PROCESSING QUALITIES OF CASHEWNUT IN RELATION TO AGROECOLOGICAL AND PHENOLOGICAL FACTORS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I here by declare that the thesis entitled "**Processing qualities of cashewnut in relation to agroecological and phenological factors**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled "**Processing qualities of *cashew nut* in relation to agroecological and phenological factors**" is a record of research work done independently by **Miss. Divya. S. Raman,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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I submit this small achievement before God Almighty who has bestowed on me good health and confidence for the successful completion of my study and I thank him just for everything.

Divya. S. Raman

Affectionately dedicated to

my

loving Parents

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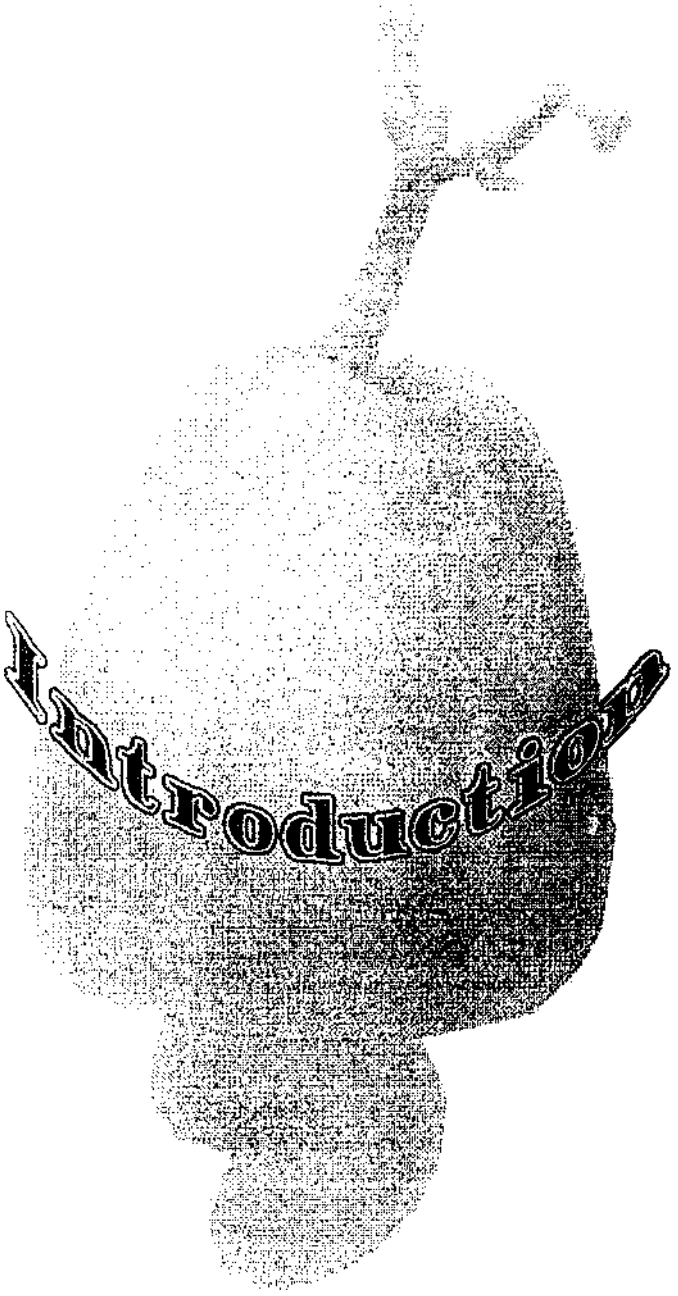

Introduction

INTRODUCTION

The tremendous potential of the technological advancement evolved by the research, while is really making a revolutionary dent into the developmental aspects of cashew, the regionalised outlook is further anchoring this aspect in a much more conspicuous manner. Regional approach in promoting cashew has been the pressing need of the hour due to the high amount of variation in ecological systems prevailing in different parts of the cashew growing states.

Cashew in India is an introduced crop of nearly 500 years of tradition for its cultivation and 75 years for processing and export. In India cashew trade is the 3rd highest foreign exchange earner among agri-based export market. Cashew kernels are the most important item of international trade. In the global market India's share is 50 per cent, closely followed by Brazil with 30 per cent.

Technologies suited to different regional perspectives on varietal basis, multiplication techniques, package of practices on nutrition, crop protection, soil and moisture conservation and physiological management of cashew, which at present are helping the development of cashew plantations of high yielding nature.

It is a fact that the performance of the varieties and hybrids are found to be region specific and they are well suited only for the region for which they have been recommended (Salam 1998). The suitability is depended on many factors like

soil type, weather parameters, especially temperature, humidity, rainfall and also the pest incidence.

Hence it is possible to have variation in quality of the nuts and kernels also depending on the agroecological region in which they are grown. This aspect remains to be an unstudied one when the whole cashew trade depends on the 'quality of kernels'. In this study attempts were made to account the variation in nut and kernel quality in relation to different agroecological regions.

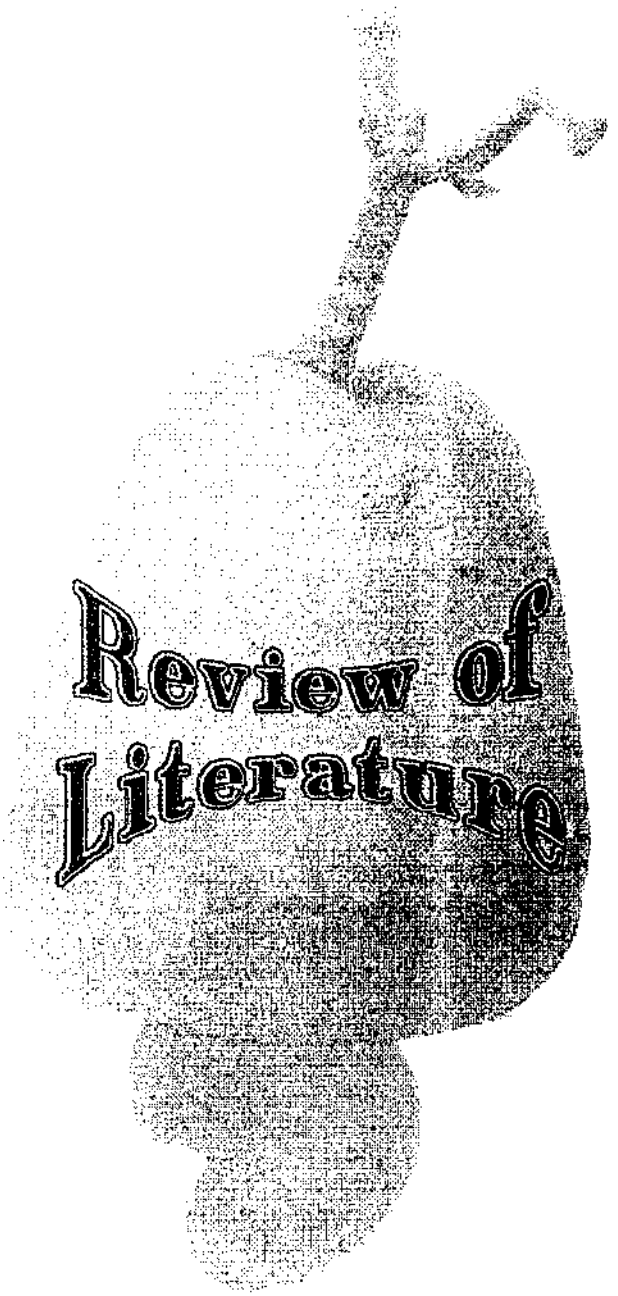
Apart from their genetical character the weather inflicted changes on flowering behaviour of cashew varieties is a usual phenomenon (Rao, 1999). The weather conditions like temperature, humidity, rainfall, sunshine etc. prevail at the time of flowering, nut set and development will have a say on quality of nuts. Hence in this study efforts were made to study the quality of nuts and kernels in relation to flowering behaviour of varieties. Again it was felt interesting to study the nut quality in relation to different parts of the harvest phase of a single variety.

Another aspect that may govern the quality of kernels is the raw nut quality. At present, in raw nut grading much emphasis is given on size of raw nuts. Lot of research efforts are also being laid down for developing varieties with good nut size (above 8g). In this perspective, it will be worthy to analyse the quality of kernels in relation to size of raw nuts.

The implication of harvesting and processing the less mature nuts on the physical and biochemical characters of the nuts is not a well studied one. Due to

obvious difficulty of undertaking harvests a number of times and fearing pilferage, the farmers usually adopt the harvesting methods like thrashing with poles or shaking the branches allowing immature nuts also to fall. Incorporating such nuts in lots for processing affect the general quality of kernels but its specific impacts are not studied. Hence this study aims to analyse the post harvest quality shifts in relation to stages of maturity.

In toto the present investigation was an integrated approach to study the processing qualities of cashewnuts in relation to agroecological regions, flowering behaviour of varieties, maturity stages of nuts, size of nuts and incidence of pest attack.


Review of
Literature

REVIEW OF LITERATURE

Quality of nut and kernel is the sum effect of the physical and biochemical characters. These characters are largely influenced by the soil and climate in which cashew is grown (Rao and Gopakumar, 1994).

Hence it will be relevant to examine the variation in nut and kernel quality as influenced by different parameters like agroecology and phenology of the crop based on the reported literatures. Size of nuts, their stage of maturity and season of harvest also bring about variation in physical and biochemical parameters.

2.1 VARIATION IN PHYSICALCHARACTERS OF NUT AND KERNEL

2.1.1 Effect of Agroecological factors

Adequate literature on variation in physical characters of nuts of the different varieties grown in a particular agroecological region is available, but work on variation in nut characters when the same variety is grown in different agroecological regions is meagre.

Giuliani and Agnoloni (1975) studied the variation in physical characters of cashew nuts collected from different agroecological regions viz ., Togo, Dahomey, Ivory Coast and Senegal and reported that size, weight and volume of nuts collected from these regions differ significantly.

According to Ohler (1979) the nut characters such as weight, length, breadth and thickness are mainly governed by genetic factors of a variety.

Kumar (1985) reported that soil fertility have profound influence on quality of nuts, mainly on protein content of kernels.

Kumar and Sreedharan (1987) reported that application of nitrogen and phosphorus reduced the nut weight and volume, while the nut density was not influenced. Application of potash did not cause significant decrease in the nut weight but there was an increase in nut density by different levels of potassium. They further reported that application of nitrogen, phosphorus and potash to the soil was found to improve shelling percentage and kernel protein content.

Tisdale *et al.* (1990) identified physiological function of potassium in nitrogen metabolism and synthesis of protein apart from catalytic action.

Latha *et al.*(1996) studied the quality of nuts in terms of protein content of kernels as influenced by nitrogen, phosphorus and potash content in soil. The nitrogen present in the soil significantly influenced the protein content of kernels. Though phosphorus and potash influenced the protein content of kernels, they did not bring marked difference.

Flowering habit of varieties was found to vary at different agroecological regions of Kerala (Rao and Gopakumar, 1999). There was a delay in cashew flowering across Kerala depending upon latitude and altitude irrespective of

the varietal difference. The flowering of cashew varied from 15th November in South (Kottarakkara 9^0 16'N; 76^0 37'E; msl –91m) to 15th December in North (Pilicode $12^0$12'N; $75^0$10'E; msl –15m) and extended upto 15th January at higher altitude (Ambalavayal- 11^0 37' N; 76^0 01'E; msl – 974 m).

2.1.2 Influence of flowering behaviour of varieties.

Vidhyachandra and Hanamashetty (1982) opined that long flowering and harvesting period is associated with low yielding varieties and short flowering and harvesting period with high yielding varieties.

Based on the difference in flowering behaviour, Nalini and SanthaKumari (1991) selected out the varieties, K-10-1, K-16-1, K-10-2 and K-26-1, having short flowering span and harvesting period.

According to Hallad and Sulikeri (1992), the shortest period of flowering was observed in 2/77 Tuni Andhra (115.66days) followed by 6/21 Moodabidri- Mysore (116.33 days). The longest period of flowering was observed in 2/64 Madhuranthakam – Madras (128.66days).

Sapkal *et al.*(1994)reported that duration of flowering in the different selections of cashew ranged from 95.08 to 119.83 days.

Variability in flowering duration was also observed among cashew genotypes under Vridhachalam conditions (Subramanian *et al.*, 1996). Shortest

flowering period (52 days) was observed with a Mysore type, ME 15/4 and longest flowering period with a Madras type, A-5/2(88 days).

Sheshagiri (1996) evaluated 15 cashew types growing at Regional Research station, Mudigiree for flowering period, and number of staminate and perfect flowers. Flowering was found to occur from mid December to late May in major selections and synchronised flowering types were not observed in the population.

Investigations carried out under All India Co-ordinated Cashew Improvement Project at Bhubaneswar during 1995-'96 in 13 clonally propogated cashew types revealed that the flowering period was found to continue up to 14 weeks in certain varieties (Lenka *et al.*, 1999).

Studies on floral characters of 14 clones were carried out at CRS, Bapatla by Dorajeerao *et al.* (1999). Duration of flowering was found to vary among clones from 57 to 72 days.

Dorajeerao *et al.* (2000) studied the influence of flowering phases on 14 cashew clones at CRS, Bapatla, and reported that early flowering clones were found to be high yielders under local agro-climatic conditions of Bapatla. Poor yielding clones like 107/3 and HY68 recorded longer duration of flowering.

Pushapalatha (2000) identified the early, mid and late season varieties based on their date of flowering and classified them into 12 early varieties (flowering

before mid November), 38 mid season varieties (flowering between mid November and December) and 17 late varieties (flowering after mid December). Variety Anakkayam–1 which recorded 50 percent flowering by first fortnight of October was identified as the earliest among the 67 varieties studied.

2.1.3 Influence of nut maturity

The pattern of growth and development of cashew apple and nut had been reported by Damodaran (1966). The ovary was found enlarged first and became visible within one week after pollination. During the first two weeks after pollination the pericarp grow more rapidly than the embryo. Later the growth of embryo was faster till it filled the shell cavity. The nut was found to reach the maximum size in five to seven weeks and later shrunk a little while the shell hardened. By the seventh week, the cashew apple surpassed the nut in terms of size.

Chattopadyay *et al.* (1983) reported that the growth patterns of cashew apple, nut and kernel was of different types. Initially the nuts grew much faster than the apples, but in later stages apple size increased much more rapidly and out grew the nut. Both pericarp and kernel are reported to reach maximum size in about 30 days.

Kumar *et al.*(1984) analysed the physical parameters of growth of cashew nuts during different stages of its growth and development. They reported that the length and breadth ratio for nut was found to increase upto 30 days and later showed a declining trend, while the volume of nut showed an increasing trend upto

50 days after fruit set. They opined that optimum fruit development occurred 70 days after fruit set.

Studies on the physical indices of maturity of the cashew nut varieties: Vengurla –1,2,3,4 and 5 was conducted by Antarkar and Joshi (1987). The weight, volume and diameter of the nut was reported to increase rapidly till ¼th grown apple stage followed by a slight decline thereafter till full grown apple stage in all the varieties studied. The specific gravity of the nut recorded an increasing trend from fruit set till maturity.

