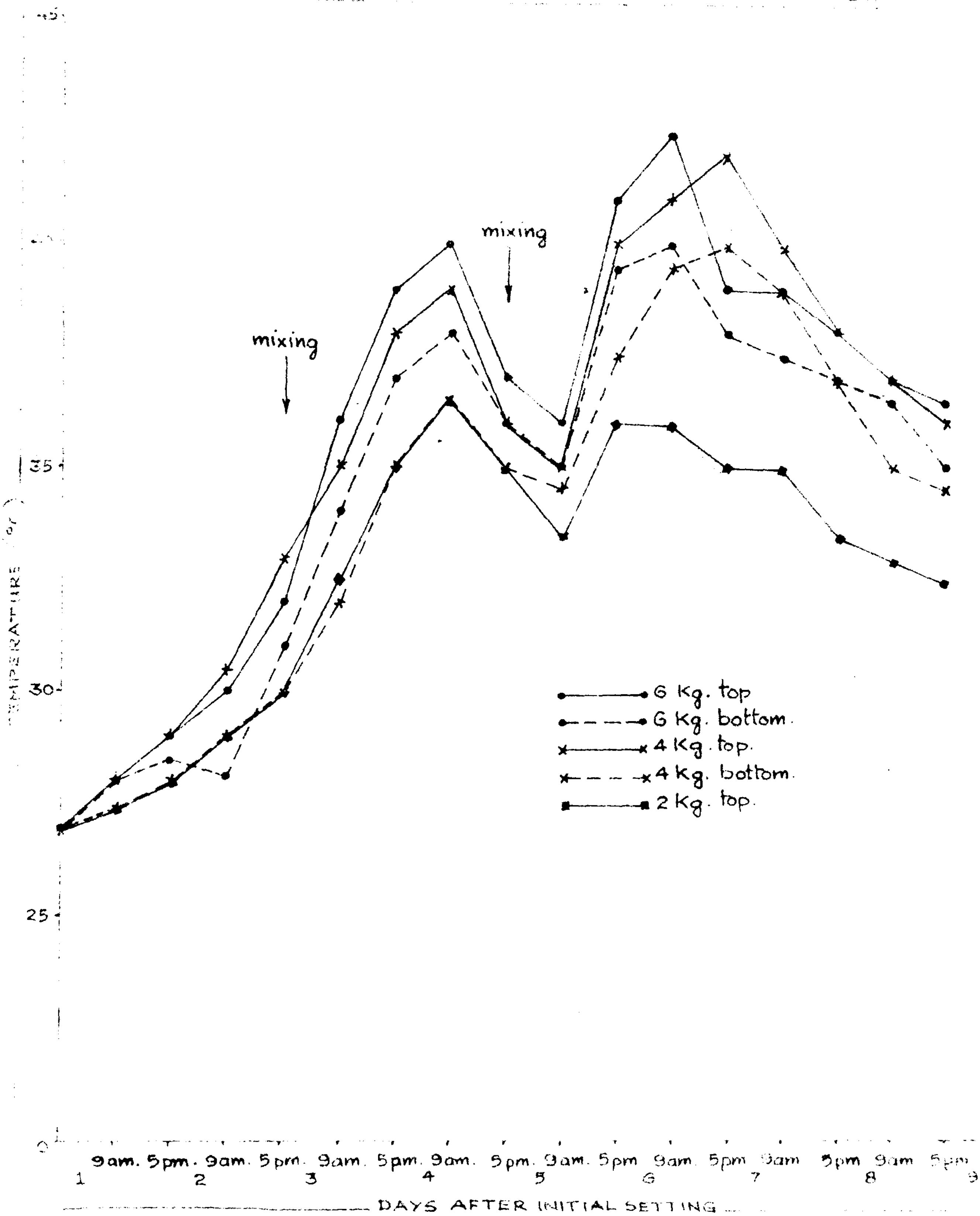
Temperature recorded at	Days after setting@								
	1	2	3	4	5	6	7	8	9
	<u>6 kg lots</u>								
Top 1/3	27.0*	29.0	32.0	39.0	37.0	41.0	39.0	38.0	36.5
	28.0**	30.0	36.0	40.0	36.0	42.5	39.0	37.0	
Bottom 1/3	27.0	28.5	31.0	37.0	36.0	39.5	38.0	37.0	35.0
	28.0	28.0	34.0	38.0	35.0	40.0	37.5	36.5	
	<u>4 kg lots</u>								
Top 1/3	27.0	28.5	33.0	38.0	36.0	40.0	42.0	38.0	36.0
	28.0	30.5	35.0	39.0	35.0	41.0	40.0	37.0	
Bottom 1/3	27.0	28.0	32.0	36.0	35.0	38.5	40.0	37.0	34.5
	27.5	28.5	33.0	37.0	34.5	29.5	39.0	35.0	
	<u>2 kg lots</u>								
Top 1/3	27.0	28.0	30.0	35.0	35.0	36.0	35.0	33.5	32.5
	27.5	29.0	32.5	36.5	33.5	36.0	35.0	33.0	

@ Beans were mixed at 9 am on the third and fifth days

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

FIG. [illegible] VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING SMALL HEAP WITH POLYTHENE SHEET



day (88 hrs) and dropped to 36.0°C, 35.0°C and 33.5°C by the fifth day (112 hrs). On the sixth day (136 hrs), temperature again rose to a peak of 42.5°C, 41.0°C, and 36.0°C. On the seventh day morning (144 hrs) with the four-kg bean lot, temperature rose to 42.0°C whereas with the six- and two-kg bean lots, temperature dropped to 39.0°C and 35.0°C. From the seventh day onwards, temperature dropped, ultimately reaching 36.5°C, 36.0°C and 32.5°C by the nineth day morning (192 hrs), with the three bean lots.

The bottom 1/3 portion of the heap revealed same trend in the temperature development (Table 5 and Fig.5).

Single tray

In the single tray method, temperature in the top 1/3 portion rose from the initial 27.0°C to 36.0°C, 36.0°C and 37.0°C by the second day (40 hrs) with the six-, four- and two-kg bean lots, respectively. The temperature rose to 43.5°C, 44.5°C and 45.0°C by the fourth day (88 hrs) and dropped to 43.0°C, 42,0°C and 42.5°C by the fifth day (112 hrs). From the fifth day onwards, temperature dropped reaching 35.0°C, 35.0°C and 32.5°C by the seventh day (144 hrs). The bottom 1/3 portion also showed the same trend in the temperature development (Table 6 and Fig.6).

Set of five small trays

In this method, the temperature of the fermenting bean

Table 6.- Temperature development (°C) in the bean mass fermented using the single trays

Temperature recorded at	Days after setting						
	1	2	3	4	5	6	7
	6 kg lots						
Top 1/3	27.0*	32.5	37.0	43.0	43.0	41.0	35.0
	31.5**	36.0	42.0	43.5	43.0	38.0	
Bottom 1/3	27.0	31.0	36.0	41.0	41.0	39.0	34.0
	30.0	34.0	40.0	42.0	40.0	36.0	
	4 kg lots						
Top 1/3	27.0	33.5	38.0	43.5	43.0	40.0	35.0
	29.0	36.0	41.0	44.5	42.0	37.0	
Bottom 1/3	27.0	32.0	36.0	43.0	42.0	38.0	33.0
	28.5	34.0	39.0	43.5	41.0	36.0	
	2 kg lots						
Top 1/3	27.0	34.0	39.0	44.5	44.0	40.0	32.5
	29.0	37.0	42.0	45.0	42.5	37.5	
Bottom 1/3	27.0	32.0	38.0	44.0	42.0	32.5	31.5
	28.0	35.0	41.0	43.5	40.0	36.0	

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

Fig. 6 - VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING SINGLE TRAY.

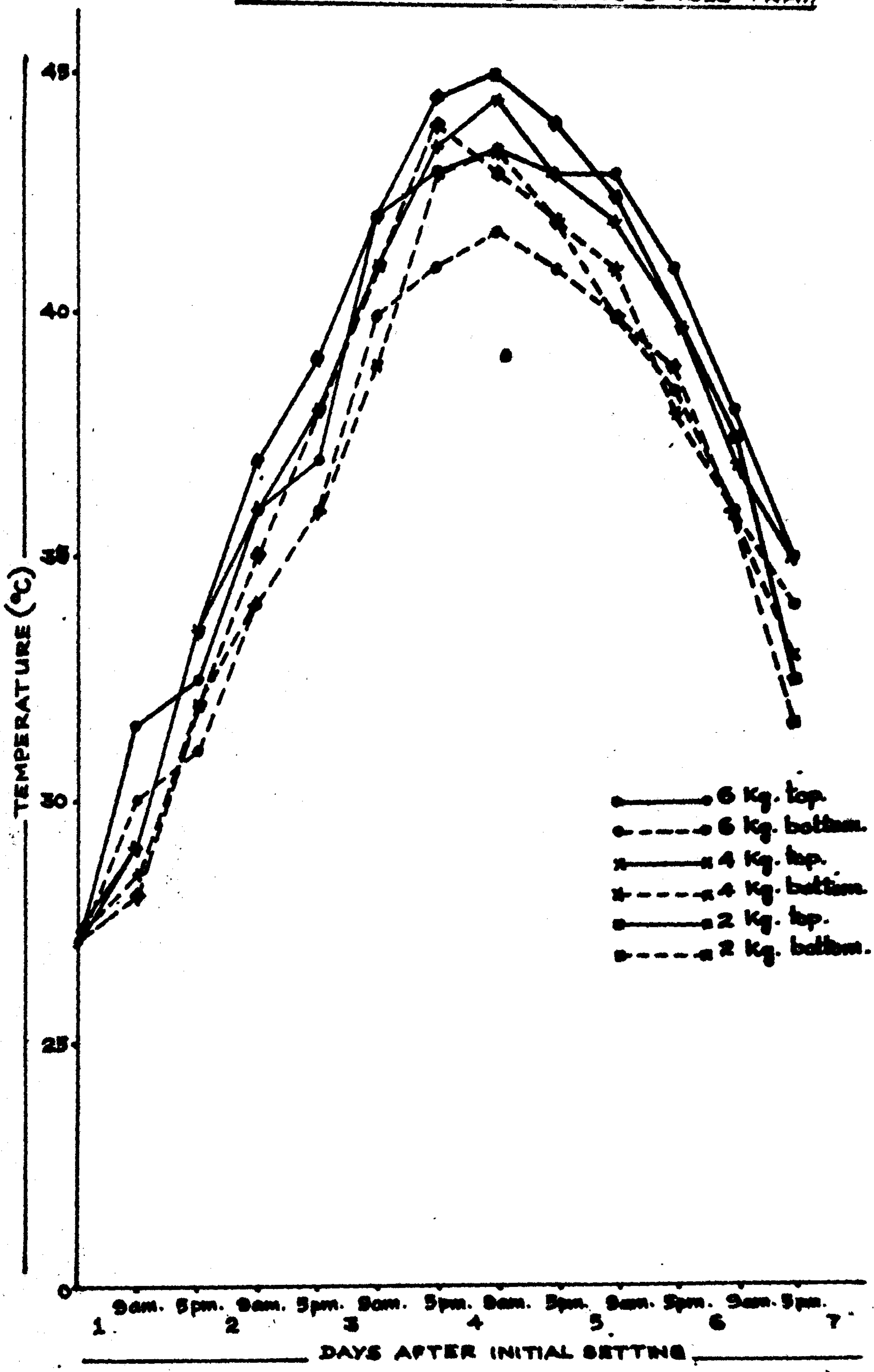


Table 7.- Temperature development (°C) in the bean mass fermented using the set of five small trays

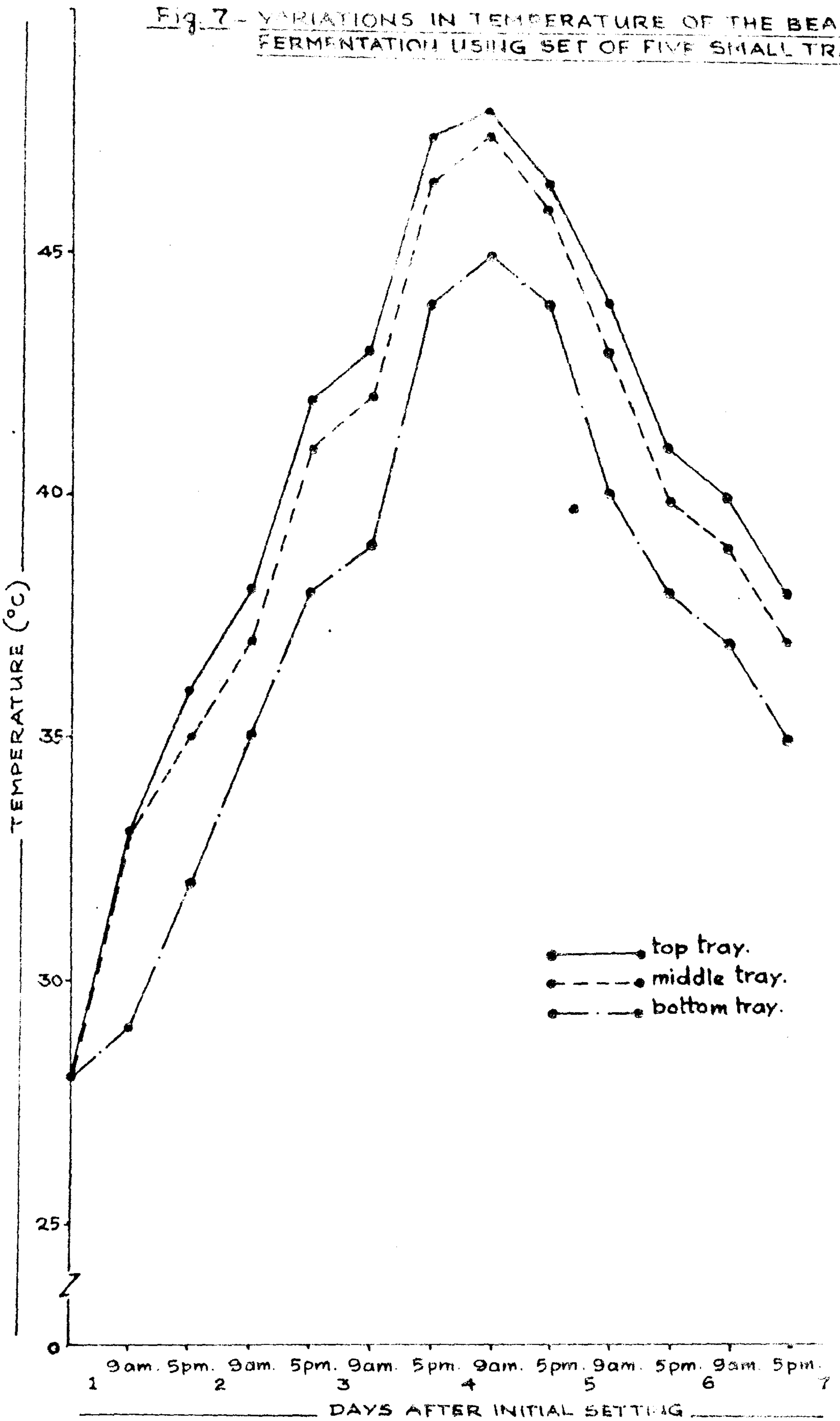
Temperature recorded at	Days after setting						
	1	2	3	4	5	6	7
	<u>10 kg lots</u>						
Top tray@	28.0*	36.0	42.0	47.5	41.5	41.0	38.0
	33.0**	38.0	43.0	48.0	44.0	40.0	
Middle tray	28.0	35.0	41.0	46.5	46.0	40.0	37.0
	33.0	37.0	42.0	47.5	43.0	39.0	
Bottom tray	28.0	32.0	38.0	44.0	44.0	38.0	35.0
	29.0	35.0	39.0	45.0	40.0	37.0	

@ Temperature recorded at the middle portion

* Temperature recorded at 9 am.