Renganayaki and Karivaratharaju (1993) studied the effect of stages of maturity on nut and kernel quality parameters. The difference in 100 seed weight was found highly significant among the stages of maturity. The nuts which attained maturity 40 days after fruit set recorded the lowest mean value of 339.40 g, the nuts of 50 DAFS recorded 465.50g and 60 DAFS recorded 537.90g.

Kutty (2000) reported highest rate of growth for cashew nut during the early stages of its growth. Nuts attained maximum size at 3o to 40 days after fruit set stage. Kernel formation was found to commence 20 days after fruit set stage.

2.1.4. Influence of nut size on kernel quality

Rao and Hassan (1956) could not find any significant correlation between nut size and kernel content. They opined that the size of nut is not a reliable index of the kernel content. They obtained a high degree of correlation between the

weight of nuts and weight of kernels, viz., the heavier nuts were found to have heavier kernel. However Gowda *et al.* (1989) opined that nut size is one of the most important characters for commercial acceptance, since they obtained high correlation between kernel size and shelling percentage with size of nuts.

Veeraraghavan (1990) reported that the nut size of cashew hybrids differ significantly under Madakkathara conditions (5.80 to 10.85). The kernel weight was found to range between 1.42 to 2.76g.

Evaluation of the cashew germplasm accessions at CPCRI, Vittal resulted in the release of NRC Cashew selection 1 and 2 (Swamy *et al.*,1990). These two selections were found to have medium nut size (7.6-9.2g) and shelling percentage (29%) together with good kernel count (210 wholes/lb).

Manoj *et al.*(1993) reported that though the nut size of hybrids studied was found to be medium, they had large sized kernels weighing more than two grams. The shelling percentage was also found to be at a higher level in hybrids (30%) having big nut size.

A study was conducted at Cashew Research Station, Madakkathra to identify varieties having favourable processing characters viz., good nut size, shelling percentage, kernel size, white wholes and less kernel pieces and rejects (Salam, 1998). Among the 18 varieties tested, H 1598, M 26/2 and H 1608 were found to be the best, possessing ideal processing characters at the maximum.

2.1.5. Effect of pest attack on nut quality

The cashew, a dollar earning nut crop is being attacked by more than fifty species of insect pests through out the world (Beccari and Gerini, 1968). However, Nair *et al.*(1979) reported more than sixty species of insect pests on cashew in India. Annually 50 percent of crop loss was reported due to pests and diseases in cashew (Haribabu *et al.*, 1983).

Eventhough the extent of crop loss and damage incurred by various pests on floral parts and immature nuts are studied, their effect on the kernel quality and ultimate produce studied is little.

Tea mosquito Bug

Tea Mosquito (*Helopeltis Antonii)* is considered to be the most voracious pest of cashew. This pest was first reported in South India by Ayyar (1942).

Infestation by the tea mosquito bug, flower thrips and fruit borers were reported to cause 12.3 percent fruit drop during mustard stage, 16.4 percent during pea nut stage and 1.1 percent during later stages (Pillai and Pillai, 1975).

Pillai and Abraham (1975) reported that immature nuts attacked by tea mosquito showed circular depressions and in majority of cases the infestation resulted in shrivelling and drying of nuts. Such nuts were characterised by the

presence of eruptive spots on them. Pest attack in early stages of fruit set and development of nuts resulted in immature fruit drop also.

The nymphs and adults suck the sap from tender shoots, inflorescence, immature nuts and apples. Pillai (1980) estimated the nut damage and fruit drop to the extent of 15 and 12.29 percent, respectively due to attack by tea mosquito.

The feeding activity of the pest is higher during the morning hours before 9a.m and in the evening hours after 4p.m (Abraham and Nair, 1981).

Haribabu *et al.* (1983) reported that cashew in India is known to be attacked by over 50 species of insects, of which *Helopeltis antonii* Sign. extracts sap from the tender shoots and nuts.

Devasahayam and Nair (1986) reported that infestation by tea mosquito bug causes lesions on the fruits which appear as brownish –black circular scabby spots. When immature nuts are infected, they shrivel and dry up; older nuts and apples develop a characteristic scabby appearance.

Thrips

Among the foliage and flower pests, the thrips which occur sporadically, cause considerable damage to cashew. *Rhynchothrips raoensis* is one of the cashew flower thrips attacking the cashew inflorescence (Abraham, 1958).

A study carried out at CPCRI, Kasaragod, revealed that attack by flower thrips alone accounts for 16.39% fruit drop (1.91% in the mustard stage, 12.57% in the peanut stage and 1.91% in the later stages) in cashew (Pillai, 1980).

Several species of flower thrips were known to attack the cashew flowers under different climatic conditions. *Rhynchothrips raoensis* Gaertn. and *Scirtothrips dorsalis* Hood. were observed in west coast agroclimatic conditions and *Haplothrips ceylonicus* (Schmutz) and *Frankliniella schultzei* (Tryhom) in east coast agroclimatic conditions (Patnaik *et al.*, 1987).

Jena (1988) reported that *Rhynchothrips raoensis* is a regular and serious pest of cashew. The injury made by the adults on immature stages of flowers, floral stalks, tender apples and green nuts results in shedding of flowers, immature fruit drop and formation of scabby, malformed fruits.

The rasping and feeding injury made by thrips results in scabs on floral branches, apples and nuts. Infestation on developing nuts results in the formation of corky layers on the affected parts; malformation of nuts and even immature fruit drop (Chatterjee, 1989).

2.2 BIOCHEMICAL CHARACTERISTICS OF CASHEW NUTS

Information on general biochemical characters of the cashew kernel are available, while studies on variation in biochemical attributes that may exist due to many factors are seemed to be reviewed in a limited extent. Hence the review is

limited to general biochemical characters of cashew kernels and available literature on biochemical characters influenced by ecological and phenological factors.

According to Fetuga *et al.* (1975) cashew nuts provide 7.76 k cal g^{-1}, 21 percent protein, 48 percent fat and are a good source of many minerals such as phosphorus, potassium, magnesium and iron.

The Cashew kernel with its close textured pulp is rich in proteins, calcium and phosphorus. It also contains unsaturated fats and vitamins B_1, B_2, D, E, and is low in carbohydrates and saturated fats. Hence it affords a high nutritional value, while its characteristics make it easily digestible and suitable even for the most delicate of diets such as those used in infancy and old age (Agnoloni and Giuliani, 1977).

At Central plantation crops Research Institute, Vittal, Nagaraja and Nampoothiri (1986) analysed cashew kernels from high yielding varieties for their biochemical constituents. No significant difference among the high yielding varieties were noticed with respect to protein, starch and amino acid contents. Reducing sugar content in all the varieties was found less compared to total sugar content which ranged between 9.34 to 19.24 percent among different varieties. Ansur –1 was reported to have the highest sugar content while variety Morgaon had the lowest sugar content.

Melo *et al.* (1998)analysed the chemical composition of the raw and toasted cashew nuts. The raw nuts are reported to contain moisture 5.05 percent; ash

2.40 percent; protein 22.11 percent; lipids 46.28 percent; total sugar 7.93 percent and starch 16.07 percent. The roasted nuts recorded moisture 1.18 percent; ash 2.43 percent; protein 21.76 percent; lipids 48.35 percent; total sugar 8.23 percent and starch 17.30 percent. Values for lipids, total sugars and starch were found significantly different, among the two samples.

Arogba (1999) reported that the cashew samples had 51 percent crude fat, 36 percent crude protein, 0.3 percent ash and 3.4 percent carbohydrate and the sample would retain its nutritional integrity when stored in atmospheres with water activities of upto 0.85.

2.2.1 Protein

Cashewnut (*Anacardium occidentale*) has the highest protein content among the tree nuts (Woodroof, 1970).

The protein content of the kernels ranged from 13.13 to 25.03 percent, indicating that the types studied differ widely in this vital constituent (Mohapatra *et al.*, 1972).

Cashewnuts contain 21 percent of vegetable proteins, which means that they are on par with soyabeans and groundnuts quantitatively, but quality wise they are more on the side of milk, eggs and meat. The amino acids, though found only in a minute measure in nuts, are in just the right amount for human specifications (Mahendru, 1978).

The kernel showed an increase in protein content upto 40 days after fruit set and it remained high till harvesting time (Chattopadhyay *et al.*, 1983).

The protein level in the cotyledonary cells of the early phase of nut development was found very low (Hariharan and Unnikrishnan, 1984) and at the mid-phase the content was found almost doubled. Storage protein granules started to occur at the mid phase. The total protein content that too in term of storage protein granules in the mature cotyledonary cells were more than double that found in the mid-phase.

Piva and Santi (1984) determined the protein and amino acid contents in whole kernel flour and in cashew byproducts obtained from different African sources (Benin, Mozambique and Tanzania) and Madagascar. They reported that the protein efficiency ratio of all the samples were almost same for whole kernels and for by products from different regions.

Varietal variation in protein content was studied by Nagaraja (1987). Defatted cashew kernel flour from M76/1 had the highest (73.14 µg/mg proteins) and Tr.273 BLA had the lowest (35.98 µg/mg protein) lysine contents. Extraction of protein from defatted kernel flour at pH 4 was almost 1/10 compared to pH 10. Lysine content in protein extracted at pH 10 was highest (63.3µg/mg protein) in variety M6/1 and lowest (35.12 µg/mg protein) in variety Tr.56BLA. He also reported that the kernel protein content among the high yielding varieties was not statistically significant and ranged between 32.1 to 43.76 percent.

Renganayaki and Karivaratharaju (1993) reported that the nuts which mature 60 DAFS recorded the highest protein content with a mean value of 34.28 percent, while the least was recorded with nuts at 40 DAFS stage (32.97 percent). The nuts which matured 50 DAFS recorded the mean protein value of 33.82 percent and was on par with that recorded at 60 days maturity stage.

Sathe (1994) reported that major proteins in cashew nut were found to be soluble in aqueous solvents and solubility is minimum at pH 5.0. Among the protein solubilising agents tested 0.1M NaOH was found as the most effective solubilizer of cashew proteins.

2.2.2 Fat

Vitagliano and Ruggiero (1969) compared the percentage of raw fat in the kernel with that found in the richer oil yielding seeds viz. peanuts, sesame, sunflower and reported the content to be almost same among these oil seeds and cashew kernels.

Murthy and Yadava (1972) studied the variations in fat content of kernels collected from different regions. The oil content in the kernels showed a wide variability and was 34.48 percent in kernels of district Ramapuram and 46.76 percent in kernels of the district Kumta. The kernel oil in the exotics showed a range between 34.8 and 42.48 percent.

By cold pressure extraction from the kernel residues, one can obtain about 40 percent of oil, known as "cashew kernel oil" or "Caribbean oil". It is reported to be sweet, light yellow in colour, odourless, non-dissecative and rich in unsaturated fatty acids (Agnoloni and Giuliani, 1977).

Nagaraja (1987) reported varietal difference with respect to the composition of neutral and glycolipids. The cashew kernels from the high yielding varieties were found to contain about 50 percent lipids. In that neutral lipid accounted for 96 percent while glycolipid and phospholipid accounted for the remaining four percent. Triglycerides were found very rich in unsaturated fatty acids (oleic and linoleic) while glycolipids were found rich in saturated fatty acids (lauric and myristic). Composition of phospholipids did not differ among high yielding varieties.

The fats in cashewnuts are abundant in vitamins A, D and E, that are cardinal in the assimilation control of fats and reinforcement of immunity function (Soman, 1990).

Renganayaki and Karivaratharaju (1993) studied the variation in fat content of cashew kernels in relation to their maturity stages. The nuts matured 50 DAFS recorded the highest mean value of 47.57 percent followed by the nuts at 60 DAFS stage (47.42 percent). The nuts matured 40 DAFS recorded the least mean value (46.88 percent).

Cashew nuts stock 47 percent of fat of which 82 percent is unsaturated fatty acids free of cholesterol (Narayanan,1998).

2.2.3 Carbohydrates and Sugars

Murthy and Yadava (1972) studied the variation in carbohydrate content of indigenous and exogenous varieties and reported that reducing sugars in indigenous cultivars ranged from 0.91 percent to 3.15 percent while it was 2.43 to 3.00 percent in exotic varieties. Non- reducing sugars in indigenous cultivars was found to vary widely and was 1.29 to 5.77 percent, compared to 3.56 to 4.42 percent in exotic varieties.

They also reported that starch content in indigenous varieties was 4.66 percent to 11.22 percent while the content in exotic varieties was 9.53 to 10.42 percent.

Chattopadhyay *et al.* (1983) analysed the pattern of sugar build up in cashew kernels of different maturity levels. A gradual build upto 40 days was recorded while the concentration was found declined sharply reaching minimum value at 48 days after nut set.

The GLC analysis on kernel meal has shown a predominance of saccharase together with smaller quantities of glucose and fructose. (Lercker and Pallotta, 1984).

Cashew kernels are reported to contain very low carbohydrates (22 percent) and one percent soluble sugars. Such a quantity is sufficient to give a pleasant taste without creating excess energy. Cashew is therefore, non fattening and can be safely consumed by those suffering from obesity and diabetics (Narayanan,1998).


Materials
and
Methods

MATERIALS AND METHODS

The present investigation on the " Processing qualities of cashewnuts in relation to agroecological and phenological factors" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during 1998-2000.

In this study, the processing qualities of cashewnuts in terms of physical and biochemical characters were evaluated in relation to:

a) Agro-ecological factors
b) Flowering behaviour of varieties
c) Maturity of the nuts
d) Size of nuts
e) Pest attack

The project work had three phases viz.,

1) Collection of the nuts for quality evaluation
2) Recording the data on soil and weather parameters pertaining to different centres of collection
3) Evaluation of physico-chemical attributes of nuts

3.1 SAMPLING PROCEDURE FOR COLLECTION OF NUTS FOR QUALITY EVALUATION

3.1.1 Nuts from different agro-ecological regions:

Based on altitude, soil, topography, rainfall and principal crops grown in the state, the entire Kerala is divided into thirteen agro-climatic zones. The features of these different zones are given in Appendix-I.

Among these zones, same varieties of cashew are being grown at research stations located at Central, Southern and Northern zones. To study the variation in processing qualities of nuts when cashew is grown in different agro-climatic zones, nuts of same varieties were collected from Cashew Research Station (CRS), Madakkathra(L_1) representing the central zone, Farming System Research Station(FSRS), Kottarakkara (L_2), representing the southern zone, Cashew Research Station (CRS), Anakkayam(L_3) and Regional Agricultural Research Station (RARS), Pilicode(L_4) representing the northern zone.

Fully matured cashewnuts (2kg each) of the varieties, Madakkathra-1(V_1), Kanaka(V_2), K-22-1(V_3) and Dhana(V_4) were collected from different research stations.

The locally available bulk nuts were collected from different places of Wynad and Alappuzha representing the hilly and sandy area tracts of the state respectively. Since nuts of the same varieties could not be collected from these two regions, they were analysed as separate samples.

The locations of agroecological regions from where the nuts were collected are shown in the map of Kerala (Plate 1).

3.1.2 Nuts from varieties of varying flowering behaviour.

One variety each under the early, mid and late season groups (Pushpalatha,2000) were selected for collecting the nut samples. The varieties selected were: Madakkathra-1 (V_1)(early season), Kanaka (V_2) (mid season) and Madakkathra-2 (V_3) (late season).

The date on which the harvest started for the selected varieties was noted. Nuts harvested from each variety were labelled for the date of collection and kept separately. The last harvest date was also noted. The total harvest period was calculated for each variety and was divided into three phases of equal interval as early, mid and late. Samples collected during first $1/3^{rd}$ of the total harvest period was taken as the early crop (S_1), the middle $1/3^{rd}$ was taken as the mid crop(S_2) and last $1/3^{rd}$ as late crop(S_3). They were studied separately for their processing characters. From each variety and phase of harvest samples were replicated thrice with a minimum of 2kg per sample. Thus the combinations evaluated were:

1. Early season crop Madakkathra-1 (S_1V_1)
2. Mid season crop Madakkathra-1(S_2V_1)
3. Late season crop Madakkathra-1 (S_3V_1)
4. Early season crop Kanaka(S_1V_2)
5. Mid season crop Kanaka (S_2V_2)
6. Late season crop Kanaka(S_3V_2)

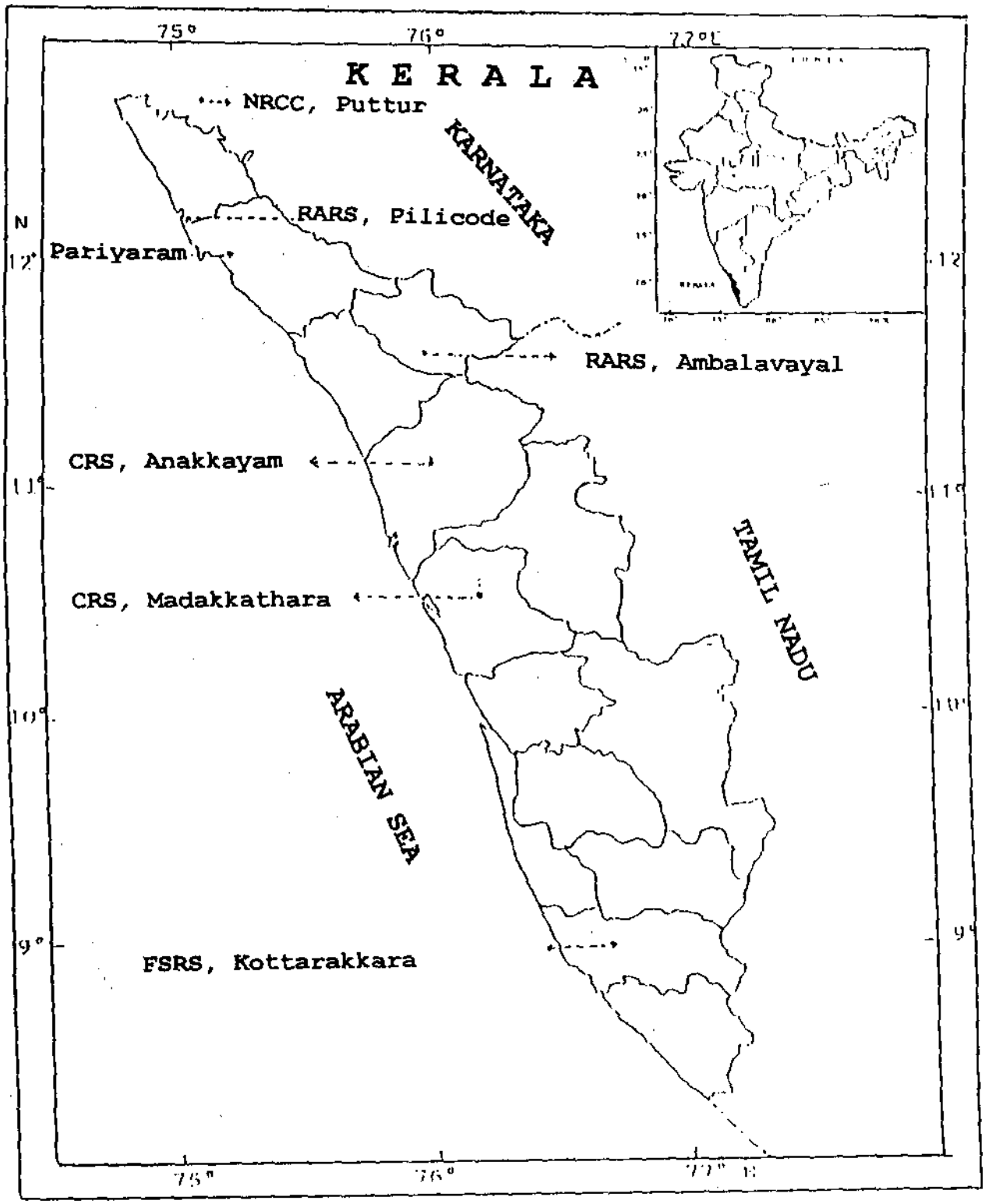


Fig 2. Cashew Research Stations in Kerala

7. Early season crop Madakkathra-2(S_1V_3)
8. Mid season crop Madakkathra-2(S_2V_3)
9. Late season crop Madakkthara-2(S_3V_3)

3.1.3 Nuts of varying maturity stages:

Hermaphrodite flowers of the varieties : Priyanka (V_1), Sulabha (V_2), Madakkathra–2 (V_3), K-22-1 (V_4) and Kanaka(V_5) were tagged on the day of fertilization which was taken as the day of nut set. Marked nuts were observed at regular intervals and samples were collected at different stages of maturity (Plate 1) as follows:

Stage1.-45-50 days after set (M_1)(nuts turning to grey colour)

Stage2.-50-55 days after set (M_2) (fully grey nuts) and

Stage3.-55-60 days after set (M_3) (fully mature nuts) picked from the ground.

3.1.4 Nuts of varying sizes of different harvest phases:

In the market, the nuts arrive as lots consisting of different sizes of nuts. The processing qualities of such nuts were studied by grouping the bulk nuts collected from CRS, Madakkathra into three size categories, based on the weight of the individual nuts (Plate 2) as:

1. Nuts having 5-7g (W_1)
2. Nuts having 7.1-9g (W_2)
3. Nuts having 9.1-11g (W_3)

Plate 1. Nuts at different stages of maturity taken for analysis

VARIETY SULABHA

45-50 DAF 50-55 DAF 55-60 DAF

VARIETY PRIYANKA

45-50 DAF 50-55 DAF 55-60 DAF

VARIETY K-22-1

45-50 DAF 50-55 DAF 55-60 DAF

The different sizes of nuts were collected during early (S_1), mid (S_2) and late (S_3) phases of the harvest season.

The harvesting period at CRS, Madakkathra started from 20-12-99 to 10-4-2000 and the number of days in the harvesting period was 111.

The three different sizes of nuts were collected during the first 1/3rd of the crop from 20-12-99 to 26-1-2000 (early season), second 1/3rd phase from 27-1-2000 to 4-3-2000 (mid season) and third 1/3rd phase from 5-3-2000 to 10-4-2000 (late season). Two kg nut samples were analysed under each treatment and replicated thrice.

3.1.5 Nuts infected by different pests

Nuts of three different varieties viz., Madakkathra–1 (V_1), Kanaka (V_2) and Priyanka (V_3) collected from CRS, Madakkathra were observed for the symptoms of pest attack during the fruiting season (1999-2000). Nuts attacked by different pests (Plate 3) were collected separately for quality evaluation.

3.2 RECORDING THE DATA ON SOIL AND WEATHER PARAMETERS

The available data on soil and weather parameters of different agroecological regions under study were collected from the records maintained at the concerned centres.

Plate 2. Grouping of nuts based on nut size

5-7g 7.1 - 9g 9.1 -11g

Plate 3. Nuts damaged due to attack by different insect pests

Nuts damaged by Tea Mosquito.

Nuts damaged by Thrips

3.3 EVALUATION OF PHYSICO – CHEMICAL ATTRIBUTES OF NUTS:

Samples collected as detailed under 3.1 were evaluated separately for their physico chemical attributes.

3.3.1 Physical characters :

3.3.1.1 Nut weight :

The average weight of nuts were recorded from a random sample of 30 nuts, after drying to constant weight, in each sample category under 3.1. An electronic balance (OHAUS portable standard) with 0.01g accuracy was used and weight was expressed in grams.

3.3.1.2 Nut length

The average length of 30 nuts in each sample was measured using a vernier caliper and expressed in centimeters.

3.3.1.3 Nut breadth

The average breadth of 30 nuts in each sample was measured along the broadest portion of the nut using vernier calipers and expressed in centimeters.

3.3.1.4 Shelling percentage

One kilogram nut samples of the different categories of nuts collected except those of pest infected ones were given for shelling to the cashewnut processing factory, Kuttanellur, Thrissur for getting the shelling percentage.

The pest infected samples were subjected to shelling under laboratory conditions. For this, the methodology standardised in the Department of Processing Technology was used. Nut samples weighting 250g was taken in the autoclave and cooked at 15 psi and 121^{0}C, for 30 minutes. These were taken out, hand shelled and the shelling percentage was worked out.

Shelling percentage of each sample was calculated using the formula :

$$\frac{\text{Weight of kernels}}{\text{Weight of raw nuts}} \times 100 \text{ and expressed as a percentage.}$$

3.3.1.5 Shell thickness

Shell thickness of 30 nuts in each sample was measured in millimeters using a vernier calipers and the average was worked out.

3.3.1.6 Kernel weight

The average weight of 30 individual kernels in each sample was determined using an electronic balance (OHAUS 200 portable standard) with 100mg accuracy and expressed in grams.

3.3.1.7 Kernel grade and colour

Kernel grade was assigned to different samples, based on number of kernels per pound. A detailed grade chart prepared by comparing it with that published by Cashew Export Promotion Council of India as given in Appendix II.

3.3.1.8 White wholes/Kernel pieces:

The number of white whole kernels and kernel pieces in different samples analysed (3.1) were counted separately, weighted and expressed in percentage.

3.3.1.9 Kernel rejects

Kernels, which did not conform to the quality standards due to pest infestation, bruises, shriveling, discolouration or rancidity were classified as kernel rejects. Their weight in each sample was taken separately and expressed as percentage.

3.3.1.10 Husk rejects

After deshelling the nuts, kernels were peeled and the total weight of the shells and the testa was expressed as percentage husk rejects for each sample.

3.3.2. Biochemical characters

Biochemical analyses were carried out at the biochemistry laboratory at AICM & AP, College of Horticulture, Vellanikkara.

Experimental Material

The cashewnut sample for different categories (nuts from different agroecological regions, nuts from different phases of harvest, nuts at different stages of maturity, nuts of different size groups and pest infested nuts) after steaming were deshelled and oven dried for 30-40 min, for easy removal of the testa. After peeling, the kernels were further dried and powdered. The powdered flour was used for estimation of fats, carbohydrates, proteins and sugars.

3.3.2.1 Total fats

Total fats in the samples were estimated by Soxhlet extraction using petroleum ether (40-60^{0}C)as solvent (AOAC,1970). Ten grams of the finely powdered kernel was taken in a filter paper thimble and extracted for 5 hours. After extraction, the solvent was removed by evaporation and the percentage recovery of fat was calculated.

3.3.2.2 Total carbohydrate

The total carbohydrates were determined using Anthrone method (Sadasivam and Manickam, 1996). The sample consisting of 100mg defatted cashew kernel flour was taken in a boiling tube and hydrolysed for 3 hours with 5 ml of hydrochloric acid. It was cooled to room temperature and neutralised with solid sodium carbonate till effervescence stopped. The volume was made upto 500 ml. Aliquots of 0.5 and 1.0 ml were taken for analysis. Standard glucose stock was prepared by dissolving 100mg of glucose in 100ml water. From this, a working

standard was made by diluting 10ml of the stock solution to 100ml with distilled water. Aliquots of 0,0.2, 0.4, 0.6, 0.8 and 1 ml were made with glucose.

The volume was made upto 1 ml in all the tubes with distilled water, followed by the addition 4ml of Anthrone reagent to all the tubes. The tubes were heated for 8 minutes in a boiling water bath, cooled rapidly and the green colour was read in a Spectrophotometer(model Spectronic 20) at 630nm. A standard curve was prepared using aliquots with known concentration of glucose. The amount of carbohydrates in the samples was calculated from the standard graph and expressed as percentage.

3.3.2.3 Protein

The total nitrogen content was estimated by Nesslers method as suggested by Snell and Snell (1967). The defatted cashew flour (0.2g) was taken in a 50ml standard flask and 4ml of concentrated sulphuric acid was added. It was heated for 30 minutes and digested with 2ml of hydrogen peroxide. Excess of hydrogen peroxide was added to get a clear solution, and this was made upto 50ml with distilled water. To 5ml of sample solution, alkali (NaOH 10%) and 1ml of 10% sodium silicate were added in a sequential manner and this was made upto 50ml. Finally 1.6ml Nesslers reagent was added to develop an unstable orange colour, (the pH of which is 11) and was read in a spectrophotometer (model spectronic 20) at 410nm. The nitrogen content thus calculated was multiplied with a factor of 6.25 to estimate the protein content.

3.3.2.4 Total sugars

The total sugars were estimated by phenol sulphuric acid method (Sadasivam and Manickam, 1996) and expressed as a percentage. Defatted flour (0.1g) was homogenised in hot 80% methanol for the complete extraction of soluble sugars, and the volume was made upto 100ml with methanol. Aliquots of 0.1ml and 0.2ml of the sample solution were taken for colour development. Standard glucose stock was prepared by dissolving 100mg of glucose in 100ml water. From this, a working standard was made by diluting 10ml of the stock solution to 100ml with distilled water. Aliquots of 0,0.2, 0.4, 0.6, 0.8 and 1 ml were made with glucose. The volume was made upto 1 ml in all tubes with distilled water. Five ml of 96% Sulphuric acid and 1ml phenol were added to all the tubes. The brownish colour was read at 490nm in a spectrophotometer (model spectronic 20). A standard graph was prepared using known quantities of glucose. The amount of total sugars was calculated from the standard graph and expressed as a percentage.

3.4 PREPARATION OF KERNEL GRADE AND COLOUR CHART

Charts showing the grade and colour of kernels were prepared pertaining to kernels from nuts of different sources as given 3.1.1, 3.1.2, 3.1.3, 3.1.4 and 3.1.5 of this chapter were prepared.

3.5 STATISTICAL ANALYSIS

The data on physical and biochemical characters of different nut samples collected as envisaged in the programme (3.1) were subjected to factorial CRD analysis Appendices – III, IV, V, VI, VII as proposed by Panse and Sukhatme (1976).

Results

RESULTS

The data and observations recorded in the present study on "Processing qualities of cashew nut in relation to agroecological and phenological factors" were analysed and the results are presented in this chapter.

Processing qualities of cashewnuts collected from plantations located across agroecological regions, from varieties having different flowering habits, maturity stages, nuts of various sizes and those affected by different pests/diseases were analysed for their physico chemical attributes.