** Temperature recorded at 5 pm.

Fig. 7 - VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING SET OF FIVE SMALL TRAYS.



mass rose from the initial 28.0°C to 38.0°C, 37.0°C and 35.0°C in the top, middle and bottom trays, respectively by the second day (40 hrs). On the fourth day (88 hrs), temperature rose to 48.0°C, 47.5°C and 45.0°C. On the fifth day (112 hrs), a temperature drop to 46.5°C, 46.0°C and 44.0°C could be observed. The drop continued till the seventh day (144 hrs) when temperatures of 38.0°C, 37.0°C and 35.0°C were recorded in the top, middle and bottom trays (Table 7 and Fig.7).

Cut test

For assessing the efficacy of the different methods, the fermented beans were sampled and subjected to the standard cut test. The data on the production of brown beans under the six methods (with three quantities of beans each) were analysed for the three durations of fermentation (Table 8). The ANOVA table (Appendix I) showed significant variation among the methods, quantities, method x quantity interaction, duration and method x duration interaction, in respect of production of brown beans.

Among the different methods, mini box (M_3) and mini basket lined with banana leaves (M_1) were found to be on par; but superior to the others. The second best methods were mini basket lined with polythene sheet (M_2) and single tray (M_6) which were also found to be on par.

In respect of the three quantities of beans fermented by the different methods, six kg (Q_1) showed superiority over four kg (Q_2) and two kg (Q_3).

When fermented using mini basket lined with banana leaves (M_1), the quantities six kg (Q_1) and four kg (Q_2) gave higher proportion of brown beans. The quantity six kg (Q_1) was found to be the best for mini basket lined with polythene sheet (M_2). The three quantities were equally effective under mini box (M_3). For single tray (M_6), four kg (Q_2) and two kg (Q_3) bean lots gave the best results (Table 9).

Among the different durations of fermentation adopted, six-day fermentation (D_1) was found to give maximum brown beans, followed by seven-day (D_2) and eight-day (D_3) fermentations.

The six-day fermentation was found to be the best (in respect of production of brown beans) when all the methods were considered together. However, for mini basket lined with polythene sheet (M_2), the three durations were on par. In the case of single tray method (M_6), four- and five-day fermentations were on par and superior to six-day fermentation (Table 9).

Brown + pale purple beans

Brown and pale purple beans are acceptable to the cocoa trade. The specifications state that a proportion of 30 to

Table 9.- Production of brown beans under six methods of fermentation

Method	Quantity (kg)				Duration (days)		
	6 kg	4 kg	2 kg	Mean	6	7	8
M_1	36.57* (35.50)@	35.62 (33.90)	33.42 (30.30)	35.20 (33.20)	44.14 (48.50)	36.35 (35.10)	25.14 (18.00)
M_2	35.56 (33.80)	25.06 (17.90)	24.04 (16.60)	28.22 (22.40)	28.86 (23.30)	28.01 (22.10)	27.78 (21.70)
M_3	35.69 (34.00)	35.66 (34.00)	36.06 (34.70)	35.80 (34.20)	42,51 (45.70)	36.96 (36.20)	27.96 (22.00)
M_4	26.14 (19.40)	22.45 (14.60)	17.74 (9.30)	22.11 (14.20)	24.30 (16.90)	22.39 (14.50)	19.66 (11.30)
M_5	26.94 (20.50)	27.49 (21.30)	20.89 (12.70)	25.10 (18.00)	25.43 (18.40)	24.17 (16.80)	25.72 (18.80)
M_6 ⊗	26.24 (19.50)	28.38 (22.60)	28.36 (22.60)	27.66 (21.60)	29.20 (23.80)	28.98 (23.50)	24.82 (17.60)
Mean	31.19 (26.80)	29.11 (23.70)	26.75 (20.30)		32.40 (28.70)	29.47 (24.20)	25.17 (18.10)

* Mean (%) of two replications.

@Values in parentheses indicate angular transformed ones.

⊗ Duration of fermentation are 4, 5 and 6 days

Quantity (kg)	Duration (days)		
	6	7	8
6	34.96 (32.80)	31.24 (26.90)	27.38 (21.10)
4	31.68 (28.60)	29.95 (24.90)	25.71 (18.80)
2	30.58 (25.90)	27.24 (20.90)	22.53 (14.70)

M_1 - Mini basket lined with banana leaves

M_2 - Mini basket lined with polythene sheet

M_3 - Mini-box

M_4 - Small heap with banana leaves

M_5 - Small heap with polythene sheet

M_6 - Single tray

CD

Methods	- 1.21 (0.01)
Quantities	-0.85 (0.01)
Method x quantity	-2.10 (0.01)
Duration	-0.86 (0.01)
Method x duration	- 2.10 (0.01)
Quantity x duration	- 1.48 (Not significant)

40 per cent pale purple beans is acceptable (Anon., 1968). As such, the efficacy of the different methods was also assessed based on the quantity of brown + pale purple beans.

The ANOVA table (Appendix II) for brown + pale purple beans showed highly significant variation among the methods, quantities, method x quantity interaction, duration and method x duration interaction. Quantity x duration interaction was not found to be significant.

Among the different methods, mini basket lined with banana leaves (M_1) and mini box (M_3), ~~which were on par~~, were found to be superior to the others in the production of brown + pale purple beans. The next best methods were mini basket lined with polythene sheet (M_2) and single tray (M_6).

In respect of the three quantities of beans fermented, six kg (Q_1) showed superiority over four kg (Q_2) and two kg (Q_3) in the production of brown + pale purple beans. The quantity six kg (M_1) was found to give higher proportion of brown + pale purple beans when the different methods were considered together. However, for mini box (M_3), the three quantities were equally effective.

Among the different durations of fermentation adopted, six-day fermentation (D_1) was found to give maximum brown + pale purple beans, followed by seven-day (D_2) and eight-day (D_3) fermentations.

Table 10.- Production of brown + pale purple beans under six methods of fermentation

Method	Quantity (kg) 6	4	2	Mean	Duration (days) 6	7	8
M_1	58.18@ (72.20)**	55.74 (68.30)	55.33 (67.60)	56.42 (69.40)	65.10 (82.30)	57.24 (70.70)	46.92 (53.40)
M_2	54.32 (66.00)	39.80 (41.00)	41.17 (43.30)	45.10 (50.20)	42.10 (45.00)	45.07 (50.10)	48.11 (55.40)
M_3	55.27 (67.50)	55.20 (67.50)	55.31 (67.60)	55.26 (67.50)	62.75 (79.00)	56.50 (69.50)	46.53 (52.80)
M_4	40.18 (41.60)	38.81 (39.30)	31.01 (26.50)	36.67 (35.70)	39.46 (40.40)	36.69 (35.70)	33.85 (31.00)
M_5	40.13 (41.50)	39.86 (41.10)	37.75 (37.50)	39.25 (40.00)	36.15 (34.80)	39.10 (39.80)	42.50 (45.70)
M_6	42.50 (45.70)	41.13 (43.30)	41.82 (44.50)	41.62 (44.10)	40.82 (42.70)	45.57 (51.00)	39.09 (39.70)
Mean	48.43 (56.00)	45.90 (51.60)	43.73 (47.80)	-	47.73 (54.80)	46.70 (53.00)	42.83 (46.20)

@ Mean (%) of two replications
** Values in parentheses indicate angular transformed ones.

Quantity (kg)	Duration (days) 6	7	8
6	49.80 (58.30)	46.78 (53.10)	46.62 (52.80)
4	49.48 (57.80)	46.15 (52.00)	44.46 (49.10)
2	46.01 (51.80)	42.84 (46.20)	40.12 (41.50)

CD		
Method	- 1.45	(0.01)
Quantity	- 1.03	(0.01)
Method x quantity	- 1.78	(0.01)
Duration	- 1.02	(0.01)
Method x duration	- 2.51	(0.01)
Quantity x duration	- 1.78	Not significant

Within the six methods of fermentation, for mini basket lined with banana leaves (M_1) and mini box (M_3), six-day fermentation (D_1) was found to be the best with respect to the production of brown + pale purple beans. For mini basket lined with polythene sheet (M_2), the production of brown + pale purple beans was found to increase as the duration increased from six days (D_1) to eight days (D_3). For single tray method (M_6), five-day fermentation was found to be the best.

Purple beans

Irrespective of the quantities and duration studied, small heap with banana leaves (M_4), small heap with polythene sheet (M_5) and single tray (M_6) methods produced comparatively higher proportion of purple beans (Table 8).

Slaty beans

Production of slaty beans could be observed in small heap with banana leaves (M_4) and small heap with polythene sheet (M_5), irrespective of the quantities and durations tried. In single trays (M_6), production of slaty beane was observed only in the six kg lots (Table 8).

Overfermented beans

In all the methods and quantities, fermentation of beans for more than six days caused the production of overfermented beans, the quantum of such beans increasing with increase in the duration of fermentation (Table 8).

THE COMPARATIVE EFFICIENCY OF FERMENTATION METHODS DURING THE DRY AND WET SEASONS

The efficiency of the three fermentation methods, identified as promising in the studies was compared during the dry and wet seasons. The temperature development, pH of the pulp and cotyledon during fermentation, pH of the dried beans, results of the cut test, average bean weight, shell percentage and the percentage recovery of cured beans were the criteria used for the comparison. The studies were limited to one quantity, based on the earlier results.

Temperature development

Mini basket lined with banana leaves

The temperature development in the top 1/3 portion and bottom 1/3 portion were recorded at the time of initial loading and thereafter at 9 am and 5 pm, each day. The data are presented in Table 11 and Fig.8. During the dry season (April and May) in the mini basket lined with banana leaves (M_1), the temperature in the top 1/3 portion rose from the initial 28.0°C to 37.0°C by the second day (40 hours). Temperature reached a peak of 48.5°C by the fourth day (88 hrs). On the fifth day (112 hrs), the temperature dropped to 39.0°C. The temperature again rose to 45.5°C on the sixth day (136 hrs).

Table 11.- Temperature development (°C) in the bean mass fermented during the dry and wet seasons

Temperature recorded at	Days after setting						
	1	2	3@	4	5@	6	7
Mini-basket lined with banana leaves (M_1)							
Dry season (S_1)							
Top 1/3	28.0*	35.0	39.0	47.0	42.0	45.0	45.0
	32.0**	37.0	42.0	48.5	39.0	45.5	-
Bottom 1/3	28.0	33.5	37.0	45.0	40.0	44.0	43.0
	31.0	35.5	40.0	46.0	38.5	44.5	-
Wet season (S_2)							
Top 1/3	26.0	31.0	34.0	41.0	37.0	42.0	39.0
	28.0	32.0	39.0	43.0	35.0	40.0	-
Bottom 1/3	26.0	30.0	32.5	39.0	36.0	40.5	38.0
	26.5	31.0	36.0	41.5	34.0	39.0	-
Mini-box (M_2)							
Dry season (S_1)							
Top 1/3	27.0	33.0	39.0	47.5	40.0	45.5	45.5
	31.0	36.0	43.0	48.0	39.0	46.0	-
Bottom 1/3	27.0	31.0	37.0	46.0	39.0	43.5	43.0
	30.0	34.0	41.0	46.5	38.0	45.0	-
Wet season (S_2)							
Top 1/3	26.0	29.0	35.0	42.0	37.5	42.0	38.0
	27.0	32.0	39.0	43.0	37.0	42.5	-
Bottom 1/3	26.0	27.5	33.5	40.0	37.0	41.0	37.0
	27.0	31.0	37.0	41.0	37.0	40.0	-
Set of five small trays (M_3)							
Dry season (S_1)							
Top tray (Middle portion)	27.0	36.0	42.0	47.5	46.5	-	-
	32.0	38.0	44.0	47.0	-	-	-
Middle tray (Middle portion)	27.0	35.0	41.5	47.0	46.0	-	-
	31.0	37.0	43.5	46.5	-	-	-
Bottom tray (Middle portion)	27.0	34.0	39.0	45.5	44.0	-	-
	29.0	35.0	40.0	45.0	-	-	-

@ Beans were turned on the third and fifty days in the basket and box.