4.1. INFLUENCE OF AGRO-ECOLOGICAL CONDITIONS ON QUALITY OF NUTS AND KERNELS

4.1.1 Influence of southern, central and northern regions on quality of nuts

4.1.1.1 Physical characters of nuts

The physical parameters of the nuts of four varieties viz. Madakkathra-1 (V_1), Kanaka (V_2), K-22-1 (V_3) and Dhana(V_4)collected from the research stations located at CRS, Madakkathra(L_1), FSRS, Kottarakkara(L_2),CRS, Anakkayam (L_3) and RARS, Pilicode (L_4)are presented in Table 1.

Nut Length

Significant difference was noticed in the length of the nuts collected from different agroecological regions. The nuts collected from FSRS, Kottarakkara

Table 1 . Physical characters of cashew nuts of four varieties collected from different agroecological regions

Location	Physical characters of nuts					
	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
L_1	3.55	2.39	6.24	3.02	27.38	72.63
L_2	4.18	2.52	7.61	2.95	25.70	74.30
L_3	4.06	2.56	7.48	3.27	24.31	75.71
L_4	3.69	2.39	6.30	3.07	25.37	74.65
CD (0.05)	0.19	0.08	0.30	0.11	0.64	0.43
SEm±	0.07	0.03	0.11	0.04	0.22	0.15
Varieties						
V_1	4.04	2.36	5.94	2.87	26.11	73.91
V_2	3.62	2.41	6.51	2.93	26.74	73.28
V_3	3.62	2.42	6.55	3.16	25.21	74.80
V_4	4.21	2.67	8.63	3.34	24.69	75.31
CD (0.05)	0.19	0.08	0.30	0.11	0.64	0.43
SEm±	0.07	0.03	0.11	0.04	0.22	0.15

Table 1. Continued

Location X Varieties						
L_1V_1	3.89	2.36	5.56	2.85	29.00	71.03
L_1V_2	3.34	2.33	5.85	2.82	28.00	72.00
L_1V_3	3.27	2.34	6.14	3.29	26.03	74.00
L_1V_4	3.70	2.51	7.40	3.11	26.50	73.50
L_2V_1	4.06	2.41	6.13	2.44	26.60	73.40
L_2V_2	4.08	2.57	8.10	3.11	24.70	75.30
L_2V_3	3.72	2.33	6.20	3.16	25.61	74.40
L_2V_4	4.87	2.79	10.01	3.08	25.90	74.10
L_3V_1	4.24	2.44	6.14	3.09	20.93	79.10
L_3V_2	3.66	2.41	6.36	3.04	26.03	74.00
L_3V_3	3.93	2.58	7.52	3.10	25.90	74.10
L_3V_4	4.43	2.81	9.89	3.85	24.38	75.66
L_4V_1	3.97	2.25	5.92	3.08	27.93	72.10
L_4V_2	3.38	2.32	5.75	2.77	28.25	71.80
L_4V_3	3.57	2.43	6.32	3.10	23.30	76.70
L_4V_4	3.84	2.54	7.23	3.32	22.00	78.00
CD (0.05)	0.37	0.16	0.60	0.22	1.28	0.86
SEm±	0.13	0.06	0.21	0.08.	0.45	0.30

L_1=CRS, Madakkathra, L_2=FSRS, Kottarakkara, L_3=CRS, Anakkayam, L_4=RARS, Pilicode

V_1=Madakkathra-1, V_2=Kanaka, V_3=K-22-1, V_4=Dhana

and CRS, Anakkayam were found to have the maximum length (4.18 and 4.06 cm respectively). Minimum length (3.55cm) was recorded for the nuts from CRS, Madakkathra.

When each variety from different agroecological regions is considered separately, all the varieties, except Madakkathra-1, showed significant difference in nut length.

Among the four samples of Kanaka and Dhana, the samples from FSRS, Kottarakkara recorded the maximum nut length (4.08 and 4.87 cm respectively).

In case of variety K–22-1, the nuts from CRS, Anakkayam were found to have maximum length (3.93 cm).

The nut samples of all the varieties collected from CRS, Madakkathra were found inferior, with respect to length.

Nut Breadth

In general, the breadth of the nuts (irrespective of the varieties) was maximum (2.56cm) for those collected from CRS, Anakkayam and minimum (2.39cm) for those from RARS, Pilicode and CRS, Madakkathra.

When samples of the four varieties was compared, the nuts of the varieties Madakkathra–1, K-22-1 and Dhana collected from CRS, Anakkayam were found to have maximum breadth (2.44cm, 2.58cm and 2.81cm respectively).

Among the four samples of variety Kanaka, those collected from FSRS, Kottarakkara was found superior (2.57cm).

The nuts of the varieties Madakkathra–1 and Kanaka from RARS, Pilicode were ranked lower with respect to nut breadth (2.25cm and 2.32cm respectively). In the case of K-22-1, nuts from FSRS, Kottarakkara (2.33cm) and for Dhana, nuts from CRS, Madakkathra (2.51cm) recorded the lowest breadth.

Nut weight

The Maximum nut weight (irrespective of the varieties) was observed for the nuts collected from FSRS, Kottarakkara (7.61g) and the minimum (6.24g) for those from CRS, Madakkathra.

In the case of variety Madakkathra–1, no significant difference was observed in the weight of the nuts collected from the different regions.

The nuts from FSRS, Kottarakkara recorded the maximum weight for the varieties Kanaka and Dhana (8.10g and 10.01g respectively).

In the variety K-22-1, maximum was for the samples from CRS, Anakkayam (7.52g).

The varieties Kanaka and Dhana from RARS, Pilicode (5.75 and 7.23g respectively) and the samples of K-22-1 from CRS, Madakkathra (6.14g) were found to have low nut weight.

Shell Thickness

In general, the shell thickness was maximum (3.27mm) for the nuts from CRS, Anakkayam and was minimum (2.95mm) in the nuts from FSRS, Kottarakkara.

Maximum shell thickness among the different samples of the varieties Madakkathra–1 and Dhana was found in the nuts collected from CRS, Anakkayam (3.09mm and 3.85mm respectively). In case of the variety Kanaka, the maximum shell thickness (3.11mm) was for the nuts from FSRS, Kottarakkara. The samples of the variety K-22-1 collected from different regions did not differ significantly with respect to shell thickness.

For the varieties Madakkathra–1 and Dhana, the nuts obtained from FSRS, Kottarakkara had the minimum shell thickness (2.44mm and 3.08mm respectively). For the variety Kanaka, the nuts from RARS, Pilicode had the minimum shell thickness (2.77mm).

Shelling percentage

The shelling percentage obtained was significantly different for the nuts collected from the different centres. The maximum was recorded in the samples collected from CRS, Madakkathra (27.38%) and the minimum (24.31%) in those from CRS, Anakkayam.

In the varieties Madakkathra–1, K-22-1 and Dhana the maximum shelling percentage (29%, 26.03% and 26.5% respectively) was obtained in the nuts collected from CRS, Madakkathra. For the variety Kanaka, the maximum (28.25%) was obtained in the nuts from RARS, Pilicode.

Among the four samples of variety Madakkathra–1, minimum shelling percentage (20.93%) was recorded in the nuts collected from CRS, Anakkayam. For variety Kanaka, nuts from FSRS, Kottarakkara had the lowest shelling percentage (24.7%).

The minimum shelling percentage among the four sample of the varieties K-22-1 and Dhana (23.29% and 22% was obtained from RARS, Pilicode.

Percentage husk rejects

Irrespective of the varieties, the minimum husk rejects (72.63%) was for the nuts collected from CRS, Madakkathra and the maximum (75.71%) was for the nuts from CRS, Anakkayam.

In variety Madakkathra-1, the nuts collected from CRS, Madakkathra had minimum husk rejects (71.03%) while those from CRS, Anakkayam had the maximum (79.10%).

Variety Kanaka recorded the minimum husk rejects (71.80%) in the nuts from RARS, Pilicode and the maximum (75.30%) in nuts from FSRS, Kottarakkara.

The varieties K-22-1 and Dhana recorded minium husk rejects (74% and 73.5% respectively) in the nuts collected from CRS, Madakkathra and the maximum (76.7% and 78% respectively) in the nuts collected from RARS, Pilicode.

4.1.1.2 Physical characters of Kernels

The physical parameters of the kernels of four varieties collected from the research stations located at Kasargode, Malappuram, Thrissur and Kottarakkara are presented in Table 2.

Kernel weight

Significant difference was observed in the kernel weights of the nuts collected from different centres (Plate 4).

Table 2 Physical characters of cashew kernels of four varieties collected from different agroecological regions

Location	Physical characters of kernels			
	Weight (g)	White wholes (%)	Pieces (%)	Rejects (%)
L1	1.78	87.71	9.95	1.70
L2	2.08	85.65	7.63	6.88
L3	1.95	93.14	5.24	1.45
L4	1.79	84.78	13.04	2.16
CD (0.05)	0.21	0.92	0.60	0.29
SEm±	0.07	0.32	0.21	0.10
Varieties				
V1	1.80	87.79	7.85	4.37
V2	1.81	88.69	8.15	2.53
V3	1.73	83.13	14.37	2.54
V4	2.25	91.68	5.50	2.75
CD (0.05)	0.21	0.92	0.60	0.29
SEm±	0.07	0.32	0.21	0.10

Table 2. Continued

Location X Varieties				
$L_1 V_1$	1.81	91.03	6.92	1.66
$L_1 V_2$	1.65	85.40	8.85	3.71
$L_1 V_3$	1.65	81.00	18.03	0.57
$L_1 V_4$	2.00	93.40	5.73	0.88
$L_2 V_1$	1.76	81.05	7.09	12.15
$L_2 V_2$	2.20	96.30	3.72	0.00
$L_2 V_3$	1.52	78.03	14.24	8.14
$L_2 V_4$	2.85	87.30	5.48	7.23
$L_3 V_1$	1.90	94.00	4.72	1.27
$L_3 V_2$	1.71	90.08	6.84	2.69
$L_3 V_3$	1.99	91.50	6.90	1.44
$L_3 V_4$	2.20	97.00	2.52	0.40
$L_4 V_1$	1.73	85.10	12.66	2.41
$L_4 V_2$	1.69	83.00	13.20	3.74
$L_4 V_3$	1.76	82.00	18.04	0.00
$L_4 V_4$	1.97	89.00	8.26	2.51
CD(0.05	0.41	1.84	1.21	0.59
SEm±	0.14	0.65	0.42	0.21

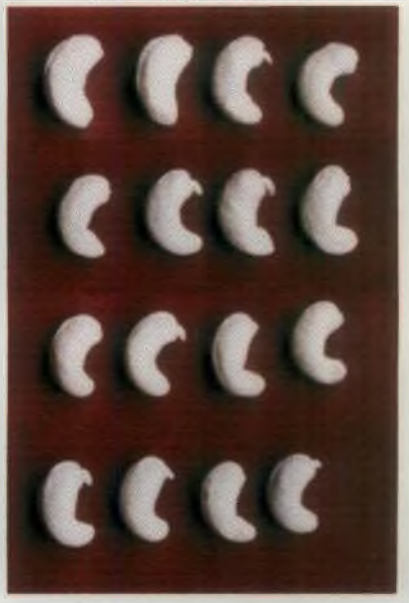
L_1=CRS, Madakkathra, L_2=FSRS, Kottarakkara, L_3=CRS, Anakkayam, L_4=RARS, Pilicode

V_1=Madakkathra-1, V_2=Kanaka, V_3=K-22-1, V_4=Dhana

Plate 4. Variation in Kernel Size of different varieties due to change in agroecological factors.

KANAKA

MADAKKATHARA - 1



Central Zone
(CRS, Madakkathara)

Southern Zone
(FSRS, Kottarakkara)

Northern Zone
(CRS, Anakkayam)

Northern Zone
(RARS, Pilicode)

DHANA

K-22-1

Central Zone
(CRS, Madakkathara)

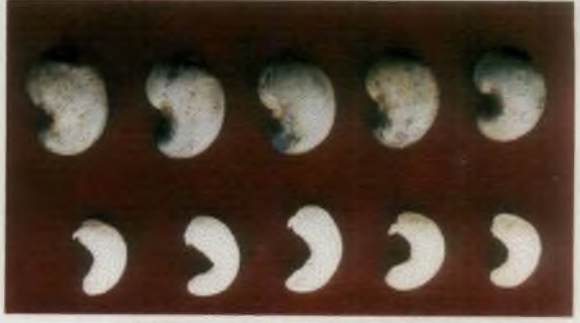
Southern Zone
(FSRS, Kottarakkara)

Northern Zone
(CRS, Anakkayam)

Northern Zone
(RARS, Pilicode)

Plate 5. Nut and Kernel Size of raw cashew nuts (bulk) collected from Wynad and Alappuzha regions

Nuts from Wynad region



Nuts from Alappuzha region

The Kernel weight was maximum (2.08g) in the nuts from FSRS, Kottarakkara and minimum (1.78g) in the nuts from CRS, Madakkathra and RARS, Pilicode.

In the variety Madakkathra-1, no significant variation was observed in the kernel weights of the nuts collected from the different regions.

Kernel weight was highest for the samples collected from FSRS, Kottarakkara in the varieties Dhana and Kanaka (2.85g and 2.20g respectively). In variety K-22-1 nuts collected from CRS, Anakkayam had highest kernel weight (1.99g).

For the variety Kanaka, the nuts from CRS, Madakkathra had the minimum kernel weight (1.65g). Variety K–22-1 recorded the minimum kernel weight (1.52g) in the nuts from FSRS, Kottarakkara and variety Dhana recorded the minimum (1.97g) in the nuts from RARS, Pilicode.

Percentage white wholes

The maximum percentage of white wholes (93.14%) was observed in the nuts from CRS, Anakkayam and the minimum (84.78%) was obtained in the nuts from RARS, Pilicode (Table 2).

For the varieties Madakkathra-1, K-22-1 and Dhana, the maximum percentage of white wholes (94%, 91.5% and 97% respectively) was obtained for

samples from CRS, Anakkayam. For the variety Kanaka, the highest recovery of white wholes (96.3%) was obtained for samples from FSRS, Kottarakkara.

The minimum recovery of white wholes for the varieties Madakkathra-1, K-22-1 and Dhana (81.05%, 78.03% and 87.3% respectively) was obtained for the nuts collected from FSRS, Kottarakkara.

For the variety Kanaka, the minimum recovery of white wholes (83%) was obtained for samples of RARS, Pilicode.

Percentage kernel pieces

The percentage of kernel pieces, varied significantly between the samples collected from different agroecological regions. In general, the lowest percentage of kernel pieces (5.24%) was obtained from CRS, Anakkayam while it was the highest (13.04%) in the samples obtained from RARS, Pilicode.

For the varieties Madakkathra-1, K-22-1 and Dhana, the minimum kernel pieces (4.72%, 6.90% and 2.52%) was obtained in the nuts collected from CRS, Anakkayam. For the variety Kanaka, the kernel pieces were minimum (3.72%) in the nuts from FSRS, Kottarakkara.

The varieties Madakkathra-1, Kanaka and Dhana had the maximum kernel pieces (12.66%, 13.2% and 8.26% respectively) for the nuts collected from

RARS, Pilicode. In case of the variety K-22-1, maximum kernel pieces (18.30%) was obtained for the nuts from CRS, Madakkathra.

Percentage kernel rejects

Irrespective of the varieties, the lowest percentage of kernel rejects (1.45% and 1.70%) was observed for the sample of CRS, Anakkayam and CRS, Madakkathra respectively, while the highest (6.88%) was observed in the nuts from FSRS, Kottarakkara (Table 2).

Varieties Madakkathra-1 and Dhana had the minimum kernel rejects (1.27% and 0.40%) in the nuts from CRS, Anakkayam and the maximum rejects (12.15% and 7.23%) in the nuts from FSRS, Kottarakkara.

For the variety Kanaka, the nut samples of FSRS, Kottarakkara had no kernel rejects, while the maximum kernel rejects was obtained for the nuts of RARS, Pilicode (3.74%) and CRS, Madakkathra (3.71%).

For the variety K-22-1, the nut samples from RARS, Pilicode had no kernel rejects, while the maximum kernel rejects (8.14%) was observed in the nuts from FSRS, Kottarakkara.

4.1.1.3 Biochemical characters

Kernel samples of four varieties collected from different agroecological regions were analysed for the estimation of sugar, carbohydrate, protein and fat content. The data is presented in Table 3 and Fig 6.

Table3 Variation in biochemical constituents of cashew kernels from different agroecological regions

Location	Biochemical constituents of kernels			
	Sugar (%)	Carbohydrates(%)	Protein (%)	Fat (%)
L_1	8.05	18.13	18.88	48.09
L_2	7.82	16.95	18.13	46.84
L_3	8.13	20.05	18.71	47.37
L_4	8.02	19.81	20.43	48.24
CD (0.05)	NS	0.41	0.39	0.66
SEm±	0.12	0.15	0.14	0.23
Varieties				
V_1	7.62	18.13	19.32	47.42
V_2	7.40	16.95	18.16	47.60
V_3	7.57	20.05	19.01	48.61
V_4	9.43	19.81	19.67	46.90
CD (0.05)	0.35	0.41	0.39	0.66
SEm±	0.24	0.29	0.27	0.47

Table 3. Continued

Location X Varieties				
$L_1 V_1$	7.83	19.26	18.53	46.87
$L_1 V_2$	7.80	19.70	19.89	49.35
$L_1 V_3$	8.00	17.11	18.92	45.17
$L_1 V_4$	8.56	16.44	18.20	50.98
$L_2 V_1$	6.98	18.17	17.57	47.89
$L_2 V_2$	6.34	16.10	18.07	50.66
$L_2 V_3$	7.06	15.91	17.15	47.53
$L_2 V_4$	10.92	17.64	19.75	41.27
$L_3 V_1$	6.73	18.38	19.58	47.29
$L_3 V_2$	8.88	20.17	17.13	42.83
$L_3 V_3$	8.11	19.01	17.92	51.85
$L_3 V_4$	8.79	22.62	20.19	47.51
$L_4 V_1$	8.93	21.58	21.60	47.62
$L_4 V_2$	6.59	19.47	17.56	47.57
$L_4 V_3$	7.12	18.01	22.05	49.89
$L_4 V_4$	9.45	20.18	20.53	47.86
CD (0.05)	0.70	0.83	0.77	1.32
SEm±	0.24	0.29	0.27	0.47

L_1=CRS, Madakkathra, L_2=FSRS, Kottarakkara, L_3=CRS, Anakkayam, L_4=RARS, Pilicode

V_1=Madakkathra-1, V_2=Kanaka, V_3=K-22-1, V_4=Dhana

Sugars

Significant different was noticed with respect to sugar content in the kernels of the same variety collected from different agroecological regions.

In the variety Madakkathra-1, highest sugar content was observed in the samples from RARS, Pilicode (8.93%) and the lowest (6.73%) in the samples from CRS, Anakkayam.

Among the different samples of variety Kanaka and K-22-1, the highest sugar content (8.88% and 8.11% respectively) was observed in the samples of CRS, Anakkayam, while the samples of the same varieties from FSRS, Kottarakkara registered the minimum sugar content (6.34% and 7.06%).

Variety Dhana recorded the highest sugar content (10.92%) in the samples collected from FSRS, Kottarakkara and the minimum (8.56%) in the samples from CRS, Madakkathra.

Carbohydrates

Significant difference existed in the carbohydrate content in the kernels of the selected varieties from the different centres. In general, the highest carbohydrate content (irrespective of the varieties) was observed in the nuts from CRS, Anakkayam (20.05%) and the minimum carbohydrate content (16.95%) in the samples from FSRS, Kottarakkara.

For the variety Madakkathra-1, the maximum carbohydrate content (21.58%) was observed in the samples from RARS, Pilicode.

In the varieties Kanaka, K-22-1 and Dhana, the highest carbohydrate content (20.17%, 19% and 22.62% respectively) was recorded in the samples collected from CRS, Anakkayam.

The carbohydrate content in the varieties Madakkathra-1, Kanaka and K-22-1 (18.17%, 16.10% and 15.91% respectively) was observed to be lowest in the nuts from FSRS, Kottarakkara.

Among the four samples of Dhana, the lowest carbohydrate content (16.44%) was recorded in the samples from CRS, Madakkathra.

Proteins

The protein content was highest (20.43%) in the samples from RARS, Pilicode and lowest (18.13%) in the nuts from FSRS, Kottarakkara.

Variations within the same variety, between different agroecological regions were also significant (Table 3).

Protein content in the varieties Madakkathra-1, K-22-1 and Dhana was highest in samples (21.60%, 22.05% and 20.53% respectively) collected from

RARS, Pilicode. In the variety Kanaka the samples from CRS, Madakkathra recorded the highest protein content (19.89%).

Lowest protein content in varieties Madakkthra-1 and K-22-1 (17.57% and 17.15% respectively) was recorded in the samples from FSRS, Kottarakkara. In varieties Kanaka and Dhana lowest protein content was seen in the samples from CRS, Anakkayam (17.13%) and CRS, Madakkathra (18.20%).

Fats

The fat content in the kernels showed significant difference between the different agroecological zones. The highest fat content (48.24%) was observed in the samples from RARS, Pilicode, which was on par (48.09%) with that from CRS, Madakkathra. The minimum fat content (46.84%) was observed in the samples from FSRS, Kottarakkara.

In the variety Madakkathra-1, no significant difference was observed in the fat content in the samples collected from different regions.

Among the four samples of the variety Kanaka, the highest fat content (50.66%) was observed in the samples collected from FSRS, Kottarakkara and the minimum (42.83%) in the nuts from CRS, Anakkayam

In case of variety K-22-1, the highest fat content (51.85%) was observed in the samples from CRS, Anakkayam and the lowest (45.17%) in the samples from CRS, Madakkathra.

Samples of variety Dhana from CRS, Madakkathra had the highest fat content (50.98%) and those from FSRS, Kottarakkara had the lowest (41.27%).

4.1.2 NUTS FROM ALAPPUZHA AND WYNAD REGIONS

The physical and biochemical characters of the bulk nuts collected from Alappuzha and Wynad regions are presented in Table 4 . The nut and kernel size of the nuts from these regions are shown in Plate 5.

4.1.2.1 Physical characters of nuts:

Nut length

The nuts from Alappuzha region had an average nut length of 4.06cm and those from Wynad region had an average length of 3.56cm.

Nut Breadth

The nuts from Alappuzha and Wynad regions have an average breadth of 2.3 and 2.27cm respectively.

Table 4 Physical and biochemical characters of the nuts collected from Alappuzha and Wynad regions

Character	Physical characters of nuts	
	Nuts from Alappuzha region	Nuts from Wyanad region
Nut length (cm)	4.06	3.56
Nut breadth (cm)	2.30	2.27
Nut weight (g)	6.86	6.23
Shell thickness(mm)	2.88	3.12
Shelling percentage	26.70	26.40
Husk rejects (%)	73.30	73.60
Physical characters of kernels		
Kernel weight (g)	1.89	1.77
White wholes (%)	79.5	95.00
Kernel pieces (%)	12.58	4.62
Kernel rejects (%)	8.01	0.73

Table 4 continued

Kernel grade	W240	W280
Biochemical characters of the kernels		
Sugars (%)	7.76	6.98
Carbohydrates (%)	18.05	17.45
Proteins (%)	17.35	17.45
Fats (%)	39.57	46.71

Each datum represents the average value of 5 samples consisting of 0.5kg nuts each collected from different locations.

Nut Weight

The average nut weight of the Alappuzha region nuts is around 6.86g and that of the Wynad region nuts is 6.23g.

Shell thickness

The average shell thickness was 2.88mm and 3.12mm in the nuts from Alappuzha and Wynad regions respectively.

Shelling percentage

The Alappuzha region nuts had an average shelling percentage of 26.7%, while the nuts from Wynad region had an average of 26.4%.

Percentage husk rejects

The Alappuzha region nuts had 73.3% husk rejects, while it was 73.6% in the nuts from Wynad region.

4.1.2.2 Physical characters of kernels:

Kernel weight

The average kernel weight was 1.89g in the nuts from Alappuzha region, while it was 1.77g for the nuts from Wynad region.

Percentage white wholes

The nuts from Alappuzha region gave 79.5% white wholes, while the nuts from Wynad region gave 95% white wholes.

Percentage kernels pieces

The percentage of kernel pieces was 12.58% and 4.62% respectively when the nuts from Alappuzha and Wynad regions were processed.

Percentage Kernel rejects

The average kernel rejects was observed to be 8.09% in the samples from Alappuzha region and 0.73% in the samples from Wynad region.

Kernel grade

Kernels of the samples obtained from Alappuzha region could be categorised under W240, while those from the Wynad region could be graded as W280.

Kernel colour

Kernels of the nuts collected from Alappuzha region were white in colour, while the kernels of the samples from Wynad region had pale ivory colour.

4.1.2.3 Biochemical Characters

Sugars

The kernels obtained from samples collected from Alappuzha region had an average sugar content of 7.76%, while in the samples from Wynad region it was 6.98%.

Carbohydrates

The kernel samples collected from the Alappuzha and Wynad regions had an average carbohydrate content of 18.05% and 17.45% respectively.

Proteins

The protein content in the samples collected from Alappuzha and Wynad regions was found to be 17.35% and 17.45% respectively.

Fats

The kernels of samples from the Alappuzha region had an average fat content of 39.57% and those from Wynad region had 46.71%.

4.1.3 WEATHER AND SOIL PARAMETERS OF DIFFERENT AGROECOLOGICAL REGIONS

Temperature

The data on maximum and minimum temperature prevailing at different regions from where nuts were collected is given in Table 5.

Table 5. Temperatures (°C) recorded in different Locations across Kerala during Aug 1999-March 2000

Locations	Temperature (°C)	N.E. monsoon		Post monsoon		Winter			Summer		
		Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
RARS Pilicode	Max	29.00	30.50	30.20	31.32	32.00	30.93	30.81	31.41	31.86	31.78
	Min	22.70	23.20	22.90	22.40	20.10	19.92	20.91	22.89	24.91	24.58
CRS Anakkayam	Max	30.87	32.15	32.00	31.95	32.90	33.81	34.54	34.23	35.00	36.20
	Min	19.06	18.62	19.00	17.16	17.00	16.24	18.42	18.00	20.35	22.87
CRS Madakkathra	Max	29.80	31.60	30.50	31.40	30.70	32.90	33.30	35.60	34.00	33.70
	Min	22.90	23.40	23.20	22.70	22.70	23.20	22.80	23.90	24.60	24.40
FSRS Kottarakkara	Max	30.83	31.86	30.65	32.34	31.28	33.52	33.96	35.21	32.84	33.70
	Min	22.15	21.93	21.24	21.02	20.22	20.83	20.04	21.48	21.66	21.38

During flushing and flowering period of almost all the cashew varieties viz., October to January the day temperature prevailing at CRS, Anakkayam was very high (31.95 to 33.81^{0}C), followed by FSRS, Kottarakkata (30.65 to 33.52^{0}C). The temperature fall recorded for these regions was also high and it was in the range of 16.24 to 19^{0}C at CRS, Anakkayam and 20.22 to 21.24^{0}C at FSRS, Kottarakkara during flushing and flowering period.

During flushing time (Oct-Nov) almost same temperature situation prevailed during day and night at CRS, Madakkathra and RARS, Pilicode (Fig.5) where as the temperature variation during day and night was high at RARS, Pilicode during the flowering period (December – January).

The temperature recorded during next reproductive phases viz., nut set and development (February to April) was also high at CRS, Anakkayam (34.5 to 35.10^{0}C)and FSRS, Kottarakkara (32.84 to 35.21^{0}C). As observed during the previous phases, the night temperature was comparatively cooler. Eventhough the day temperature at CRS, Madakkathra was high during later phases of reproduction, the fall in temperature was not so intensive. Thus, the minimum temperature prevailed at this region recorded during February to April was 22.8 to 24.6^{0}C. The temperature from February to April at RARS, Pilicode was comparatively low and the intensity of fall in temperature was also low (Fig. 5).

Rainfall

The data on rainfall recorded at different centres for the period from October to May (from flushing to harvest) is given in Table 6. During flush initiation

Table 6. Rain fall recorded at different locations across Kerala during August 1999-May 2000 (mm)

Rainfall (mm)										
Locations	S.W. Monsoon		Post Monsoon		Winter			Summer		
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
RARS Pilicode	444.10	72.50	505.00	6.40	1.60	40.00	-	4.40	71.80	286.40
CRS Anakkayam	83.00	89.20	537.90	42.00	0.00	0.00	5.00	0.00	27.00	14.20
CRS Madakkathra	260.10	28.40	506.20	9.10	0.00	0.00	4.60	0.00	67.90	117.20
FSRS Kottarakkara	114.80	56.80	376.20	100.80	0.00	1.60	109.90	13.40	38.80	35.60

time the rainfall received at CRS, Anakkayam was high (537.90mm), where as it was very low at FSRS, Kottarakkara. The rainfall received during November at FSRS, Kottarakkara was high (100.8mm) compared to other centres. The rainfall received during flowering period (December – January) at different centres were practically nil or very little.

During nut set and development, the centre RARS, Pilicode received a total rainfall of 76.20mm and CRS, Anakkayam 32.00mm. The rainfall received at other two centres were very low. The post monsoon started at RARS, Pilicode and CRS, Madakkathra very early and there the rainfall recorded during May were 286.40 and 117.20mm respectively.

Relative humidity

The data on relative humidity (RH%) recorded for the different centres are given in Table 7.