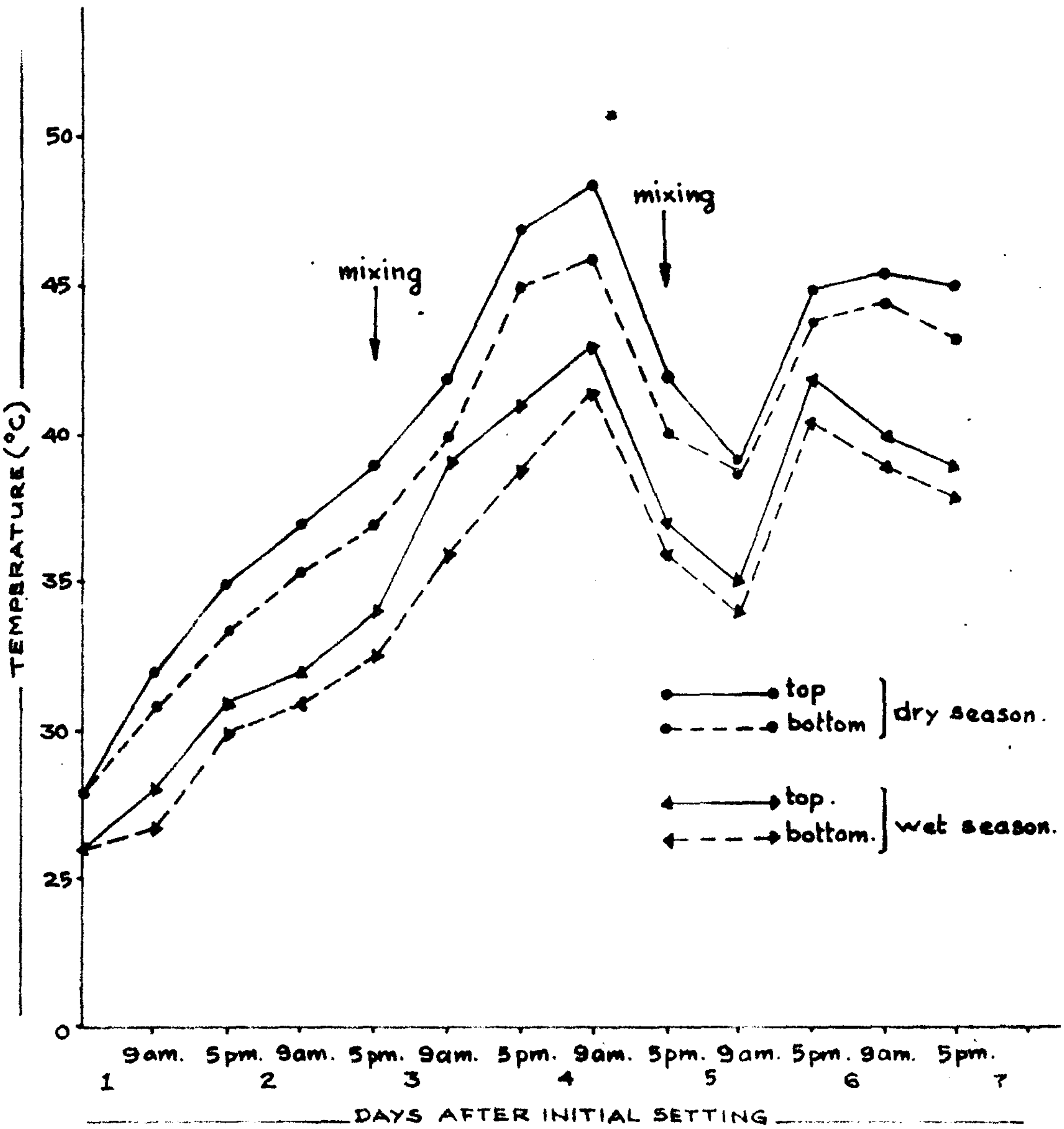
* Temperature recorded at 9 am. ** Temperature recorded at 5 pm.

(contd.)

Table 11. - Continued

Temperature recorded at	Days after setting						
	1	2	3	4	5	6	7
	Wet season (S_2)						
Top tray (Middle portion)	26.0 28.0	31.0 34.0	37.0 39.0	42.0 41.0	40.5 -	- -	- -
Middle tray (Middle portion)	26.0 28.0	30.0 33.0	36.5 38.5	41.0 40.0	40.0 -	- -	- -
Bottom tray (Middle portion)	26.0 27.0	28.0 30.0	35.0 36.0	38.5 38.0	37.0 -	- -	- -

Fig-8- SEASONAL VARIATIONS IN TEMPERATURE OF THE BEANS FERMENTED USING MINI-BASKET LINED WITH BANANA-LEAVES (6 Kg. BEAN LOT)



On the seventh day (144 hrs), the temperature of the fermenting bean mass was 45.0°C.

During the wet season (July and August), the temperature in the top 1/3 portion rose from the initial 26.0°C to 32.0°C by the second day (40 hrs). On the fourth day (88 hrs), the temperature rose to 43.0°C. The temperature dropped to 35.0°C on the fifth day (112 hrs). On the sixth day (136 hrs), the temperature again rose to 42.0°C. On the seventh day (144 hrs), the temperature of the fermenting bean mass was 39.0°C.

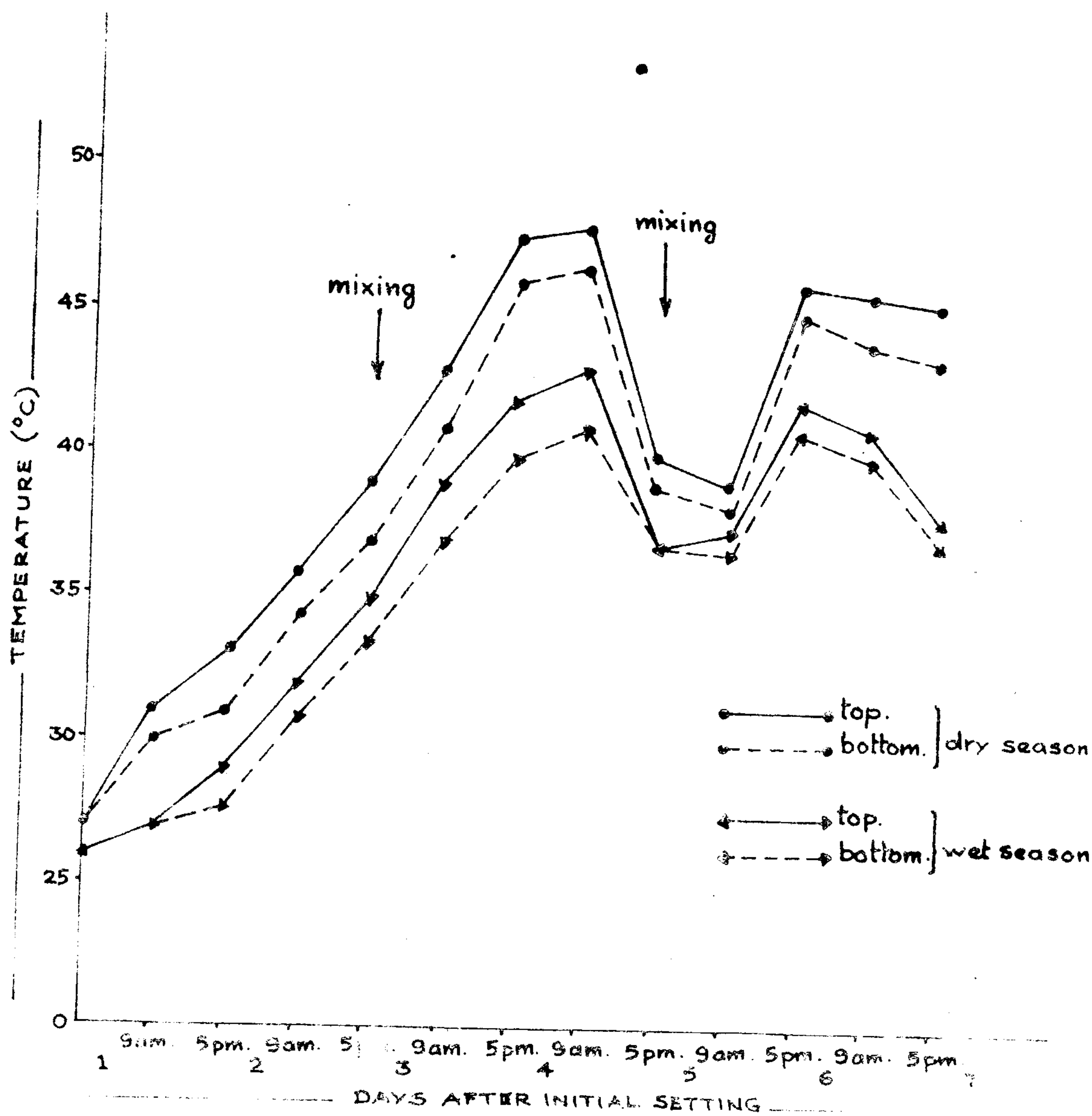
The bottom 1/3 portion of the fermenting bean mass also recorded similar trends in temperature variation during the dry and wet seasons.

<u>Mini box</u>

In mini box fermentation (M_2) during the dry season, the temperature in the top 1/3 portion rose from the initial 27.0°C to 36.0°C by the second day (40 hrs). On the fourth day (88 hrs), the temperature rose to 48.0°C. It dropped to 39.0°C on the fifth day (112 hrs). On the sixth day (136 hrs), the temperature rose to 46.0°C. On the seventh day (144 hrs), the temperature dropped to 45.5°C.

During the wet season, the temperature in the top 1/3 portion rose from the initial 26.0°C to 32.0°C by the second day (40 hrs) and rose to a peak of 43.0°C by the fourth day

Fig. 9 - SEASONAL VARIATIONS IN TEMPERATURE OF THE BEANS FERMENTED USING MINI BOX (6 Kg. BEAN LOT.)



(88 hrs). On the fifth day (112 hrs), the temperature dropped to 37.0°C. On the sixth day (136 hrs), the temperature again rose to 42.5°C. On the seventh day (144 hrs), the temperature of the fermenting bean mass was 38.0°C.

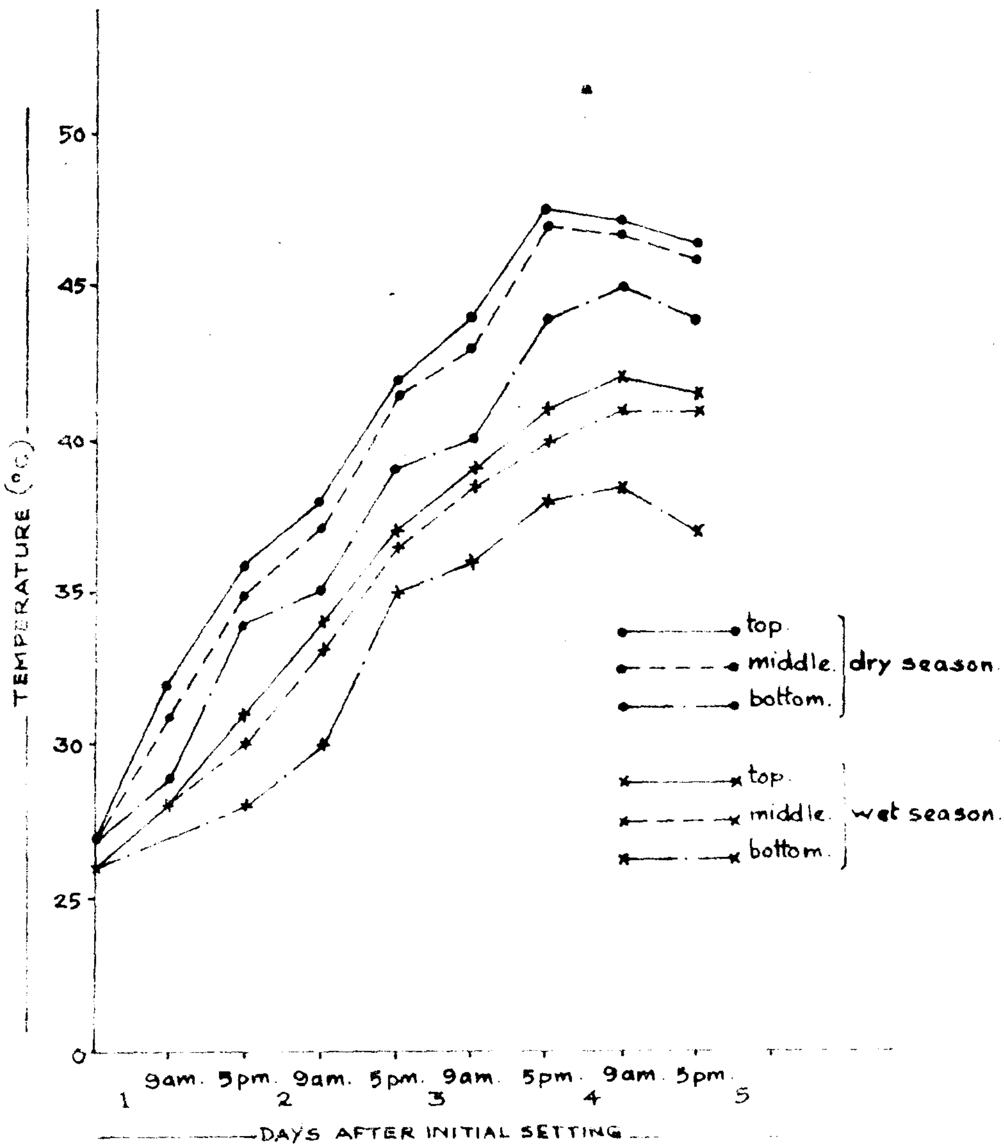
The data on temperature revealed that the bottom 1/3 portion also recorded similar trends during the dry and wet seasons (Table 11 and Fig.9).

Set of five small trays

When fermenting with a set of five small trays (M_3), by the second day (40 hrs) during the dry season, a temperature rise from 27.0°C to 38.0°C could be observed in the top tray (middle portion), to 37.0°C in the middle tray (middle portion) and to 35.0°C in the bottom tray (middle portion). On the third day (64 hrs), the temperature rose to 44.0°C, 43.5°C and 40.0°C in the top, middle and bottom trays, respectively. On the fourth day (72 hrs), the temperature rose to peaks of 47.5°C, 47.0°C and 45.5°C, respectively. The temperature dropped to 46.5°C, 46.0°C and 44.0°C in the three trays, on the fifth day (112 hrs).