The RH prevailing at RARS, Pilicode and CRS, Madakkathra was comparatively high (85.5 and 84.5% respectively) during flush initiation time. During the later part of reproductive growth and development, the humidity level decreased in these centres and the intensity of reduction was more at CRS, Madakkathra. At CRS, Anakkayam the variation in humidity was not so high as recorded for other centres. (Fig.5). The centres FSRS, Kottarakkara experienced high humidity during alternate months starting from October and it was found

Table 7. Relative humidity (RH %) recorded in different locations across Kerala during August 1999-May 2000

RH(%)										
Locations	S.W. Monsoon		Post monsoon		Winter			Summer		
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
RARS Pilicode	90.50	83.00	85.00	75.50	73.50	74.50	68.00	72.00	72.80	76.30
CRS Anakkayam	74.50	74.00	72.00	71.50	64.00	67.50	69.50	67.00	64.00	67.00
CRS Madakkathra	83.50	76.00	84.50	69.00	60.00	59.50	68.50	66.50	74.00	72.00
FSRS Kottarakkara	90.00	90.50	80.50	67.50	81.50	66.00	79.50	65.50	71.50	76.50

reduced sharply during other months. Thus the fluctuation in humidity was very high at this centre during reproductive cycle of cashew.

Soil characters of different agroecological regions

The soil characters of different agroecological regions from where the nuts were collected are given in Table 8. The soil of different regions were rated as low, medium and high with reference to the amount of available nitrogen (N2), phosphorus (P) and Potassium(K) content. The criteria adopted for the classification is given in Appendix- VIII

The soil texture of different centres except CRS, Anakkayam is demarcated as gravelly clay loam. The soil texture of CRS, Anakkayam is laterite type. The type of soil in all the centres are very deep and well drained in nature.

The P^{H} of the soil of the different centres ranged between 5.20 to 5.75. The organic carbon content of RARS, Pilicode is high (1.64%) compared to other centres and the content is found to be medium in the other three centres. The available N_2 and P recorded were medium (306kg/ha and 10.3kg/ha) at the centre RARS, Pilicode, while other three centres recorded low N_2 and P content. In all the four locations, the K content recorded in the soil was medium (Table 8).

Table 8. Soil characters of different agroecological regions of Kerala

Location	Soil texture/ type	PH	EC (mm hoscm^{-1})	Organic carbon (%)	Available N2 (Kg ha^{-1})	Available P205 (Kg ha^{-1})	Available K20 (Kg ha^{-1})
CRS, Madakkathra (L_1)	Gravelly clay very deep and well drained	5.6	0.10	1.07	331.5	4.8	216
FSRS, Kottarakkara (L_2)	Gravelly clay loam	5.20	0.13	1.30	203.45	7.08	157.03
CRS, Anakkayam (L_3)	Laterite very deep and well drained	5.75	0.10	0.53	218.4	9.41	172
RARS, Pilicode (L_4)	Gravelly clay very deep and well drained	5.27	0.12	1.64	306	10.3	215.68

4.2 NUT QUALITY IN RELATION TO FLOWERING BEHAVIOUR OF VARIETIES

The date on which the harvest started and ended for the varieties: Madakkathra-1 (V_1), Kanaka (V_2) and Madakkathra-2 (V_3) are given below with total harvesting period and different phases of harvest for each variety.

Total harvesting period and different phases of harvest for each variety during the year 2000

Variety	Total Harvest			Early harvest phase		Mid harvest phase		Late harvest phase	
	From	To	Total period (days)	From	To	From	To	From	To
	(Date / month)			(Date / month)		(Date / month)		(Date / month)	
MDK-1	2-1	10-3-	67	2-1	24-1	25-1	16-2	17-2	10-3
Kanaka	15-2	4-4	48	15-2	3-3	4-3	20-3	21-3	4-4
MDK-2	25-3	18-5	54	25-3	12-4	13-4	1-5	2-5	18-5

The total harvest period of the variety Madakkathra-1 was 67 days and the nuts collected from 2-1-2000 to 24-1-2000 was considered as early harvest crop (S_1), from 25-1-2000 to 16-2-2000 was considered as mid harvest crop (S_2) and from 17-2-2000 to 10-3-2000 was considered as late harvest crop (S_3). Similarly the early, mid and late harvest phases for the varieties Kanaka and Madakkathra-2 were calculated and nuts collected during each phase was treated as separate samples.

The samples were analysed for their physical and biochemical characters. The results are presented below :

4.2.1 Physical characters of nuts:

The results of the studies on physical characters of nuts under this experiment are presented in Table 9.

Nut length

Nut length did not show significant variation between early, mid and late season crops in any of the varieties studied.

Nut breadth

Nut breadth did not show significant variation between early, mid and late season crops in any of the varieties studied.

Nut weight

Irrespective of the varieties, the average nut weight was highest for the nuts of mid phase crop (6.55g).

When the nuts of the individual varieties from the different crop phases was compared, the highest nut weight (6.05g) for variety Madakkathra-1, was observed for its mid phase crop and the lowest (5.53g) for the early crop.

Table 9. Nut characters in relation to flowering behaviour of varieties and different phases of harvest

Crop phase	Physical characters of nuts					
	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
S_1	3.77	2.40	6.15	3.00	30.51	69.56
S_2	3.93	2.34	6.55	2.99	28.28	71.73
S_3	3.91	2.40	6.39	3.09	29.00	71.01
CD (0.05)	NS	NS	NS	NS	1.05	0.39
SEm±	0.14	0.03	0.08	0.05	0.35	0.13
Varieties						
V_1	3.90	2.37	5.84	2.81	29.36	70.73
V_2	3.47	2.33	5.77	3.09	29.30	70.70
V_3	4.25	2.44	7.47	3.19	29.13	70.87
CD (0.05)	0.42	NS	0.25	0.16	NS	NS
SEm±	0.14	0.03	0.08	0.05	0.35	0.13
Crop phase X varieties						
S_1V_1	3.66	2.37	5.53	2.69	31.13	69.07
S_1V_2	3.31	2.39	5.72	3.07	31.00	69.00
S_1V_3	4.34	2.45	7.20	3.26	29.40	70.60
S_2V_1	4.07	2.33	6.05	2.70	26.93	73.10
S_2V_2	3.57	2.32	5.92	3.08	27.90	72.10
S_2V_3	4.15	2.37	7.66	3.20	30.00	70.00
S_3V_1	3.95	2.41	5.95	3.04	30.00	70.03
S_3V_2	3.52	2.29	5.67	3.12	29.00	71.00
S_3V_3	4.25	2.50	7.56	3.11	28.00	72.00
CD (0.05)	NS	NS	0.42	NS	1.82	0.68
SEm±	0.24	0.06	0.14	0.09	0.61	0.23

S_1=Early part of harvest phase, S_2=Mid part of harvest phase, S_3=Late part of harvest phase
V_1=Madakkathra-1, V_2=Kanaka, V_3=Madakkathra-2

In the variety Kanaka, no significant variation was observed in the weight of nuts collected from the early, mid and late crop phases.

In case of variety Madakkathra-2, the highest nut weight (7.66g) was in the mid crop phase and lowest nut weight (7.20g) in the early crop phase.

Shell thickness

Irrespective of the varieties, the average shell thickness of the nuts showed no significant difference, between the early, mid and late crop seasons.

Within the varieties also, there was no significant difference in the shell thickness over the early, mid and late crops.

Shelling percentage

Irrespective of the varieties, the average shelling percentage obtained, was highest (30.51%) in the early crop season, and the lowest (28.28%) was observed in the mid season crop.

In the varieties Madakkathra-1 and Kanaka, the highest shelling percentage (31.13% and 31% respectively), was obtained in the early crop season and the lowest (26.93% and 27.90% respectively) in the mid season crop.

In the case of Madakkathra-2, the highest shelling percentage (30%) was observed in the mid phase crop and the lowest (28%) in the late phase crop.

Percentage husk rejects

Irrespective of the varieties, the average husk rejects, was lowest (69.56%) in the early phase crop and highest (71.73%) in the mid phase crop. This was true for the varieties Madakkathra-1 and Kanaka, for which the minimum husk rejects (69.07% and 69% respectively) was observed in the early phase crop and the maximum (73.10% and 72.10% respectively) in the mid phase crop.

Variety Madakkathra-2 had the lowest husk rejects (70.00%) during the mid phase crop and it was highest (72.00%) during the late phase crop.

4.2.2 Physical characters of kernels

The data on the physical characters of kernels under this experiment are presented in Table 10 :

Kernel weight

The average kernel weight did not vary significantly between the early, mid and late crop seasons, irrespective of the varieties.

Table 10.Kernel characters in relation to flowering behaviour of varieties and different phases of harvest

Crop phase	Physical characters of kernels			
	Weight (g)	White wholes (%)	Pieces (%)	Rejects (%)
S_1	1.82	89.64	9.59	0.82
S_2	1.93	89.94	9.54	0.59
S_3	1.84	93.59	4.92	1.60
CD (0.05)	NS	1.07	0.63	0.25
SEm±	0.07	0.36	0.21	0.08
Varieties				
V_1	1.86	90.4	7.80	1.87
V_2	1.61	86.88	12.77	0.46
V_3	2.12	95.90	3.49	0.68
CD (0.05)	0.21	1.07	0.63	0.25
SEm±	0.07	0.36	0.21	0.08
Crop phase X varieties				
S_1V_1	1.70	87.5	10.13	2.47
S_1V_2	1.62	86.1	13.93	0.00
S_1V_3	2.15	95.33	4.71	0.00
S_2V_1	1.96	90.00	9.03	1.06
S_2V_2	1.66	84.50	14.84	0.72
S_2V_3	2.17	95.33	4.75	0.00
S_3V_1	1.94	93.70	4.23	2.08
S_3V_2	1.54	90.03	9.53	0.67
S_3V_3	2.03	97.02	0.99	2.04
CD (0.05)	NS	1.85	1.09	0.43
SEm±	0.12	0.62	0.37	0.14

S_1=Early part of harvest phase, S_2=Mid part of harvest phase, S_3=Late part of harvest phase
V_1=Madakkathra-1, V_2=Kanaka, V3=Madakkathra-2

Within each variety also, significant variation in kernel weight was not observed when samples collected during different phases of the crop were compared.

Percentage white wholes

The recovery of white wholes was highest (93.59%) from the late crop and lowest (89.64%) from the early crop. This was found true also when the individual varieties were considered separately. Thus for the varieties Madakkathra-1, Kanaka and Madakkathra-2, the recovery of white wholes was maximum (93.70%, 90.03% and 97.02% respectively) from the late crop of each variety.

For the variety Madakkathra-1, the minimum recovery of white wholes (87.5%) was obtained in its early crop phase. In the variety Kanaka, the minimum recovery of white wholes (84.50%) was from the mid crop phase.

For the variety Madakkathra-2, the recovery of white wholes was (95.33%) both in the early and mid crop phases.

Percentage kernel pieces

Irrespective of the varieties, the lowest kernel pieces (4.92%) was recorded from the late season crop and the highest (9.59%) from the early season crop.

When each variety was considered separately, lowest count of kernel pieces was recorded in the late crop.

In the variety Madakkathra-1, the highest kernel pieces (10.13%) was observed in its early phase crop. In the varieties Kanaka and Madakkathra-2, the kernel pieces was highest (14.84% and 4.75% respectively) in the mid phase crop of these varieties.

Percentage kernel rejects

Irrespective of the varieties, the minimum kernel rejects (0.59%) was observed in the mid season crop, and maximum (1.60%) in the late season crop.

In the variety Madakkathra-1, minimum kernel rejects (1.06%) was observed in its mid crop phase and the maximum (2.47%) in the early crop phase.

Variety Kanaka had no kernel rejects in the early season crop. Highest kernel rejects (0.72%) was recorded in the mid phase crop.

Variety Madakkathra-2 had no kernel rejects in the early and mid crop phases. 2.04% rejects were found in the late phase crop.

4.2.3 Biochemical characters

The variation in the biochemical characters of cashew kernels according to flowering behaviour are presented in Table 11.

Table 11. Biochemical constituents of kernels in relation to flowering behaviour of varieties and different phases of harvest .

Crop phase	Biochemical constituents of kernels			
	Sugar (%)	Carbohydrates(%)	Protein (%)	Fat (%)
S_1	8.75	21.06	20.16	44.11
S_2	9.57	20.09	20.11	43.35
S_3	8.53	19.23	18.99	45.29
CD (0.05)	0.57	0.88	0.53	1.12
SEm±	0.19	0.30	0.18	0.38
Varieties				
V_1	8.98	19.38	18.94	45.29
V_2	8.41	18.68	19.77	47.49
V_3	9.46	22.32	20.54	39.97
CD (0.05)	0.57	0.88	0.53	1.12
SEm±	0.19	0.30	0.18	0.38
Crop phase X varieties				
S_1V_1	8.39	21.39	19.09	45.37
S_1V_2	8.16	18.04	20.60	45.65
S_1V_3	9.71	23.73	20.79	41.31
S_2V_1	10.79	17.04	19.09	41.35
S_2V_2	8.79	20.77	20.00	49.10
S_2V_3	9.12	22.48	21.23	39.61
S_3V_1	7.77	19.70	18.63	49.15
S_3V_2	8.28	17.23	18.73	47.72
S_3V_3	9.54	20.76	19.60	39.00
CD (0.05)	0.99	1.53	NS	1.94
SEm±	0.33	0.51	0.31	0.65

S_1=Early part of harvest phase, S_2=Mid part of harvest phase, S_3=Late part of harvest phase
V_1=Madakkathra-1, V_2=Kanaka, V_3=Madakkathra-2

Sugars

The average sugar content in the kernels was highest (9.57%) in the mid season crop and lowest (8.53%) in the late season crop.

In the variety Madakkathra-1, the sugar content in the kernels was highest (10.79%) in the mid phase crop and lowest (7.77%) in the late phase crop.

In varieties Kanaka and Madakkathra-2, the sugar content in the kernels did not vary significantly between the early, mid and late crop phases.

When the varieties were compared, sugar content was highest (9.46%) in the late season variety Madakkathra-2 and lowest (8.41%) in the mid season variety Kanaka.

Carbohydrates

The highest carbohydrate content (21.06%) was observed in the early season crop and the lowest (19.23%) was observed in the late season crop.

In the varieties Madakkathra-1 and Madakkathra-2, the highest carbohydrate content (21.39% and 23.73% respectively) was observed in the early crop phase of these varieties. Variety Kanaka had the highest carbohydrate content (20.77%) in its mid crop phase.

In the variety Madakkathra-1, the carbohydrate content was lowest (17.04%) in its mid crop phase. Varieties Madakkathra-2 and Kanaka, had this constituent lowest (17.23% and 20.76%) in their late crop phases.

The late season variety Madakkathra-2 had the highest carbohydrate content (22.32%) and the mid season variety Kanaka had the lowest (18.68%) among the varieties examined.

Proteins

Protein content was highest (20.16%) in the early season crop, and the lowest (18.99%) in the late season crop, irrespective of the varieties.

The three varieties did not show significant variation with respect to protein content during the early, mid and late crop phases.

When the varietal comparison was made, the highest protein content (20.54%) was observed in the late season variety, Madakkathra-2 and lowest (18.94%) in the kernels of the early season variety, Madakkathra-1.

Fat

The highest fat content (45.29%) was observed the late season crop and the lowest (43.35%) in the mid season crop.

A large variation was observed in the fat content present in the kernels of the three varieties, when each variety, was analysed during the three crop seasons (Table 11).