By the second day (40 hrs) of the wet season, the temperature rose from the initial 26.0°C to 34.0°C in the top tray, to 33.0°C in the middle tray and to 30.0°C in the bottom tray. On the third day (64 hrs), the temperature rose to 39.0°C, 38.5°C and 36.0°C in the three trays. The peaks of

Fig. 10 - SEASONAL VARIATIONS IN TEMPERATURE OF THE BEANS FERMENTED USING SET OF FIVE SMALL TRAYS (10 Kg. BEAN LOT)



42.0°C, 41.0°C and 38.5°C were obtained on the fourth day (72 hrs). At the time of taking the beans for drying on the fifth day (112 hrs), the temperature of the fermenting bean mass was 40.5°C, 40.0°C and 37.0°C in the three trays (Table 11 and Fig.10).

pH of the pulp

In the mini basket lined with banana leaves (M_1), during the dry season (April and May), the pH of the pulp rose steadily from the initial 3.80 to 4.50 by the sixth day (144 hrs). On the seventh day (168 hrs), the pH dropped to 4.20. During the wet season (July and August), the initial pH, which was 3.50, rose steadily to 4.15 by the sixth day (144 hrs). The pH recorded a drop to 3.90 by the seventh day (168 hrs).

In the mini box (M_2), during the dry season, the pH of the pulp rose steadily from the initial 4.00 to 4.60 by the sixth day (144 hrs). The pH dropped to 4.30 by the seventh day (168 hrs). During the wet season, the pH rose steadily from the initial 3.40 to 4.10 by the sixth day (144 hrs). The pH dropped to 4.00 by the seventh day (168 hrs).

In the set of five small trays (M_3), during the dry season, the initial pH which was 3.90, rose steadily to 4.45 by the fifth day (120 hrs). During the wet season, the

Table 12.-Seasonal variation in pH of the pulp during fermentation

Treatments	Days after setting						
	1	2	3@	4	5@	6	7
Mini-basket lined with banana leaves (M_1)	3.80*	3.90	4.10	4.20	4.40	4.50	4.20
	3.50**	3.65	3.88	4.00	4.10	4.15	3.90
Mini-box (M_2)	4.00	4.00	4.20	4.25	4.40	4.60	4.30
	3.40	3.50	3.85	4.00	4.08	4.10	4.00
Set of five small trays (M_3)	3.90	4.00	4.28	4.40	4.45	-	-
	3.50	3.75	3.90	4.00	4.00	-	-

@ The beans were turned on the third and fifth days in the basket and box

* pH during the dry season

** pH during the wet season

Table 13.- Seasonal variation in pH of the cotyledons during fermentation

Treatments	Days after setting							
	1	2	3@	4	5@	6	7	Dried
Mini-basket lined with banana leaves (M_1)	6.50*	5.60	4.90	4.70	4.80	4.86	4.90	5.52
	6.20**	5.90	5.20	4.90	4.80	4.75	4.75	4.94
Mini-box (M_2)	6.60	5.50	5.00	4.70	4.75	4.82	4.90	5.42
	6.20	5.80	5.20	4.80	4.70	4.70	4.72	4.90
Set of five small trays (M_3)	6.40	5.40	4.90	4.85	4.85	-	-	5.58
	6.00	5.70	5.10	4.75	4.72	-	-	4.93

@ The beans were turned on the third and fifth days in the basket and box.

* pH during the dry season

** pH during the wet season

initial pH was 3.50. The pH steadily rose to 4.00 by the fifth day (120 hrs) (Table 12).

pH of the cotyledon

In the mini baskets lined with banana leaves (M_1) during the dry season, an initial pH of 6.50 was recorded by the cotyledons. The pH decreased steadily to 4.70 by the fourth day (96 hrs). An increase to 4.90 was observed by the seventh day (168 hrs). In the dried beans, a pH of 5.52 was recorded. During the wet season, the initial pH of the cotyledons was 6.20. The pH dropped steadily to 4.75 by the seventh day (168 hrs). In the dried beans the pH recorded was 4.94.

In the mini box (M_2) during the dry season, pH of the cotyledons dropped steadily from the initial 6.60 to 4.70 by the fourth day (96 hrs). Thereafter, the pH rose steadily to 4.90 by the seventh day (168 hrs). In the dried beans, the pH was 5.42. During the wet season, the initial pH recorded was 6.20. It dropped steadily to 4.70 by the sixth day (144 hrs). The pH rose to 4.72 by the seventh day (168 hrs). The pH was 4.90 in the dried beans.

In the set of five small trays (M_3) during the dry season, the pH of the cotyledons dropped steadily from the initial 6.40 to 4.85 by the fifth day (120 hrs). The dried beans recorded a pH of 5.58. During the wet season, the initial pH of 6.00 dropped to 4.72 by the fifth day (120 hrs). In the dried beans the pH was 4.93 (Table 13).

Cut test

Data on the production of brown beans under the mini basket lined with banana leaves (M_1), mini box (M_2) and the set of five small trays (M_3) during the dry (S_1) and wet (S_2) seasons were analysed. Highly significant variation in the proportion of brown beans was observed between the seasons (Table 14). Dry season (S_1), which was found to be superior, gave 43.52 per cent brown beans as against 29.33 per cent during the wet season (S_2). Regarding the methods, mini basket lined with banana leaves (M_1), mini box (M_2) and the set of five small trays (M_3) were found to be on par.

Since the brown and pale purple beans were acceptable to the cocoa trade, the seasonal variation with respect to the production of brown + pale purple beans was also assessed. The dry season (S_1) was found to be superior (giving 61.56 per cent acceptable beans) to the wet season (giving only 48.70 per cent acceptable beans). Among the methods, mini basket lined with banana leaves (M_1) and mini box (M_2), which were on par, were superior to set of five small trays (M_3) (Table 15).

The data presented in Table 16 indicated that the wet season (S_2) produced comparatively higher proportion of purple

Table 14.- Seasonal variation in the production of brown beans in different methods

Seasons	Methods			Mean
	Mini-basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)	
Dry (S_1)	47.60[@] (54.50)*	46.60 (52.80)	46.40 (52.40)	43.52 (52.70)
Wet (S_2)	31.80 (27.80)	28.00 (22.00)	28.20 (22.30)	29.33 (24.00)
Mean	39.70 (40.80)	37.30 (36.70)	37.30 (36.70)	-

Seasons

F - 217.17**

CD- 2.41

Methods

F - 2.35^{NS}

CD - 2.95

Season x Method

F - 0.38^{NS}

CD - 4.17

@ Mean (%) of five replications

* Values in parentheses indicate angular transformed ones

** Significant at 1% level

NS Not significant

Table 15.- Seasonal variation in the production of brown + pale purple beans in different methods

Seasons	Methods			Mean
	Mini-basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)	
Dry (S_1)	64.97@ (82.10)*	63.89 (80.60)	58.84 (73.20)	61.56 (77.30)
Wet (S_2)	49.96 (58.60)	49.53 (57.90)	46.61 (52.80)	48.70 (56.40)
Mean	57.47 (71.10)	56.71 (69.90)	52.73 (63.30)	

Seasons	Methods
F - 280.95**	F - 12.64**
CD - 1.70	CD - 2.09

Season x Method

F - 1.09 NS

CD - 2.95

@ Mean (%) of five replications

* Values in parentheses indicate angular transformed ones.

** Significant at 1% level

NS Not significant

Table 16.- Seasonal variation in the production of purple beans in different methods

Season	Methods			Mean	F	CD
	Mini-basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)			
Dry (S_1)	25.03@ (17.90)***	26.42 (19.80)	30.05 (26.60)	27.16 (21.43)	200.25**	3.62
Wet (S_2)	40.04 (41.40)	38.70 (39.70)	41.89 (44.60)	40.21 (41.90)		
Mean	32.54 (29.65)	32.55 (29.75)	35.97 (35.60)			

F - 7.81*

CD - 2.96

<u>Method x Season</u>

F - 1.28^{NS}

CD - 5.12

@ Mean (%) of five replications

*** Values in parentheses indicate angular transformed ones.

* Significant at 5% level

** Significant at 1% level

NS Not significant

beans (40.21 per cent) than the dry season (S_1 - 27.16 per-cent). Among the methods, set of five trays (M_3) produced higher percentage of purple beans than the mini basket lined with banana leaves (M_1) and mini box (M_2).

<u>Average bean weight</u>

Results obtained during the dry and wet seasons adopting the mini basket lined with banana leaves (M_1), the mini box (M_2) and the set of five small trays (M_3) indicated that the dry season (S_1) was significantly superior to the wet season (S_2) in giving higher average bean weight (1.04 g against 0.86 g). The three methods were found to be on par in respect of the average bean weight (Table 17).

<u>Shell percentage</u>

Regarding the shell percentage, fermentation during the dry season (S_1) was found to be significantly superior to that during the wet season in contributing the least shell percentage (14.83 against 19.50).

The mini box (M_2) and the set of five small trays (M_3) were on par; but significantly superior to the mini basket lined with banana leaves (M_1) in contributing the least shell percentage (Table 18).

<u>Percentage recovery of cured beans</u>

The data on the percentage recovery of cured beans to

Table 17.- Seasonal variation on the average bean weight in different methods

Seasons	Methods			Mean
	Mini basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)	
Dry (S_1)	1.11*	0.89	1.11	1.04
Wet (S_2)	0.87	0.85	0.85	0.86
Mean	0.991	0.871	0.982	

Seasons	Methods
F - 129.40**	F - 0.27^{NS}
CD - 0.045	CD - 0.124

Season x Method

F - 1.22^{NS}

CD - 0.23

* Mean of five replications

** Significant at 1% level

NS Not significant

Table 18.- Seasonal variation on the shell percentage in different methods

Seasons	Methods			Mean
	Mini basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)	
Dry (S_1)	15.40@ (23.15)*	14.60 (22.42)	14.50 (22.39)	14.83 (22.65)
Wet (S_2)	20.30 (26.80)	18.80 (25.66)	19.40 (26.13)	19.50 (26.19)
Mean	17.85 (24.97)	16.70 (24.04)	16.95 (24.23)	

Seasons	Methods
F - 129.40^{xx}	F - 3.56^{x}
CD - 1.04	CD - 0.85

Season x Method

F - 0.33^{NS}
CD - 1.66

@ Mean (%) of five replications

* Values in parentheses indicate angular transformed ones

x Significant at 5% level

xx Significant at 1% level

NS Not significant

Table 19.- Seasonal variation on the percentage recovery in different methods

Seasons	Methods			Mean
	Mini-basket lined with banana leaves (M_1)	Mini-box (M_2)	Set of five small trays (M_3)	
Dry (S_1)	36.50@ (37.15)*	35.30 (36.45)	35.80 (36.72)	35.87 (34.30)
Wet (S_2)	28.50 (32.26)	28.70 (32.36)	29.00 (32.58)	28.73 (23.10)
Mean	32.50 (34.71)	32.00 (34.41)	32.40 (34.65)	

<u>Seasons</u>

F - 194.73^{xx}

CD - 0.65

<u>Methods</u>

F - 0.45^{NS}

CD - 1.11

<u>Method x Season</u>

F - 2.19^{NS}

CD - 4.12

@ Mean (%) of five replications

* Values in parentheses indicate angular transformed ones.

xx Significant at 1% level

NS Not significant

the wet weight of beans (Table 19) indicated that the dry season gave significantly higher recovery (35.87) than the wet season (28.73).

The three methods were found to be on par in respect of the percentage recovery of cured beans.

MATURITY OF PODS AT HARVEST IN RELATION TO FERMENTATION OF COCOA BEANS

Cocoa pods of different maturity (green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods) were harvested and the beans were fermented. In order to study the influence of pod maturity on the fermentation characteristics, the temperature development, pH of the pulp and cotyledons during fermentation, pH of the dried beans, results of the standard cut test, average bean weight, shell percentage and the percentage recovery of cured beans were recorded. These parameters were studied with reference to one method (mini basket lined with banana leaves) and one quantity (six kg) identified as promising in the earlier studies.

Temperature development

The temperature development in the top 1/3 portion and bottom 1/3 portion were recorded at the time of initial loading and thereafter at 9 am and 5 pm each day. The data are presented in Table 20 and Fig.11.

Table 20.- Temperature development (°C) in the bean mass fermented using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods

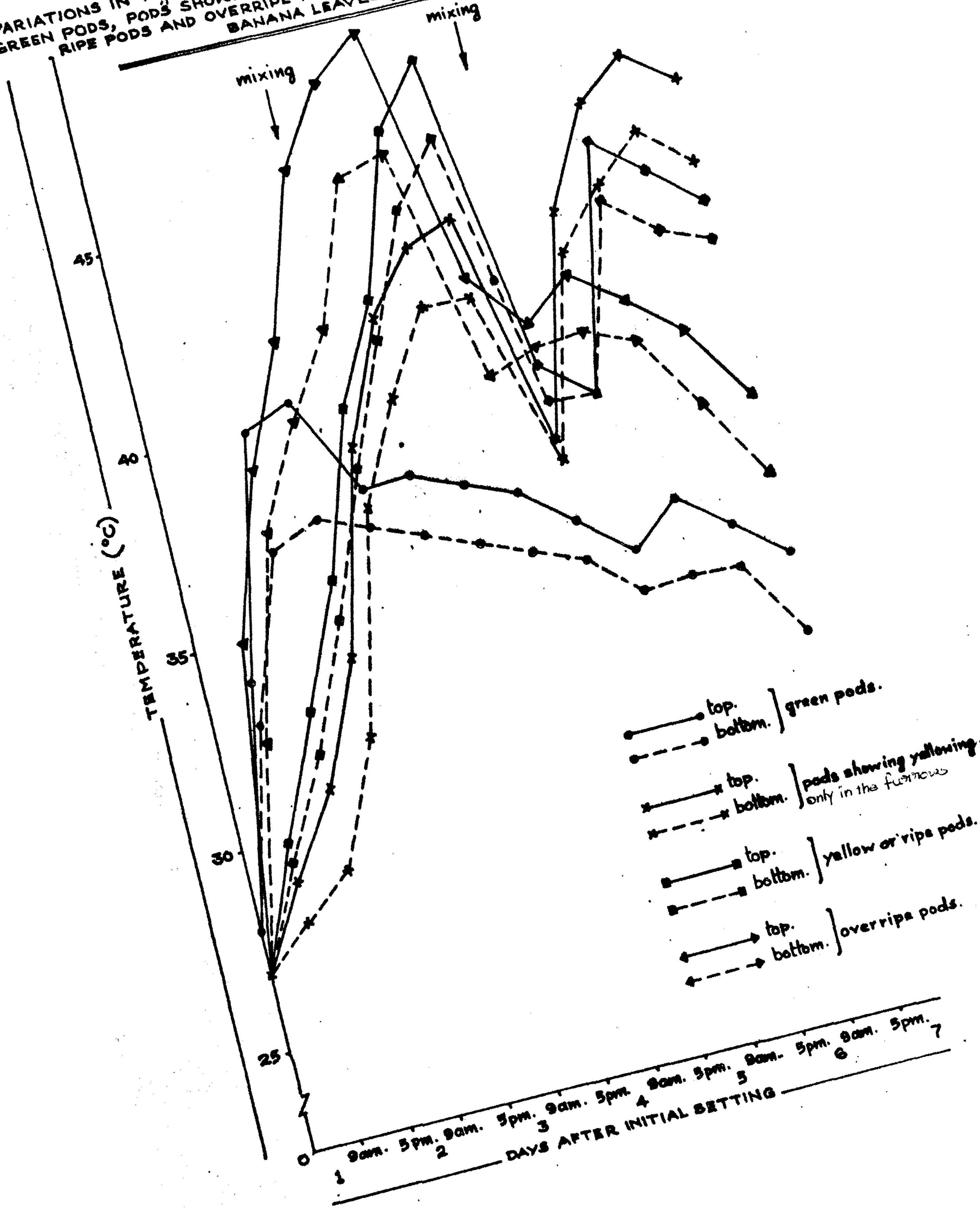
Temperature recorded at	Treatments	Days after setting						
		1	2	3[@]	4	5[@]	6	7
Top 1/3	Green pods	28.0*	40.0	38.0	37.5	36.0	36.0	34.0
		34.0**	40.5	38.0	37.0	35.0	35.0	-
Bottom 1/3		28.0	37.0	37.0	36.0	35.0	35.0	32.0
		33.0	37.5	37.5	35.5	34.0	34.0	-
Top 1/3	Pods showing yellowing only in the furrows	27.0	31.0	39.0	43.5	38.0	46.0	46.0
		29.0	34.0	42.0	44.0	43.5	47.0	-
Bottom 1/3		27.0	29.0	37.5	42.0	37.5	44.0	44.0
		28.0	32.0	40.0	42.0	42.5	45.0	-
Top 1/3	Yellow/ripe pods	27.0	33.0	40.0	46.5	40.0	45.0	43.0
		30.0	36.0	42.5	48.0	39.0	44.0	-
Bottom 1/3		27.0	32.0	38.5	44.5	39.0	43.5	42.0
		29.5	35.0	41.5	46.0	39.0	42.5	-
Top 1/3	Over-ripe pods	27.0	39.0	46.0	49.0	41.0	41.0	38.0
		35.0	42.0	48.0	42.5	42.0	40.0	-
Bottom 1/3		27.0	37.5	42.0	46.0	40.5	40.0	36.0
		32.5	40.0	45.5	40.0	40.5	38.0	-

@ Beans were turned on the third and fifth days

* Temperature recorded at 9 am

** Temperature recorded at 5 pm.

Fig.11- VARIATIONS IN TEMPERATURE OF THE BEANS DURING FERMENTATION USING GREEN PODS, PODS SHOWING YELLOWING ONLY IN THE FURROWS, YELLOW OR RIPE PODS AND OVERRIPE PODS USING MINI BASKET LINED WITH BANANA LEAVES (6 Kg. BEAN LOT)



When beans from the green pods were fermented, the temperature rose from 28.0°C to 40.5°C by the second day (40 hrs). The temperature dropped steadily to 37.0°C by the fourth day (88 hrs) and then to 34.0°C by the seventh day (144 hrs).

Beans from the pods with "yellowing only in the furrows" showed a temperature rise in the top 1/3 portion from the initial 27.0°C to 34.0°C by the second day (40 hrs). The temperature rose to 44.0°C by the fourth day (88 hrs) and to 38.0°C by the fifth day (96 hrs). Temperature again rose to a peak of 47.0°C by the sixth day (136 hrs) to record a drop to 46.0°C by the seventh day (144 hrs).

The bean mass from yellow/ripe pods showed a temperature rise in the top 1/3 portion from the initial 27.0°C to 36.0°C during the second day (40 hrs). The temperature rose to a peak of 48.0°C by the fourth day (88 hrs). The temperature dropped to 39.0°C by the fifth day (112 hrs), recorded a rise to 45.0°C by the sixth day (136 hrs) and then dropped to 43.0°C by the seventh day (144 hrs).

The beans from over-ripe pods which reoorded an initial temperature of 27.0°C, attained a temperature of 42.0°C by the second day (40 hrs) and 49.0°C by the fourth day (72 hrs). The temperature dropped to 42.0°C on the fifth day (112 hrs). No rise in temperature was observed on the sixth day (136 hrs).

The temperature dropped steadily to 38.0°C by the seventh day (144 hrs).

Beans from the cocoa pods of different maturity groups recorded temperature variations in the bottom 1/3 portions as observed in the top 1/3 portions.

pH of the pulp

The data are furnished in Table 21.

The pH of the pulp rose steadily from the initial 4.50 to 4.67 by the fifth day (120 hrs) when beans from the green pods were fermented. The pH dropped to 4.66 by the seventh day (168 hrs).

The beans from the pods with "Yellowing only in the furrows" recorded a steady rise in pH from the initial 4.00 to 4.60 by the sixth day (144 hrs). The pH dropped to 4.40 by the seventh day (168 hrs).

When the beans from yellow/ripe pods were fermented the pH of the pulp rose from initial 3.80 to 4.70 on the sixth day (144 hrs). The pH dropped to 4.30 by the seventh day (168 hrs).

The beans from the over-ripe pods recorded a steady rise in pH from the initial 4.00 to 4.65 by the sixth day (144 hrs) and a drop to 4.25 by the seventh day (168 hrs).

Table 21.- Variation in pH of the pulp during fermentation using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods

Treatments	Days after setting						
	1	2	3@	4	5@	6	7
Green pods	4.50*	4.60	4.65	4.66	4.67	4.66	4.66
Pods showing yellowing only in the furrows	4.00	4.00	4.10	4.30	4.40	4.60	4.40
Yellow/ripe pods	3.80	3.90	4.00	4.35	4.50	4.70	4.30
Over-ripe pods	4.00	4.20	4.40	4.50	4.55	4.65	4.25

@ Beans were turned on the third and fifth days
* Mean value of five replications

Table 22.- Variation in pH of the cotyledons during fermentation using green pods, pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods

Treatments	Days after setting							Dried
	1	2	3@	4	5@	6	7	
Green pods	6.80*	6.40	6.25	6.00	5.96	5.92	5.92	5.85
Pods showing yellowing only in the furrows	6.40	6.00	5.80	5.20	5.25	5.30	5.35	5.65
Yellow/ripe pods	6.60	5.80	5.60	4.80	4.90	4.95	5.10	5.55
Over-ripe pods	6.40	5.00	4.80	4.95	5.00	5.20	5.20	5.58

@ Beans were turned on the third and fifth days
* Mean value of five replications

pH of the cotyledons

The data are presented in Table 22.

The initial pH of the cotyledons was 6.80 when the beans from green pods were fermented. It dropped steadily to 5.92 by the seventh day (168 hrs). In the dried beans, the pH was 5.85.

On fermenting the beans from pods with "Yellowing only in the furrows", a steady pH drop from 6.40 to 5.20 by the fourth day (96 hrs) was observed. The pH rose to 5.35 by the seventh day (168 hrs). In the dried beans, the pH was 5.65.

When the beans from yellow/ripe pods were fermented, the initial pH of the cotyledons was 6.60. The pH dropped steadily to 4.80 by the fourth day (96 hrs). From the fifth day onwards, the pH rose steadily, reaching 5.10 by the seventh day (168 hrs). In the dried beans, the pH was 5.55.

When fermented, the beans from over-ripe pods recorded a steady drop in pH from the initial 6.40 to 4.80 by the third day (72 hrs). The pH then rose steadily to 4.95 by the fourth day (96 hrs) and 5.20 by the seventh day (168 hrs). In the dried beans, the pH was 5.58.

Cut test

Data on the cut test conducted are furnished in Table 23.

Table 23.- Effect of ripeness of pods in the production of brown, brown + pale purple and purple beans

Treatments	Brown beans	Brown + pale purple beans	Purple beans
Green pods	19.46* (11.10)**	27.48 (21.30)	62.51 (78.70)
Pods showing yellowing only in the furrows	35.40 (33.50)	53.87 (65.20)	36.12 (34.70)
Yellow/ripe pods	43.39 (47.20)	66.64 (84.30)	23.36 (15.70)
Over-ripe pods	52.00 (62.10)	72.41 (90.90)	17.59 (9.10)
F	125.03xx	371.45xx	371.77xx
CD	3.71	3.10	3.11

* Mean (%) of five replications

** Values in parentheses indicate angular transformed ones

xx Significant at 1% level

Immaturity of pods significantly lowered the production of brown beans as well as brown + pale purple beans (19.46 per cent and 27.48 per cent respectively) on fermentation. The beans from yellow/ripe pods and pods with "yellowing only in the furrows" gave intermediate levels of brown beans as well as brown + pale purple beans (43.39 per cent and 66.64 per cent; 35.40 per cent and 53.87 per cent respectively). Production of maximum quantity of brown beans as well as brown + pale purple beans (52.00 per cent and 72.41 per cent respectively) was observed when beans from over-ripe pods were fermented.

The over-ripe pods yielded the least quantity of purple beans (17.59 per cent) whereas the green pods recorded the highest (62.51 per cent). Ripe pods and pods with "yellowing only in the furrows" yielded intermediate levels (23.36 per-cent and 36.12 per cent respectively).

Average bean weight

The beans from over-ripe and yellow/ripe pods, on fermentation and curing, had significantly higher average bean weight (1.15 g and 1.14 g respectively) as compared to those from the pods with "yellowing only in the furrows" (1.00 g) and the green pods (0.746 g) (Table 24).

Shell percentage

After fermentation and curing, the beans of over-ripe pods were found to be significantly superior to those from

Table 24.- Effect of ripeness of pods on the average bean weight, shell percentage and percentage recovery

Treatments	Average bean weight (g)	Shell percentage	Percentage recovery
Green pods	0.746*	24.00** (29.33)***	24.87 (17.70)
Pods showing yellowing only in the furrows	1.00	17.70 (24.86)	35.01 (32.90)
Yellow/ripe pods	1.14	15.80 (23.45)	35.76 (34.10)
Over-ripe pods	1.15	13.90 (21.88)	36.04 (34.60)
F	80.97xx	26.08xx	82.94xx
CD	0.062	1.39	0.792

* Mean of five replications
** Mean (%) of five replications
*** Values in parentheses indicate angular transformed ones
xx Significant at 1% level

the other three treatments in having produced the least shell percentage (13.90). The beans from the green pods recorded maximum shell percentage (24.00), the other two treatments recording intermediate values (17.70 per cent for pods with yellowing only in the furrows and 15.80 per cent for yellow/ripe pods (Table 24).

Percentage recovery of cured beans

Maximum percentage recovery of cured beans was observed in the treatment over-ripe pods (36.04) which was on par with that observed in yellow/ripe pods (35.76). These were significantly superior to the recovery obtained in the other two treatments. Minimum recovery was obtained in the treatment, green pods (24.87) (Table 24).

EFFECT OF STORING HARVESTED PODS ON THE FERMENTATION CHARACTERISTICS

Beans were extracted from the pods on the day of harvest as well as after storing the pods for periods of two days, four days and six days. In each case, six kg (Q_1) beans were fermented by the mini basket lined with banana leaves (M_1). The fermentation characteristics were assessed based on the temperature development, pH of the pulp and cotyledons, pH of the dried bean, results of the standard cut test, average bean weight, shell percentage and percentage recovery of cured beans.

Temperature development

The data are presented in Table 25 and Fig.12. Beans collected from the pods and loaded for fermentation on the day of harvest recorded a temperature rise (in the top 1/3 portion) from the initial 28.0°C to 33.0°C by the second day (40 hrs). The temperature reached a peak of 45.0°C by the fourth day (88 hrs). The temperature dropped to 38.5°C by the fifth day (112 hrs), rose to 44.5°C by the sixth day (136 hrs) and then dropped to 44.0°C by the seventh day (144 hrs) when the fermentation was completed. In the bottom 1/3 portion, the temperature rose from the initial 28.0°C to 31.0°C by the second day (40 hrs). The temperature reached a peak of 42.0°C by the fourth day (88 hrs). The temperature dropped to 38.0°C by the fifth day (112 hrs), rose to 43.5°C by the sixth day (136 hrs) and dropped again to 42.5°C by the seventh day (144 hrs) when the fermentation was completed. It can be then seen that the bottom 1/3 portion also recorded more or less similar variations in temperature development.