The varietal comparison showed highest fat content (47.49%) in the mid season variety Kanaka and the lowest content (39.97%) in the late season variety Madakkathra-2.

4.3 INFLUENCE OF MATURITY OF NUTS ON PROCESSING QUALITIES

4.3.1 Physical characters of nuts

The physical characters of nuts of the five varieties viz. Priyanka (V_1), Sulabha (V_2), Madakkathra-2(V_3), K-22-1(V_4) and Kanaka (V_5) studied at the three maturity stages viz., 45-50 days after nut set (M_1), 50-55 days after nut set (M_2) and 55-60 days after nut set (M_3) are presented in Table 12.

The physical characters of nuts studied in relation to stages of maturity are presented in Table12:

Nut length

In the varieties studied, no significant variation was observed in the nut length at the three maturity stages viz., 45-50, 50-55 and 55-60 days after nut set.

Table 12. Influence of stages of maturity on physical characters of cashewnuts of different varieties

Days after nut set	Physical characters of nuts					
	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
M_1	3.89	2.43	7.27	2.79	26.20	73.65
M_2	3.87	2.45	7.47	3.06	25.78	74.27
M_3	3.91	2.46	7.73	3.06	27.03	73.15
CD (0.05)	NS	NS	NS	0.09	0.36	0.57
SEm±	0.08	0.04	0.17	0.03	0.12	0.20
Varieties						
V_1	4.64	2.74	10.07	3.19	25.82	74.21
V_2	3.97	2.50	8.09	2.62	28.60	71.41
V_3	4.28	2.33	6.97	2.84	26.54	73.48
V_4	3.22	2.27	6.26	3.19	24.21	75.82
V_5	3.34	2.41	6.06	3.01	26.51	73.52
CD (0.05)	0.31	0.14	0.62	0.12	0.46	0.74
SEm±	0.11	0.05	0.21	0.04	0.16	0.26

Table 12. continued

Varieties X Stages of maturity						
M_1V_1	4.62	2.71	9.67	2.82	26.20	73.83
M_1V_2	4.03	2.42	7.77	2.17	28.40	70.80
M_1V_3	4.23	2.29	6.68	2.87	26.30	73.70
M_1V_4	3.22	2.27	6.26	3.28	23.80	76.20
M_1V_5	3.37	2.46	5.99	2.82	26.30	73.73
M_2V_1	4.58	2.77	9.96	3.38	25.42	74.60
M_2V_2	3.97	2.47	8.05	2.83	28.20	71.80
M_2V_3	4.31	2.36	6.95	2.81	25.83	74.23
M_2V_4	3.21	2.26	6.25	3.17	23.43	76.67
M_2V_5	3.28	2.37	6.12	3.09	26.03	74.05
M_3V_1	4.73	2.73	10.58	3.35	25.83	74.20
M_3V_2	3.91	2.59	8.47	2.86	29.20	71.63
M_3V_3	4.28	2.33	7.27	2.85	27.50	72.50
M_3V_4	3.23	2.27	6.26	3.12	25.40	74.60
M_3V_5	3.37	2.40	6.07	3.11	27.21	72.80
CD (0.05)	NS	NS	NS	0.20	0.79	NS
SEm±	0.19	0.08	0.37	0.07	0.27	0.44

M_1= 45-50 days after nut set , M_2= 50-55 days after nut set, M_3= 55-60 days after nut set

V_1=Priyanka, V_2=Sulabha, V_3=Madakkathra-2, V_4=K-22-1, V_5=Kanaka

Nut breadth

The nut breadth also, did not vary significantly between the three maturity stages of nuts, in the varieties studied.

Nut weight

The nut weight recorded at the three stages of maturity of nuts did not show significant variation in the varieties studied.

Shell thickness

Significant variations were observed in the shell thickness of the nuts between the three maturity stages, analysed. In general, a maximum shell thickness of 3.06mm was observed in the nuts 50-55 days after nut set and fully mature nuts. The shell thickness was minimum (2.79mm) in the nuts 45-50 days after nut set.

For the varieties Priyanka, Sulabha and Kanaka maximum shell thickness was observed in the fully mature nuts, while the nuts of 45-50 days had the minimum shell thickness (Table 12)

In varieties Madakkathra-2 and K-22-1, the shell thickness did not differ significantly among the three maturity stages.

Shelling percentage

Significant variation was observed in the shelling percentage obtained at the three maturity stages of nuts, of all the varieties studied, except Priyanka.

For Priyanka, the shelling percentage obtained did not record significant variation among the three maturity stages and the average was 25.8%.

For the varieties Madakkathra-2, K-22-1, Kanaka and Sulabha the maximum shelling percentage (27.5%, 25.40%, 27.21% and 29.20% respectively) was obtained in the fully mature nuts.

For all the varieties studied, the minimum shelling percentage was obtained for the nuts, at maturity of 50-55 days after nut set.

Percentage husk rejects

The husk rejects obtained, from the nuts of different maturity stages, did not differ significantly, when variety wise analysis was done (Table 12).

Irrespective of the varieties, maximum husk rejects (74.27%) was observed in the nuts at 50-55 days after nut set. The husk rejects obtained from the nuts at full maturity level (73.15%) was on par with (73.65%) obtained from the nuts at 45-50 days after nut set.

4.3.2 Physical characters of kernels

The results of the physical characters of kernels studied in relation to stages of maturity are presented in Table13:

Kernel weight

In all the varieties studied, the kernel weight did not vary significantly between the three maturity stages analysed.

Percentage white wholes

It was observed that the recovery of white wholes was highest (91.01%) from the fully mature nuts.

Variety Priyanka gave the highest recovery of white wholes (91.05%) from the nuts 50-55 days after nut set.

In the varieties Sulabha, Madakkathra-2, K-22-1 and Kanaka, the recovery of white wholes was maximum (91, 96.03, 90.00 and 90.02 percent respectively) from the fully mature nuts.

From the Table13, it is evident that the recovery of white wholes was less from the nuts collected during the first two maturity stages.

Table 13. Influence of stages of maturity on physical characters of kernels of different cashew varieties

Days after nut set	Physical characters of kernels			
	Weight (g)	White wholes (%)	Pieces (%)	Rejects (%)
M_1	1.93	87.34	11.59	0.99
M_2	1.95	89.23	9.42	1.30
M_3	2.06	91.01	7.74	0.85
CD (0.05)	NS	0.89	0.55	0.26
SEm±	0.04	0.31	0.19	0.09
Varieties				
V_1	2.60	89.35	8.19	2.24
V_2	2.06	88.67	11.04	0.04
V_3	2.09	94.21	4.49	1.30
V_4	1.52	84.47	15.11	0.30
V_5	1.63	89.27	8.97	1.39
CD (0.05)	0.15	1.14	0.71	0.33
SEm±	0.05	0.40	0.25	0.11

Table 13. Continued

Stage of maturity X varieties				
M_1V_1	2.53	89.00	8.69	2.33
M_1V_2	2.11	87.00	12.69	0.00
M_1V_3	1.97	93.55	4.81	1.53
M_1V_4	1.50	78.37	21.63	0.00
M_1V_5	1.54	88.80	10.11	1.09
M_2V_1	2.57	91.05	4.60	4.38
M_2V_2	1.94	88.00	12.00	0.00
M_2V_3	2.07	93.04	5.95	1.03
M_2V_4	1.50	85.05	14.79	0.16
M_2V_5	1.66	89.00	9.78	0.92
M_3V_1	2.69	88.00	11.27	0.00
M_3V_2	2.11	91.00	8.43	0.11
M_3V_3	2.23	96.03	2.70	1.24
M_3V_4	1.56	90.00	9.25	0.75
M_3V_5	1.68	90.02	7.02	2.15
CD (0.05)	NS	1.98	1.23	0.57
SEm±	0.09	0.69	0.43	0.20

M_1= 45-50 days after nut set, M_2=50-55 days after nut set, M_3=55-60 days after nut set

V_1=Priyanka, V_2=Sulabha, V_3=Madakkathra-2, V_4=K-22-1, V_5=Kanaka

Percentage kernel pieces

The percentage of kernel pieces obtained from the nuts at 55-60 days after set was low (7.74%) compared to the nuts at 45-50 and 50-55 days after nut set (11.59% and 9.42% respectively).

When each variety was considered individually, for the variety Priyanka minimum kernel pieces (4.6%)was obtained from the nuts 50-55 days after nut set. For the other varieties Sulabha, Madakkathra-2, K-22-1 and Kanaka, the kernel pieces were lowest (8.43, 2.70, 9.25 and 7.02 percent respectively) when used at fully mature stage.

Percentage kernel rejects

The highest kernel rejects (1.29%) was obtained in the nuts at 50-55 days after nut set.

In variety Priyanka, there were no kernel rejects in the fully mature nuts, while the maximum (4.38%) was observed in the nuts at 50-55 days after nut set.

In the varieties Sulabha and Madakathara-2, the percentage of kernel rejects obtained, did not vary significantly among the three maturity levels. In the varieties K-22-1 and Kanaka maximum kernel rejects (0.75% and 2.15% respectively) were observed in the fully matured nuts.

4.3.3 Biochemical characters of kernels

The results of the biochemical characters of kernels studied in relation to stages of maturity are presented in Table14:

Sugars

As the nuts matured, the sugar content of the kernels increased. The highest sugar content (9.37%) was observed in the kernels from fully mature nuts, while it was minimum (7.99%) in the nuts at 45-50 days after nut set.

When the individual varieties were considered, the kernels of the variety Priyanka had highest sugar content (12.15%) at fully mature stage. In varieties Sulabha, Kanaka and K-22-1, the sugar content did not vary significantly between the three maturity stages.

In the variety Madakkathra-2, kernels from nuts at 45-50 days after nut set had the lowest sugar content (8.06%). The sugar content in the kernels from fully matured nuts (10.14%) was on par with that present in the kernels from nuts at 50-55 days after nut set (9.7%).

Carbohydrates

The carbohydrate content in the kernels showed a decreasing trend as the nuts matured. The highest content (21.37%) was observed in the nuts at 45-50 days after nut set and the lowest (17.85%) in the kernels from fully matured nuts. This was true when the five selected varieties were analysed individually, at the three stages of maturity.

Table 14. Influence of stages of maturity on the biochemical constituents of kernels of different cashew varieties

Days after nut set	Biochemical constituents of kernels			
	Sugar(%)	Carbohydrate (%)	Protein (%)	Fat(%)
M_1	7.99	21.37	17.48	44.42
M_2	8.81	19.37	20.51	44.67
M_3	9.37	17.85	21.34	45.01
CD (0.05)	0.45	0.59	0.50	NS
SEm±	0.16	0.21	0.17	0.19
Varieties				
V_1	10.27	20.05	21.50	43.97
V_2	8.07	18.44	19.83	45.58
V_3	9.30	21.21	19.98	42.36
V_4	8.05	18.92	18.29	44.80
V_5	7.92	19.03	19.29	46.80
CD (0.05)	0.59	0.77	0.64	0.72
SEm±	0.20	0.27	0.22	0.25

Table 14. continued

Stage of maturity X varieties				
M_1V_1	8.46	21.33	18.49	44.49
M_1V_2	7.83	19.22	16.68	46.53
M_1V_3	8.06	24.06	17.35	42.92
M_1V_4	7.94	21.50	16.80	42.63
M_1V_5	7.65	20.75	18.08	45.53
M_2V_1	10.20	21.15	22.49	43.90
M_2V_2	7.83	18.85	20.93	45.19
M_2V_3	9.70	20.12	21.07	42.63
M_2V_4	7.87	18.17	18.78	45.42
M_2V_5	8.01	18.56	19.27	46.22
M_3V_1	12.15	17.68	23.52	43.51
M_3V_2	8.55	17.24	21.87	45.03
M_3V_3	10.14	19.44	21.53	41.53
M_3V_4	8.35	17.09	19.29	46.33
M_3V_5	8.10	17.77	20.51	48.65
CD (0.05)	1.02	1.33	1.11	1.25
SEm±	0.35	0.46	0.39	0.43

M_1= 45-50 days after nut set , M_2=50-55 days after nut set, M_3=55-60 days after nut set

V_1=Priyanka, V_2=Sulabha, V_3=Madakkathra-2, V_4=K-22-1, V_5=Kanaka

Proteins

The protein content in the kernels from nuts of the five varieties analysed, showed an increasing trend as the nut reached maturity. Highest protein content (21.34%) was observed in the fully matured nuts and the lowest (17.48%) was observed in the kernels at 45-50 days after nut set.

Fat

The fat content present in the kernels did not vary significantly when analysed at the three maturity stages, viz: 45-50, 50-55 and 55-60 days after nut set.

The result was same for the variety Priyanka, when the varieties are considered individually. But in the varieties Sulabha and Madakkathra-2, highest fat content (46.53% and 42.92% respectively) was observed in the kernels at 45-50 days after nut set, and in the varieties K-22-1 and Kanaka, the fat content was high (46.33% and 48.65% respectively) in the fully matured nuts (Table 14).

4.4 NUT QUALITY IN RELATION TO SIZE AND TIME OF ARRIVAL IN THE MARKET

The three size groups of nuts viz., 5-7g (W_1), 7.1-9g(W_2) and 9.1-11g(W_3) from early(S_1), mid(S_2) and late(S_3) crop phases were evaluated. The results of their physical and biochemical characters are presented below:

4.4.1 Physical characters of nuts

The physical characters of the nuts studied under this experiment are presented in Table 15 .

Nut length

The length of nuts did not vary with respect to phases (early, mid and late crop phases) of harvest of the different sizes of nuts studied.

Nut breadth

Irrespective of the size of nuts, the average nut breadth did not show significant variation among the early, mid and late crop phases.

The result was same when nuts of different sizes were examined separately for early, mid and late crop phases.

Nut weight

The nut weight of early, mid and late crop phases of different sizes of nuts did not show significant variation.

Shell thickness

The shell thickness of the nuts of early, mid and late crop phases did not show significant variation, when nuts were grouped according to the size categories.

Table 15. Variation in nut quality in relation to size and time of nut arrival in the market.

Size of nuts	Physical characters of nuts					
	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
W_1	3.47	2.34	5.65	2.93	29.85	70.16
W_2	4.26	2.50	7.67	3.19	28.47	71.54
W_3	4.66	2.69	9.92	3.44	25.68	74.33
CD (0.05)	0.14	0.13	0.56	0.17	1.03	0.65
SEm±	0.05	0.04	0.19	0.06	0.35	0.22
Crop phase						
S_1	4.15	2.51	7.71	3.15	28.59	71.42
S_2	4.16	2.54	7.80	3.22	27.73	72.28
S_3	4.09	2.49	7.72	3.20	27.67	72.34
CD (0.05)	NS	NS	NS	NS	NS	NS
SEm±	0.05	0.04	0.19	0.06	0.35	0.22
Nut size X Crop phase						
W_1S_1	3.47	2.36	5.63	2.82	31.05	68.95
W_1S_2	3.51	2.33	5.51	2.88	29.00	71.03
W_1S_3	3.43	2.34	5.80	3.07	29.50	70.51
W_2S_1	4.34	2.44	7.65	3.26	29.40	70.61
W_2S_2	4.20	2.56	7.79	3.20	28.00	72.00
W_2S_3	4.25	2.49	7.56	3.11	28.00	72.00
W_3S_1	4.63	2.71	9.85	3.35	25.33	74.70
W_3S_2	4.76	2.73	10.10	3.57	26.20	73.80
W_3S_3	4.58	2.63	9.80	3.41	25.50	74.50
CD (0.05)	NS	NS	NS	NS	NS	NS
SEm±	0.08	0.07	0.33	0.10	0.60	0.38

W_1= Nuts of size 5-7g, W_2=Nuts of size 7.1-9g, W_3=Nuts of size 9.1-11g

S_1=Early part of harvest phase, S_2=Mid part of harvest phase, S_3=Late part of harvest phase

Shelling percentage

The shelling percentage did not register significant variation among the nuts collected during early, mid and late crop phases when individual sizes of nuts were analysed separately.