Beans extracted and fermented after two days of storage of pods, recorded (in the top 1/3 portion of the fermenting bean mass) a temperature rise from the initial 28.0°C to 36.0°C

Table 25.- Temperature development (°C) in the bean mass fermented using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days

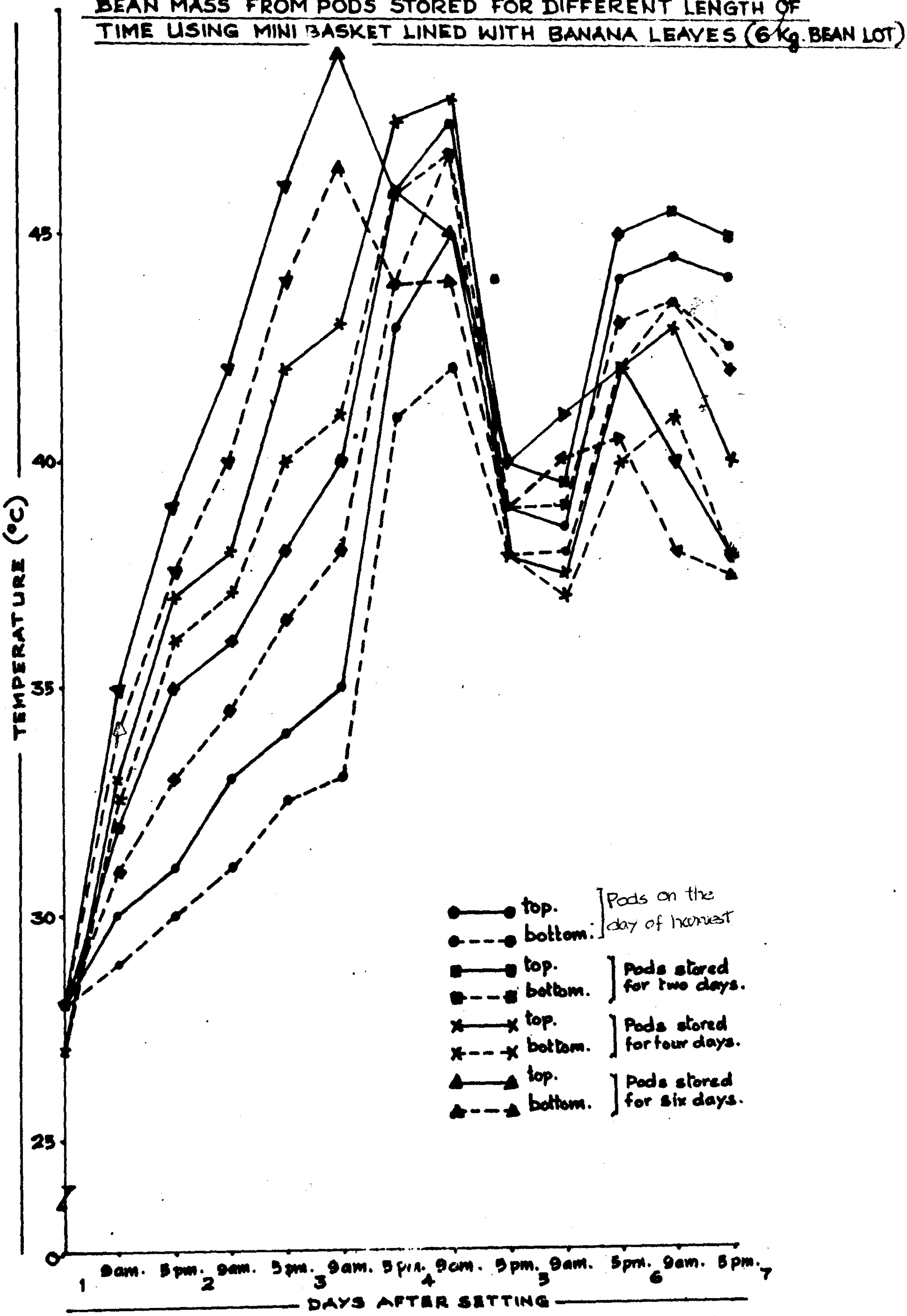
Temperature recorded at	Days after setting 1	2	3@	4	5@	6	7
On the day of harvest							
Top 1/3	28.0*	31.0	34.0	43.0	39.0	44.0	44.0
	30.0**	33.0	35.0	45.0	38.5	44.5	-
Bottom 1/3	28.0	30.0	32.5	41.0	38.0	42.0	42.5
	29.0	31.0	33.0	42.0	38.0	43.5	-
Pods stored for two days							
Top 1/3	28.0	35.0	38.0	46.0	40.0	45.0	45.0
	32.0	36.0	40.0	47.5	39.5	45.5	-
Bottom 1/3	28.0	33.0	36.5	44.0	39.0	43.0	42.0
	31.0	34.5	38.0	45.5	39.0	43.5	-
Pods stored for four days							
Top 1/3	27.0	37.0	42.0	47.5	38.0	42.0	40.0
	33.0	38.0	43.0	48.0	37.5	43.0	-
Bottom 1/3	27.0	36.0	40.0	46.0	38.0	40.0	38.0
	32.5	37.0	41.0	46.5	37.0	41.0	-
Pods stored for six days							
Top 1/3	28.0	39.0	46.0	46.0	40.0	42.0	38.0
	35.0	42.0	49.0	45.0	41.0	40.0	-
Bottom 1/3	28.0	37.5	44.0	44.0	39.0	40.5	37.5
	34.0	40.0	46.5	44.0	40.0	38.0	-

@ The beans were turned on the third and fifth days

* Temperature recorded at 9 am

** Temperature recorded at 5 pm.

Fig. 12 - TEMPERATURE DEVELOPMENT DURING FERMENTATION IN THE BEAN MASS FROM PODS STORED FOR DIFFERENT LENGTH OF TIME USING MINI BASKET LINED WITH BANANA LEAVES (6 Kg. BEAN LOT)



by the second day (40 hrs). The temperature rose to 47.5°C by the fourth day (88 hrs), dropped to 39.5°C by the fifth day (112 hrs) and again rose to 45.5°C by the sixth day (136 hrs). On the seventh day (144 hrs), the fermenting bean mass recorded a temperature of 45.0°C. The bottom 1/3 portion also recorded similar trends in temperature.

When the beans collected from the pods stored for four days were fermented, the top 1/3 portion of the mass attained a temperature of 38.0°C by the second day (40 hrs). The temperature rose to 48.0°C by the fourth day (88 hrs) and dropped to 37.5°C by the fifth day (112 hrs). On the sixth (136 hrs) and seventh (144 hrs) days, the temperatures noted were 43.0°C and 40.0°C respectively. The bottom 1/3 portion also recorded similar trends in temperature.

Beans extracted from the pods stored for six days after the harvest, when fermented recorded a rise in the temperature (in the top 1/3 portion), from the initial 28.0°C to 42.0°C by the second day (40 hrs). The temperature rose to 49.0°C by the third day (64 hrs) and dropped to 40.0°C by the fifth day (96 hrs). On the sixth day (136 hrs), the temperature rose to 42.0°C. On the seventh day (156 hrs), the temperature of the fermenting bean mass was 38.0°C. The bottom 1/3 portion also recorded similar trends in temperature.

pH of the pulp

The data are presented in Table 26.

Table 26.- Variations in pH of the pulp during fermentation by using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days

Treatments	Days after setting						
	1	2	3	4	5	6	7
Pods on the day of harvest	4.20*	4.22	4.25	4.30	4.40	4.60	4.20
Pods stored for two days	3.90	4.00	4.20	4.35	4.55	4.65	4.25
Pods stored for four days	3.80	4.00	4.20	4.40	4.50	4.68	4.25
Pods stored for six days	4.00	4.28	4.40	4.50	4.50	4.55	4.30

* Mean of five replications

Table 27.- Variation in pH of the cotyledons during fermentation by using pods on the day of harvest, pods stored for two days, pods stored for four days and pods stored for six days

Treatments	Days after setting							Dried
	1	2	3	4	5	6	7	
Pods on the day of harvest	6.60*	5.80	5.70	5.30	5.10	5.20	5.35	5.68
Pods stored for two days	6.50	5.60	4.90	4.70	4.80	4.80	5.05	5.55
Pods stored for four days	6.60	5.20	5.00	4.70	4.80	4.85	5.10	5.54
Pods stored for six days	6.40	5.00	4.80	4.85	4.90	5.10	5.15	5.57

* Mean of five replications

When the beans were extracted and fermented on the day of pod harvest, the initial pH of the pulp was 4.20. The pH rose steadily to 4.60 by the sixth day (144 hrs) and dropped to 4.20 by the seventh day (168 hrs).

The initial pH of the mass was 3.90 when the beans from pods stored for two days were extracted and fermented. The pH rose to 4.65 by the sixth day (144 hrs) and dropped to 4.25 by the seventh day (168 hrs).

Storing the pods for four days before extraction of beans lowered the initial pH to 3.80. The pH of the mass rose to 4.68 by the sixth day (144 hrs) and dropped to 4.25 by the seventh day (168 hrs).

When the beans were extracted after six days of storage of the pods and utilized for fermentation, the initial pH was found to be 4.00. The pH rose to 4.55 by the sixth day (144 hrs) and dropped to 4.30 by the seventh day (168 hrs).

pH of the cotyledons

Initial pH of the cotyledons varied from 6.40 (when the beans were extracted after six days of storage of pods) to 6.60 (when the beans were extracted on the day of harvest or after four days of storage). The pH dropped to a minimum by the third to fifth day of fermentation (Table 27), after which an increase in the pH was seen. At the completion of fermentation, the pH in the different treatments ranged from 5.05 to 5.35. The pH of the dried bean varied between 5.54 and 5.68.

Cut test

The data on the cut test presented in Table 28 indicate the percentage recovery of brown, brown + pale purple and purple beans. Statistical analysis of the data revealed that the maximum recovery of brown beans was obtained in the Treatment 3 (pods stored for four days before extraction of the beans). The Treatment 3 and the Treatment 2 (pods stored for two days before extraction of the beans) giving 42.47 and 41.78 per cent brown beans, respectively, were on par. Extracting and fermenting the beans on the day of harvest (Treatment 1) yielded the least quantity (31.94 per cent) of brown beans.

When the production of brown + pale purple beans was considered, the treatment effects were highly significant. Storing the harvested pods for four days and then fermenting the beans (Treatment 3) gave 63.96 per cent brown + pale purple beans. The next best treatment was storing the pods for two days before extracting the beans for fermentation (giving 60.04 per cent brown + pale purple beans). Fermenting the beans from the freshly harvested pods (Treatment 1) yielded the least quantity of brown + pale purple beans (46.03 per cent).

Table 28.- Effect of storing the harvested pods in the production of brown, brown + pale purple and purple beans

Treatments	Brown beans	Brown + pale purple beans	Purple beans
Pods on the day of harvest	31.94* (28.00)**	46.03 (51.80)	43.97 (48.20)
Pods stored for two days	41.78 (44.40)	60.04 (75.00)	29.96 (24.90)
Pods stored for four days	42.47 (45.60)	63.96 (80.70)	26.04 (19.30)
Pods stored for six days	37.92 (37.80)	57.42 (71.00)	32.58 (29.00)
F	36.02xx	56.05xx	66.03xx
CD	2.41	2.84	2.84

* Mean (%) of five replications

** Values in parentheses indicate angular transformed ones.

xx Significant at 1% level

Table 29.- Effect of storing the harvested pods on the average bean weight, shell percentage and percentage recovery

Treatments	Average bean weight	Shell percentage	Percentage recovery
Pods on the day of harvest	1.04*	16.40** (23.89)***	34.73 (32.40)
Pods stored for two days	1.08	13.85 (21.81)	35.40 (33.60)
Pods stored for four days	1.07	13.80 (21.83)	35.45 (33.60)
Pods stored for six days	1.08	13.20 (21.30)	35.53 (33.80)
F	1.17^{NS}	5.29^{xx}	2.54^{x}
CD	0.27	0.68	0.70

* Mean value of five replications

** Mean percentage of five replications

*** Values in parentheses indicate angular transformed ones.

x Significant at 5% level

xx Significant at 1% level

NS Not significant

In respect of production of purple beans, the least value (26.04 per cent) was recorded by Treatment 3 (pods stored for four days).

Average bean weight

The treatment effects were found to be not significant with respect to average bean weight (Table 29).

Shell percentage

Storing the harvested pods for two, four and six days and then fermenting the beans were found to be on par in the production of the least shell percentage which were significantly superior to that obtained under beans from the pods on the day of harvest (Table 29).

Percentage recovery

Storing the pods for six days prior to fermentation (Treatment 4) gave 35.53 per cent recovery of cured beans. This treatment was on par with "storing the pods for four days prior to fermentation" (Treatment 3) which gave 35.45 per cent recovery of cured beans and "storing the pods for two days prior to fermentation" (Treatment 2) which gave 35.40 per cent recovery (Table 29).

QUALITY ATTRIBUTES OF CURED BEANS IN RELATION TO STORAGE

The data on the changes in the quality attributes of

Table 30.- Changes in the quality attributes of cured beans during storage

Months after storage	Brown beans	Brown + pale purple beans	Purple beans	Bean pH
August '80	48*	74	26	5.20**
September '80	49	76	24	5.22
October '80	52	77	23	5.25
November '80	52	78	22	5.28
December '80	54	82	18	5.35
January '81	58	87	13	5.46
February '81	60	89	11	5.48
March '81	66	90	10	5.48
April '81	70	90	10	5.45
May '81	71	92	8	5.46

* Mean (%) of three replications

** Mean of three replications

Fig. 13 - CHANGES IN THE QUALITY ATTRIBUTES OF CURED BEANS DURING STORAGE

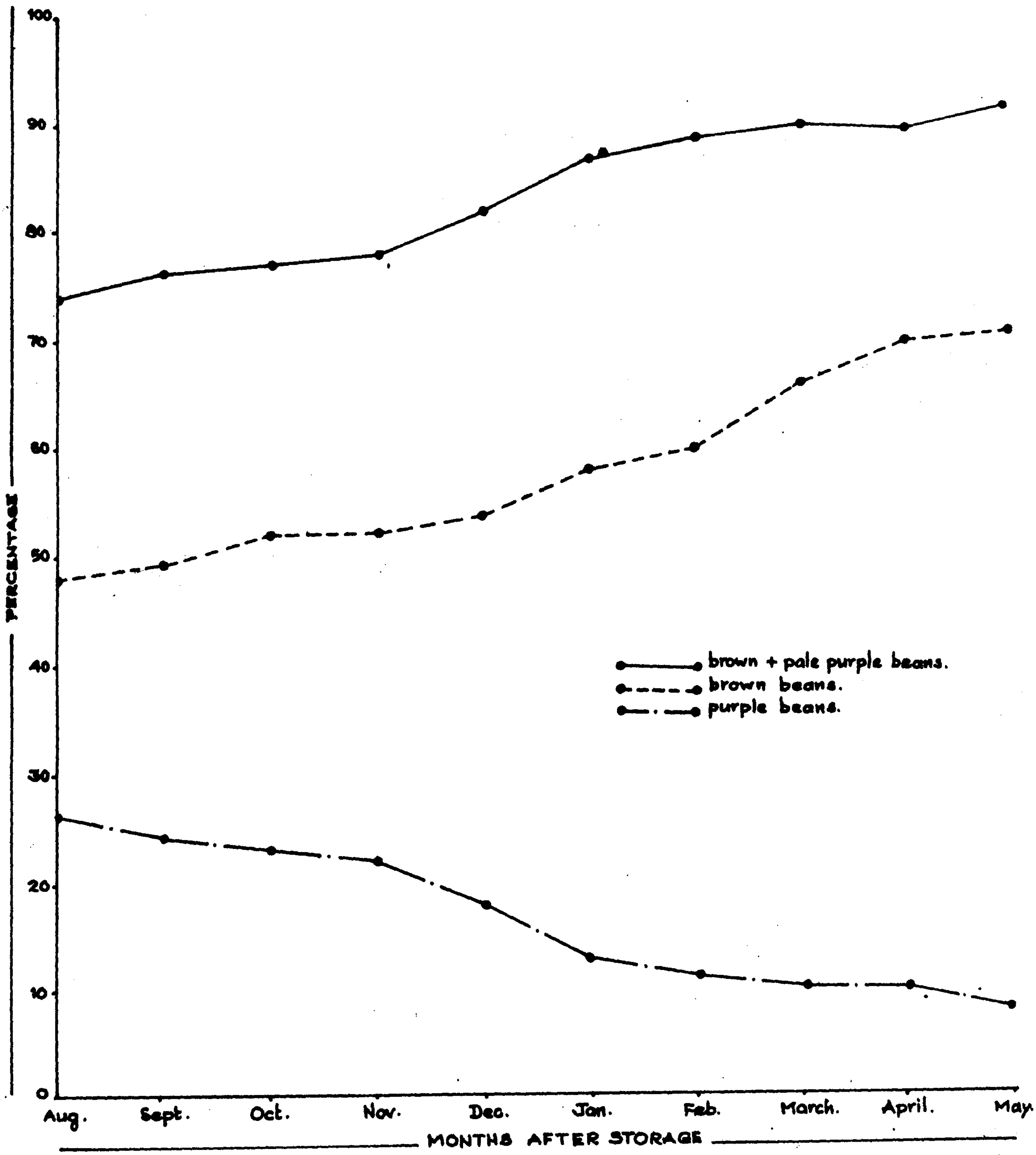
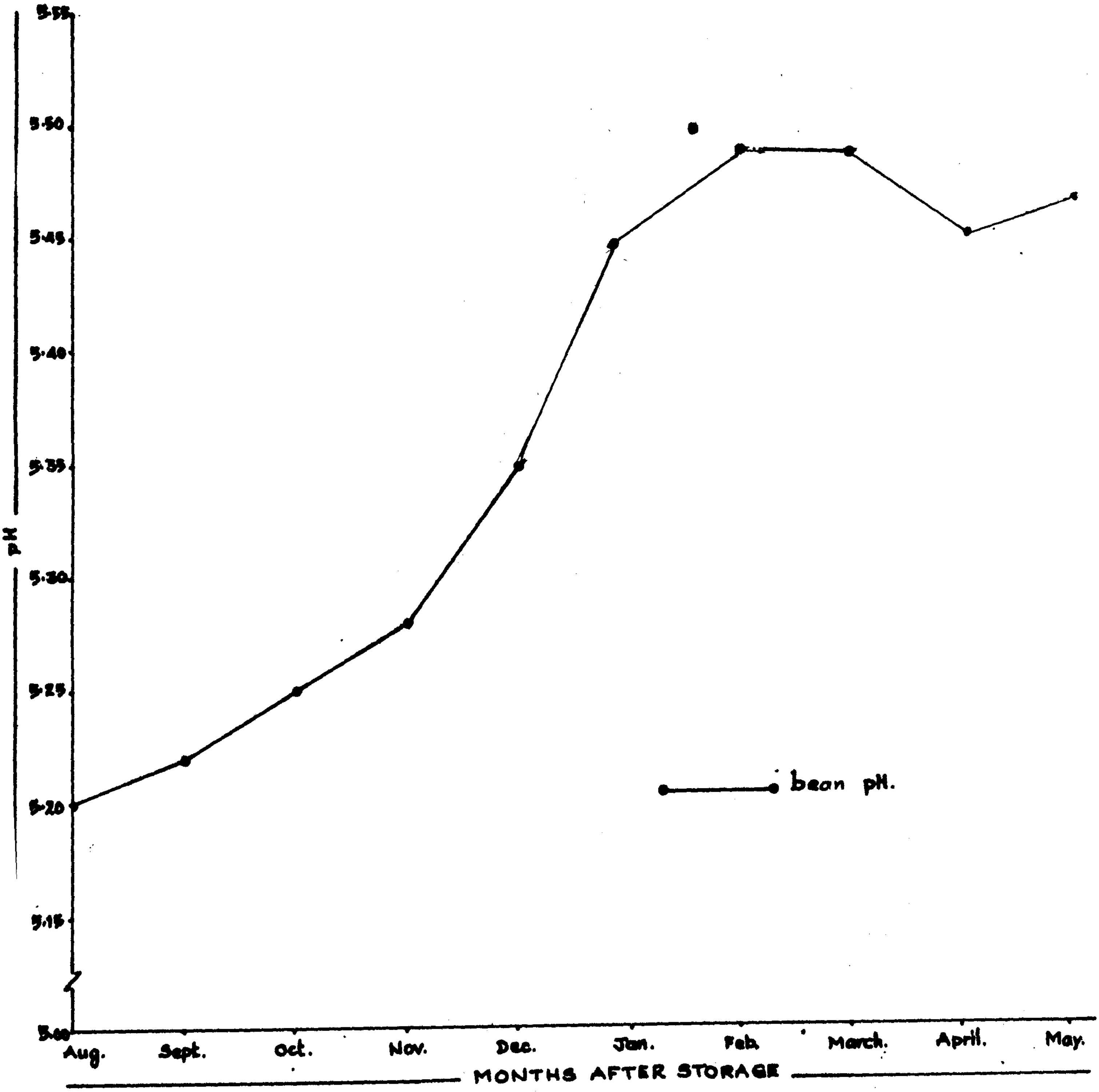


Fig. 14 - CHANGES IN pH OF THE COTYLEDONS OF THE CURED BEANS DURING STORAGE.



the cured beans during ten months of storage are presented in Table 30, Fig.13 and Fig.14.

During the ten-month storage, the percentage of brown beans increased from the initial 48 to 71. The percentage of commercially acceptable beans (brown + pale purple) increased from 74 during August 1980 to 92 during May 1981. There was a decrease in the quantity of purple beans (from 26.0 per cent to 8.0 per cent). The pH of the cured beans increased from 5.20 in August 1980 to 5.48 in February and March 1981. During the last two months of storage, a slight reduction in the pH was observed.

Discussion

DISCUSSION

The attractive price that prevailed during the early 1970's and the massive development programmes implemented by the State Department of Agriculture made cocoa a very popular crop in Kerala. As a result, India became a cocoa exporter by 1980 having exported 1000 tonnes of cocoa products valued at Rs.10 lakhs (Anon., 1981). However, the fall in the international price level and the hesitancy of the manufacturing companies to buy cocoa caused heavy losses to the cocoa growers during the late 1970's. The cocoa growers of Kerala were not familiar with the post-harvest fermentation and curing techniques. Further, the fact that cocoa growers in Kerala were small holders accentuated the problem. It was felt that standardisation of small scale methods of fermentation and curing of cocoa will enable the small scale cocoa growers to store the cured product till the market price level improved.

Results of the studies conducted at the College of Horticulture during 1979-81 period are discussed in this chapter. The studies aimed at identifying a method of fermentation suitable for small quantities of cocoa beans and at standardising the factors influencing the quality of cured beans.

EFFICACY OF DIFFERENT METHODS OF FERMENTATION

Based on a critical study of the extant information, seven methods were selected. These included the mini-basket method, the tray method and the box method which have been indicated by earlier workers as methods suitable for fermentation of small quantities of cocoa (Rohan, 1958; Quesnel and Lopez, 1975 and Kumaran et al., 1980). The efficacy of these methods was assessed based on the development of temperature during fermentation and on the results of the standard cut test. Temperature development in the top and bottom portions of the bean mass was monitored during the period of fermentation and the data (Tables 1 to 7) indicated that the temperature rose from the initial level to a peak by the fourth day, dropped a little on the fifth day and again rose on the sixth day. From the sixth day onwards, there was a steady drop in temperature. Similar trends have been observed by Hardy (1960), Wood (1975) and Adomako _et al_. (1981). Though the trend was the same in the seven methods and with the three quantities of beans, the actual level of temperature attained varied with the method and with the quantity.

A critical analysis of the results indicated that the optimum temperature level was developed when the beans were fermented in the mini-baskets lined with banana leaves or in the mini-boxes. In the mini-baskets lined with polythene sheet and small heap with polythene sheet, the development of temperature was found to be inadequate. This can be attributed to the improper insulation and aeration. The use of polythene sheet instead of banana leaves might have led to unsatisfactory aeration and hence low temperature build up during fermentation.

In the large scale methods of fermentation, the maximum temperature normally ranged between 48.0°C and 50.0°C. The peak is reached by the third or fourth day after setting (Hardy, 1960 and Wood, 1976). In the mini-basket lined with banana leaves and mini-box (identified as the best methods in the present study), the peak temperatures attained were slightly lower (46.0°C to 48.5°C), as compared to those under large scale methods of fermentation. The lower peak temperatures observed can be explained as due to the small quantities of beans and the consequent dissipation of the heat developed due to inefficient conservation concomitant with excess aeration in the ferment. With regard to the three quantities studied, there was differential behaviour between the two methods identified as the best. In the mini-baskets lined with banana leaves, temperature development with six kg beans was better than with the other two quantities. In the mini-boxes, however, the difference in temperature development between the three quantities was not significant. These observations and the results obtained by Kumaran et al. (1980) suggest that wooden containers retain the temperature better, even if the quantities fermented are small.

While the results obtained with single trays accommodating six, four and two kg wet beans were not encouraging, the stack of five small trays (each with two kg bean lot totalling to ten kg) gave as good temperature development as the mini-baskets lined with banana leaves and mini-boxes. As compared to the mini-basket and mini-box methods, aeration was satisfactory in the stack of trays and this helped in maintaining the temperature.

The cut test has been accepted as one of the most reliable methods for assessing the quality of the fermented beans (Wood, 1975). As such, the standard cut test was performed in the beans fermented by the different methods. The results showed significant variation among the methods, quantities, method x quantity interaction and method x duration interaction in respect of production of brown beans (Table 9). Among the different methods, mini-basket lined with banana leaves and mini-box were found to be on par; but superior to the others. It may be recalled that development of optimum temperature was observed in these two methods only. A temperature range of 40.0°C to 50.0°C is necessary for most of the biochemical activities to proceed in the fermenting cocoa beans (Hardy, 1960). In the above two methods, this temperature range was obtained. The three quantities of cocoa beans were found to be equal with respect to the production of brown beans under the mini-box, whereas under the mini-basket lined with banana leaves, six kg and four kg gave higher proportion of brown beans than two kg. A perusal of the data showed that the temperature development was almost identical with respect to the three quantities of beans fermented in mini-box, whereas higher temperature was observed in the mini-basket with the larger quantity. This may be the reason for six, four and two kg being equally effective when fermented by the mini-box method. Among the three durations of fermentation tried, six days gave maximum proportion of brown beans. Fermenting for more than six days lowered the percentage of brown beans. This may be due to the lowering of phenolics in the cotyledons by hydrolysis of the glycosides under prolonged fermentation.

Brown and pale purple beans are acceptable in the cocoa trade. The specifications state that a proportion of 30 to 40 per cent pale purple beans is acceptable (Anon., 1968). As such, data on the production of brown + pale purple beans under the different methods were analysed. The results indicated trends similar to those observed when production of brown beans alone was analysed.

All the methods, except the mini-basket lined with banana leaves and the mini-box produced comparatively higher proportion of purple beans. The purple colour is due to the presence of unchanged anthocyanins in the dried beans. During proper fermentation, the anthocyanins are hydrolysed to colourless leuco-anthocyanins (Wood, 1975). In the methods other than the mini-basket and the mini-box, temperature development during fermentation was inadequate. As such, the biochemical reactions leading to the hydrolysis of the anthocyanins would not have taken place. This may be the reason for the higher proportion of purple beans.

Slaty beans were observed in the small heaps (with banana leaves as well as with polythene sheet) and single tray methods. Slaty beans have been defined as those having a slaty colour on half or more of the surface exposed by a cut made lengthwise through the centre (Wood, 1975). According to him drying the beans before completion of the changes associated with fermentation causes the production of slaty beans. In the methods mentioned above, temperature development was not proper, probably due to the smallness of the bean mass. This resulted in non-completion of the biochemical processes connected with fermentation and in the production of slaty beans.

Over-fermented beans will have a dull, dark appearance when cut. Further, unpleasant odour develops in the fermenting bean mass (Wood, 1975). In the present studies, fermentation beyond six days led to the production of over-fermented beans.

THE COMPARATIVE EFFICIENCY OF THE FERMENTATION METHODS DURING DRY AND WET SEASONS

The efficiency of the three fermentation methods (mini-basket lined with banana leaves, mini-box and set of five small trays) identified as promising in the earlier studies was compared during the dry (April and May) and wet (July and August) seasons. The temperature development, pH of the pulp and the cotyledons during fermentation, pH of the dried beans, results of the cut test, average bean weight, shell percentage and the percentage recovery of cured beans were the criteria used for the comparison. The studies were limited to one quantity, based on the earlier results.

Temperature recorded in the top portion and bottom portion of the fermenting bean mass indicated that though the trend in temperature development was the same during the dry and wet seasons, the peak temperature attained was considerably lower during the wet season (Table 11). Similar observations have been recorded by Allison and Kenten (1963) who suggested that the ratio of water to dry matter in the raw unfermented beans would be higher during the wet season and that this would account for the slower rate of heating during the wet season. The production of heat during fermentation results from the activities of the micro-organisms (Kenten and Powel, 1960). The environmental conditions, particularly the temperature, during the dry season will be more conducive to the microbial activities than those during the wet seasons. This would have been the reason for the lower peak values obtained during the wet season.

Data on the pH of the pulp (Table 12) indicated that the pH of the pulp was lower in the wet season than that during the dry season. The oxidation of acetic acid is likely to be less during the wet season which would have led to the low pH values. In both the seasons, a gradual increase in the pH of the pulp could be observed as fermentation progressed. The acids produced during fermentation infiltrate into the cotyledons, thus leading to an increase in pH of the pulp as fermentation progressed (Wood, 1975).

In the case of the cotyledon also, the pH was lower in the wet season as compared to that during the dry season (Table 12). During the dry season degradation of the acetic acid produced will be more which will result in an increase in pH (Roelofsen, 1958). In the dried bean, satisfactory pH (5.42 to 5.58) was obtained in the dry season. In the dry season, the beans were sun-dried whereas in the wet season, they were dried artificially. Drying was completed within 48 hours at a temperature of 47-51°C. Drying at lower temperatures with prolonged duration was not possible during the wet season as the beans became mouldy. Under the forced artificial drying at 47-51°C with short duration, low pH values were obtained. According to Quesnel (1972), rapid high temperature during drying will not lend sufficient time for the volatilisation of acetic acid, thus leading to higher acidity in the dried cotyledons.

In both the seasons, the variation in the pH of the pulp and cotyledons was small and inconsistent, in the three methods tried.

In the three methods studied, the cut test showed highly significant variation between seasons in the production of brown and brown + pale purple beans (Tables 14 and 15). The dry season gave significantly higher proportion of brown and brown + pale purple beans than the wet season. Development of optimum temperature and the occurrence of the biochemical reactions in a more favourable manner would have led to higher proportion of brown and brown + pale purple beans. During the wet season, higher proportion of purple beans were obtained (Table 16). Proper hydrolysis of the anthocyanins might not have taken place during the wet season. This would have led to higher proportion of purple beans.

The dry season gave higher average bean weight, lesser shell percentage and greater percentage recovery (Tables 17, 18 and 19) than the wet season. These observations are in conformity with the results reported by Hudson (1913), de Verteuil (quoted by Rohan, 1960), Allison and Kenten (1963), Toxopeus and Wessel (1970) and Egbe and Owolabi (1972). The recovery during the wet season was observed to be 33.3 to 35.3 per cent and upto 40.0 per cent in the dry season (Hudson, 1913). de Verteuil (quoted by Rohan, 1960) found 42.3 to 42.5 per cent recovery during the wet season and 45.0 per cent, during the dry season. According to Toxopeus and Wessel (1970), beans harvested in the wet season (June-July) start their development in the dry season. Therefore, they will be small and with a higher shell percentage.

MATURITY OF PODS AT HARVEST IN RELATION TO FERMENTATION OF COCOA BEANS

Fermentation characteristics of the beans from four maturity groups of pods were assessed after fermenting six kg beans in mini-baskets. Temperature development was very poor when beans from green pods were fermented (Table 20). Beans from the pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods recorded higher maximum temperatures. However, beans from the pods showing yellowing only in the furrows and yellow/ripe pods took one to three days longer to reach the peak temperature than the beans from over-ripe pods.

When beans from green pods were fermented, variation in the pH of the pulp and the cotyledons was low and inconsistent (Table 21 and 22). Knapp (1926) classified the green pods as under-ripe pods and stated that the pulp will be deficient in sugars. As such, it is possible that proper fermentation might not take place when such beans are fermented. A rapid drop in the pH of the cotyledons was observed on the fourth day when beans from yellow/ripe pods and over-ripe pods were fermented. This may be due to the fact that the beans from the yellow/ripe and over-ripe pods contained higher fermentable sugars in their pulp and larger quantities of acids produced during fermentation entered the cotyledons, causing a rapid pH drop. From the fifth day onwards, a steady rise in pH could be observed which may be explained as due to the volatilisation of acetic acid from the well-aerated fermenting bean mass.

On drying, satisfactory pH (5.55 to 5.95) was obtained in the case of beans from the pods showing yellowing only in the furrows, yellow/ripe pods and over-ripe pods.

Results of the cut test conducted revealed that the over-ripe pods gave the highest value for brown and brown + pale purple beans (Table 23). Beans from the green pods gave low proportion of brown and brown + pale purple beans on fermentation.

Physical quality characteristics of the cured beans indicated that over-ripe pods and yellow/ripe pods were superior to the others, as they gave higher average bean weight, lesser shell percentage and greater percentage recovery (Table 24).

EFFECT OF STORING HARVESTED PODS ON THE FERMENTATION CHARACTERISTICS

Storing the harvested pods (before the extraction of beans for fermentation) influenced the fermentation characteristics of the beans. Beans from pods stored for two, four and six days recorded increasing temperature during the first three days, compared to the beans extracted from pods on the day of harvest. The peak was attained on the fourth day in all the four categories of pods (Table 25). MacLean and Wickens (1951) found that by storing the pods for two or more days, significant temperature increase could be obtained during the first 48 hours of fermentation as compared to the beans from pods stored for only one day.

The difference in the initial pH of the pulp and the cotyledons was small among the four treatments (Table 26 and 27). A steady increase in the pH of the pulp was observed as fermentation progressed, followed by a drop on the seventh day. In the case of cotyledons, a steady drop in the pH was observed, followed by a gradual rise. In the case of beans from the pods stored for two, four and six days, pH variations in the pulp and the cotyledons were more marked. The pre-fermentation reactions within the stored pods might have resulted in the rapid fermentation at the initial stages.

The cut test (Table 28) showed significant variation between the treatments with respect to the production of brown and brown + pale purple beans. Pods stored for two and four days produced significantly higher proportions of these types of beans. Extracting the beans on the day of harvest was found to yield low proportion of brown and brown + pale purple beans.

The average bean weight was not significantly influenced by storage of the pods after harvest. Beans from the pods stored for two, four and six days gave significantly lower shell percentage and higher recovery of cured beans, while the beans from freshly harvested pods produced the least values (Table 29).

Quality attributes of beans in relation to storage

The cured beans were stored for a period of ten months to monitor the changes in the quality characteristics during storage. As the storage period increased, there was an increase in the proportion of brown and brown + pale purple beans. The purple bean percentage decreased as the storage period increased. MacLean and Wickens (1951) studied the rate of change of the purple bean count during storage of cured cocoa beans and observed that purple bean percentage fell from 30 to 20 during 36 weeks of storage. According to Roelofsen (1958), the oxidation of flavonoid polyphenols yield high molecular brown products. Unoxidised polyphenols such as cyanins are present in the purple cotyledons. He also suggested that the extent of browning is a function of the extent to which the dissolved oxygen diffuses into the testa before the oxidase enzyme is inactivated by drying. It may be assumed, therefore, that during storage, oxidation of flavonoid polyphenols like cyanins might have occurred which in turn converted the purple beans to pale purple beans and pale purple beans to brown beans.

Bean pH was found to increase during storage. Couprie (1970) reported that pH of the cured beans increased during the first six months of storage. In the present studies, maximum pH value was obtained during the seventh month of storage. After remaining steady for another month, the pH recorded a slight reduction in the nineth and tenth month. During storage, volatilisation of acetic acid present in the cured beans might have taken place leading to an increase in pH.

Summary

SUMMARY

Studies were conducted at the College of Horticulture, Vellanikkara during 1979-1981 to identify a method of fermentation suitable for small quantities of cocoa beans and to standardise the factors that influence the quality of cured beans. Results of the investigations are summarised below:

1. Temperature development in the top and bottom portions of the bean mass was monitored during the period of fermentation in the seven methods compared in the studies. Temperature rose from the initial level to a peak on the fourth day, dropped a little on the fifth day and again rose on the sixth day. From the sixth day onwards, there was a steady drop in the temperature. Peak temperatures attained under mini-basket lined with banana leaves and mini-box were satisfactory (47.5°C to 48.5°C).

2. Polythene sheet was found to be a poor insulating material as compared to banana leaves. The use of polythene sheet led to unsatisfactory aeration and low temperature build up during fermentation.

3. With the three quantities studied, there was differential behaviour between the methods as far as the temperature development was concerned. In the mini-basket lined with banana leaves, six kg bean lots gave proper temperature

development whereas in the mini-box all the three quantities were on par in this respect.

4. Results of the cut test showed significant variation among the methods, quantities, method x quantity interaction and method x duration interaction in respect of production of brown and brown + pale purple beans. Among the different methods, mini basket lined with banana leaves and mini box were found to be on par. They exhibited superiority over the others in the production of beans acceptable to the cocoa trade (79 to 83 per cent against 30 to 58 per cent in other methods). With respect to the three quantities studied, six and four kg bean lots gave better results when fermented under mini-basket lined with banana leaves whereas the three quantities were on par under mini box. These two methods produced least quantities of purple beans (18.10 to 19.50 per cent against 48.00 to 69.00 per cent in other methods).

5. Based on the temperature development in the ferment and on the results of the cut test, mini-basket lined with banana leaves and mini-box were identified as suitable for fermenting small quantities of beans.

6. Fermentation beyond six days led to the production of over-fermented beans in all the methods.

7. Though the trend in temperature development was the same during the dry and wet seasons, the peak temperature attained was better during the dry season (47.5°C to 48.5°C in the dry season against 41.0°C to 43.0°C in the wet season). Further, pH of the dried beans (5.42 to 5.58 in the dry season against 4.90 to 4.94 in the wet season), proportion of commercially acceptable beans (58.84 per cent in the dry season against 46.61 per cent in the wet season) and physical quality characteristics of the beans such as average bean weight (1.04 g in the dry season against 0.86 g in the wet season), shell percentage (14.83 in the dry season against 19.50 in the wet season), percentage recovery (35.87 in the dry season against 28.73 in the wet season) etc. were better during the dry season than during the wet season.

8. The studies indicated that it is desirable to extract beans from yellow/ripe pods and over-ripe pods for fermentation. Fermentation of such beans gave optimum temperature development (48.0°C to 49.0°C), desirable pH in the dried beans (5.55 to 5.58), higher proportion of commercially acceptable beans (72.41 per cent) and desirable physical quality characteristics such as average bean weight (1.14 g to 1.15 g), shell percentage (13.90 to 15.80) and percentage recovery (35.76 to 36.04).

9. The studies suggested that storing the harvested pods for two to six days before the extraction of beans for fermentation will result in optimum temperature development (47.5°C to 48.0°C), pH of the dried beans (5.54 to 5.59), production of acceptable beans (57.42 to 63.96 per cent). Further, the beans had good physical quality characteristics (1.07 g to 1.08 g average bean weight, 13.20 to 13.85 shell percentage and 35.40 to 35.53 percentage recovery) also.

10. Storing the cured beans increased the brown as well as brown + pale purple bean count (from 48 to 71 and 74 to 92, respectively). An increase in the pH of the beans (from 5.20 to 5.48) was also observed during the 28-week storage.

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* Originals not seen

Appendices

APPENDIX I
ANOVA Table

Production of brown beans under six methods of fermentation

	Transformed data (angular transformation	
Source	df	MS
Methods	5	539.48**
Quantity	2	177.67**
Method x Quantity	10	55.64**
Duration	2	476.04**
Method x Duration	10	94.14**
Quantity x Duration	4	5.24
Method x Quantity x Duration	20	2.42
Error	54	3.29

** Significant at 1% level

APPENDIX II

ANOVA Table

Production of brown + pale purple beans under six methods of fermentation

Source	df	MS
		Transformed data (Angular transformation)
Method	5	1241.32**
Quantity	2	210.48**
Method x Quantity	10	69.99**
Duration	2	241.17**
Method x Duration	10	177.90**
Quantity x Duration	4	6.40
Method x Quantity x Duration	20	5.24
Error	54	4.72

** Significant at 1% level

APPENDIX III

ANOVA Table

Comparative efficiency of the fermentation methods during the dry and wet seasons

Source	df	Mean squares					
		Brown beans	Pale purple beans	Purple beans	Average bean weight	Shell percentage	Percentage recovery
Method	2	24.08*	115.63*	120.10*	0.001	4.25	24.82
Season	1	2218.8**	76.80**	3080.53**	0.47**	163.80**	2018.80**
Method x Season	2	24.08	39.90	19.63	0.42	0.0004	24.39
Error	24	10.22	18.98	9.22	0.004	1.27	10.50

* Significant at 5% level
** Significant at 1% level

APPENDIX IV

ANOVA Table

Maturity of pods in relation to fermentation characteristics

Source	df	Mean squares					
		Brown beans	Pale purple beans	Purple beans	Average bean weight	Shell percentage	Percentage recovery
Pods	3	1351.54**	1995.12**	1358.56**	0.18**	51.39**	28.96**
Error	16	6.19	5.37	6.22	0.002	1.97	0.35

** Significant at 1% level

APPENDIX V

ANOVA Table

Effect of storing the harvested pods on the fermentation characteristics

Source	df	Mean squares					
		Brown beans	Pale purple beans	Purple beans	Average bean weight	Shell percentage	Percentage recovery
Pods	3	318.26**	296.78**	322.72**	0.003	3.66**	6.84*
Error	16	5.76	4.50	5.95	0.002	0.69	0.27

*-Significant at 5% level
**-Significant at 1% level

STUDIES ON THE FERMENTATION AND CURING OF COCOA BEANS

By

T. PREMALATHA

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Horticulture (Plantation Crops & Spices)
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

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ABSTRACT

Investigations conducted at the College of Horticulture, Vellanikkara during 1979-81 indicated mini-basket lined with banana leaves and mini-box as the methods suitable for fermenting small quantities of beans. These methods were chosen from among the seven studied, based on the temperature development in the ferment and on the results of the cut test.

Polythene sheet was found to be a poor insulating material as compared to banana leaves having led to unsatisfactory aeration and low temperature build up during fermentation.

Fermentation during the dry season was found to be better with respect to the fermentation characteristics and physical quality characteristics of the beans.

Fermentation of beans from yellow/ripe pods and over-ripe pods gave higher proportion of commercially acceptable beans. The cured beans had desirable pH and good physical quality characteristics.

Storing the harvested pods for two to six days before the extraction of beans for fermentation led to the development of optimum temperature in the ferment, desirable pH in the dried bean and the production of a higher proportion of commercially acceptable beans.

Storing the cured beans increased the proportion of commercially acceptable beans. An increase in the pH of the beans was also observed during the 28-week storage.