Percentage husk rejects

When the different nut sizes were compared, the 9.1-11g sized nuts recorded the highest husk rejects (74.33%) and the lowest (70.16%) was observed in the nuts of size 5-7g.

The percentage husk rejects did not show significant variation during the early, mid and late crop seasons.

4.4.2 Physical characters of kernels

The results on the studies of the physical characters of kernels are presented in Table 16:

Kernel weight

The weight of kernels from the three different size groups of nuts collected during early, mid and late crop phases did not show significant difference.

This was also true when the average kernel weight from different size groups of nuts over different crop phases were compared.

Table 16 Variation in kernel quality in relation to size and time of nut arrival in the market.

Size of nuts	Physical characters of kernels			
	Weight (g)	White wholes (%)	Pieces (%)	Rejects (%)
W_1	1.73	88.22	10.16	1.63
W_2	2.12	95.12	3.84	1.07
W_3	2.65	91.34	7.19	1.48
CD (0.05)	0.17	1.22	0.70	0.25
SEm±	0.06	0.41	0.23	0.08
Crop phase				
S_1	2.17	91.03	8.12	0.86
S_2	2.22	90.69	7.75	1.59
S_3	2.11	92.96	5.33	1.73
CD(0.05)	NS	1.22	0.70	0.25
SEm±	0.06	0.41	0.23	0.08
Nut size X Crop phase				
W_1S_1	1.68	86.80	12.02	1.19
W_1S_2	1.78	86.00	11.59	2.42
W_1S_3	1.74	91.85	6.87	1.28
W_2S_1	2.15	95.30	4.71	0.00
W_2S_2	2.17	94.07	4.75	1.26
W_2S_3	2.03	96.00	2.06	1.96
W_3S_1	2.69	91.00	7.62	1.38
W_3S_2	2.70	92.00	6.90	1.10
W_3S_3	2.56	91.03	7.05	1.95
CD (0.05)	NS	2.11	1.21	0.43
SEm±	0.10	0.71	0.41	0.38

W_1= Nuts of size 5-7g, W_2=Nuts of size 7.1-9g, W_3=Nuts of size 9.1-11g

S_1=Early part of harvest phase, S_2=Mid part of harvest phase. S_3=Late part of harvest phase

Percentage white wholes

When the different sizes were compared over the crop phases, the maximum recovery of white wholes (95.12%) was observed for the nuts having 7.1-9g weight and the minimum (88.22%) was observed for the nuts of size 5-7g.

Irrespective of the size of nuts, the maximum recovery of white wholes (92.96%) was observed with that of late crop phase and the recovery was minimum (90.69%) for the mid crop phase.

For the nuts of size 5-7g, the recovery of white wholes was maximum (91.85%) in the late season crop and it was minimum (86.00%)in the mid season crop.

The nuts of three crop phases belonging to the sizes 7.1-9g and 9.1-11g did not register significant variation with respect to the recovery of white wholes when analysed separately.

Percentage kernel pieces

Irrespective of the size of nuts, the minimum kernel pieces (5.33%) was obtained from the late season crop and maximum (8.12%) was observed in the early season crop.

In the nuts of size group 5-7g and 7.1-9g, the minimum kernel pieces (6.87% and 2.06% respectively) was observed in the late season crop.

For the 5-7g size group, kernel pieces were more in the early crop phase (12.02%) and in the 7.1-9g size group, maximum kernel pieces (4.75%) was observed in the mid crop phase.

For the nuts of size group 9.1-11g the percentage of kernel pieces after processing did not vary significantly for the three crop seasons.

When the nuts of three categories were studied the minimum kernel pieces (3.84%) was observed for the nuts of size group 7.1-9g and the maximum (10.16%) for the nuts of size group 5-7g.

Percentage kernel rejects

Irrespective of the size of nuts, kernel rejects (0.86%)was less in the early season crop compared to 1.73% in the late season crop.

The nuts of size group 5-7g when processed recorded the lowest kernel rejects (1.19%) in the early crop phase and nuts of 7.1-9g size group had no kernel rejects during the same crop phase. The nuts of 9.1-11g size group had lowest kernel rejects (1.10%) in the mid crop phase.

When the different size groups of nuts were compared, the 7.1-9g size group had the lowest kernel rejects (1.07%) while the 5-7g size group had highest rejects (1.63%).

4.4.3 Biochemical characters of kernels

The biochemical characteristics of kernels evaluated under the study are given in the Table 17:

Sugars

The average sugar content in different size groups of nuts from early, mid and late crop seasons, did not show significant difference.

When the sugar content of the different size groups of nuts were compared over seasons, the nuts of 9.1-11g size group recorded the highest sugar content of 9.31% while the nuts of size group 5-7g had the lowest sugar content (8.22%).

Carbohydrates

The average carbohydrates content in the different size groups of nuts from early, mid and late crop seasons did not register significant difference.

Table 17. Biochemical constituents of the kernels in relation to size of nuts and time of nut arrival in the market.

Nut size	Biochemical constituents of kernels			
	Sugar (%)	Carbohydrates(%)	Protein (%)	Fat (%)
W_1	8.22	20.86	19.39	46.32
W_2	9.28	23.19	20.55	42.61
W_3	9.31	20.09	20.71	44.44
CD (0.05)	0.79	1.05	0.91	1.07
SEm±	0.26	0.35	0.31	0.36
Crop Phase				
S_1	9.35	21.23	20.57	43.84
S_2	8.50	22.83	20.61	45.01
S_3	8.96	21.08	20.47	44.52
CD (0.05)	NS	NS	NS	NS
SEm±	0.26	0.35	0.31	0.36
Nut size X Crop phase				
W_1S_1	8.24	19.99	19.86	45.53
W_1S_2	8.39	23.24	19.59	45.07
W_1S_3	8.03	19.34	18.71	48.37
W_2S_1	9.72	23.70	20.82	42.00
W_2S_2	8.57	24.00	21.32	45.63
W_2S_3	9.54	21.88	19.51	40.20
W_3S_1	10.10	20.01	21.02	44.00
W_3S_2	8.53	21.25	20.91	44.33
W_3S_3	9.31	19.01	20.20	45.00
CD (0.05)	NS	NS	NS	1.86
SEm±	0.46	0.61	0.53	0.63

W_1= Nuts of size 5-7g, W_2=Nuts of size 7.1-9g, W_3=Nuts of size 9.1-11g

S_1=Early part of harvest phase, S_2=Mid part of harvest phase. S_3=Late part of harvest phase

Among the different sizes of nuts studied, the carbohydrate content was maximum (23.19%) in the 7.1-9g size group and minimum (20.09%) in the nuts of size group 9.1-11g.

Proteins

The protein content in the kernels did not differ significantly when the nuts of each category based on size, were analysed during the early, mid and late crop seasons separately.

Among the different size groups of nuts, the protein content was highest (20.71%) in the nuts of size group 9.1-11g and lowest (19.39%) in the nuts of size group 5-7g.

Fats

Irrespective of the size of nuts the average fat content in the kernels did not vary significantly during the early, mid and late crop seasons. When the size of nuts were considered, the nuts of 5-7g size group had the highest fat content (48.37%) in the late crop phase and the lowest (45.07%) was observed in the mid crop phase.

In the nuts of size group 7.1-9g, the highest fat content (45.63%) was observed in the mid crop phase and the lowest (40.20%) in the late crop phase.

In the nuts of size group 9.1-11g, the fat content in the kernels did not vary between crop phases.

Among the different groups based on size, maximum fat content (46.32%) was observed in the nuts of size group 5-7g and the minimum (42.61%) in the nuts of size group 7.1-9g.

4.5 INFLUENCE OF PEST ATTACK

4.5.1 Physical characters of nuts

The physical characters of the nuts of three varieties, Madakkathra-1 (V_1), Kanaka (V_2) and Priyanka (V_3) attacked by two different pests viz., tea mosquito (P_1) and thrips (P_2) are presented in Table 18. The physical characters of the non infected nuts (P_3) of different varieties are given in the same table for comparison.

Nut length

The infected nuts were smaller compared to non infected ones. The TMB infected nuts recorded an average length of 3.67cm and the thrips infected ones 3.69cm, as against 4.03 cm for nuts not infected by pests.

The attack by tea mosquito bug and thrips did not cause significant difference in the length of nuts when the individual varieties were considered.

Table 18. Effect of Tea mosquito bug and thrips attack on physical characters of cashew nuts of different varieties

Pest attack	Physical characters of nuts					
	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
P_1	3.67	2.32	6.33	2.69	22.08	77.94
P_2	3.69	2.28	6.39	2.73	22.77	77.24
P_3	4.03	2.46	7.33	3.07	27.67	72.33
CD (0.05)	0.30	0.14	0.34	0.10	0.86	0.44
SEm±	0.10	0.05	0.11	0.03	0.29	0.15
Varieties						
V_1	3.56	2.25	5.19	2.80	24.01	76.01
V_2	3.28	2.22	5.41	2.77	24.73	75.27
V_3	4.56	2.59	9.44	2.92	23.77	76.24
CD (0.05)	0.30	0.14	0.34	0.10	NS	0.44
SEm±	0.10	0.05	0.11	0.03	0.29	0.15
Pest attack X Varieties						
P_1V_1	3.43	2.23	5.06	2.65	21.03	79.00
P_1V_2	3.14	2.22	5.24	2.84	22.60	77.40
P_1V_3	4.43	2.50	8.69	2.58	22.60	77.43
P_2V_1	3.38	2.16	4.91	2.86	22.00	78.02
P_2V_2	3.20	2.11	5.15	2.46	23.60	76.40
P_2V_3	4.50	2.55	9.11	2.89	22.70	77.30
P_3V_1	3.85	2.36	5.60	2.90	29.00	71.00
P_3V_2	3.50	2.32	5.85	3.00	28.00	72.00
P_3V_3	4.73	2.70	10.53	3.30	26.02	74.00
CD (0.05)	NS	NS	0.59	0.17	1.49	0.77
SEm±	0.17	0.08	0.20	0.06	0.50	0.26

P_1=Tea mosquito bug attack, P_2=Thrips attack, P_3=non infected nuts

V_1=Madakkathra-1, V_2=Kanaka, V_3=Priyanka

Nut breath

The pest attack did not cause significant variation when the nut breadth of Madakkathra-1, Kanaka and Priyanka were considered individually. But when the data was analysed irrespective of the varieties, the thrips and TMB infected nuts had less nut breadth (2.28 cm and 2.32 cm respectively) compared to control (2.46 cm).

Nut weight

Non infected nuts weighted more (7.33g) than TMB and thrips infected nuts (6.33g and 6.39g respectively).

Both the pest infestations were found to reduce the nut weight in all the varieties studied, compared to control (Table18)

Shell thickness

The infected nuts had lower shell thickness (2.69mm and 2.73mm) compared to non infected nuts (3.07mm).

When individual varieties are considered, the thrips attack did not cause significant variation in the shell thickness of Madakkathra-1, while the TMB infected nuts recorded reduced shell thickness (2.65mm) compared to control.

For the variety Kanaka, the shell thickness of the non infected nuts and TMB infected nuts (3mm and 2.84mm) were on par, while the thrips attack reduced the shell thickness significantly.

In the variety Priyanka, significant reduction in the shell thickness was caused due to TMB attack.

Shelling percentage

The shelling percentage of nuts infected by TMB and thrips were lower (22.08% and 22.77%) than the non infected nuts (27.67%).

In all the three varieties studied Madakkathra-1, Kanaka and Priyanka the highest shelling percentage was obtained in the non infected nuts (29%, 28% and 26.02% respectively). The pest attack resulted in lower shelling percentage (Table18).

Percentage husk rejects

When the effect of pest attack on the husk rejects was pooled and analysed, the highest husk rejects (77.94%) was recorded in the TMB infected nuts and the lowest (72.33%) in the non infected nuts.

When each variety was considered separately also, the lowest husk rejects was observed in the non infected nuts and ranged from 71 to 74%. The

highest husk rejects was observed in the TMB infected nuts (79%, 77.4% and 77.43% respectively) for varieties Madakkathra-1, Kanaka and Priyanka.

4.5.2 Physical characters of kernels

The physical characters of kernels of the different varieties studied in relation to pest attack are presented in Table 19.

Kernel weight

Pest attack was not found to affect kernel weight significantly, in the three varieties studied. However when the overall effect, irrespective of varieties was analysed, the pest infected nuts were found to have low kernel weight (1.68g for TMB infected nuts and 1.75g for thrips infected nuts) compared to non infected nuts (2.05g).

Percentage white wholes

Irrespective of the varieties, the highest recovery of white wholes was obtained from the non infected nuts (88%) and the recovery was lowest (70.06%) in the TMB infected nuts.

When the effect of pest attack on white whole kernel recovery of individual varieties was considered, non infected nuts were significantly superior

Table 19 . Effect of Tea mosquito bug and thrips attack on physical characters of cashew kernels of different varieties

Pest attack	Physical characters of kernels			
	Weight (g)	White wholes (%)	Pieces (%)	Rejects (%)
P_1	1.68	70.06	16.83	13.15
P_2	1.75	74.53	14.36	11.12
P_3	2.05	88.01	7.84	1.72
CD(0.05)	0.22	1.17	0.77	0.50
SEm±	0.07	0.39	0.26	0.17
Varieties				
V_1	1.54	79.27	11.59	8.26
V_2	1.54	75.16	13.69	9.91
V_3	2.39	78.18	13.76	7.83
CD(0.05)	0.22	1.17	0.77	0.50
SEm±	0.07	0.39	0.26	0.17
Pest attack X varieties				
P_1V_1	1.40	72.00	15.69	12.39
P_1V_2	1.40	68.63	16.98	14.40
P_1V_3	2.24	69.53	17.83	12.67
P_2V_1	1.42	75.80	13.83	10.33
P_2V_2	1.51	70.80	16.07	13.23
P_2V_3	2.31	77.00	13.17	9.81
P_3V_1	1.81	90.00	5.24	2.05
P_3V_2	1.70	86.03	8.03	2.10
P_3V_3	2.63	88.00	10.27	1.00
CD (0.05)	NS	2.02	1.34	0.87
SEm±	0.13	0.68	0.45	0.29

P_1=Tea mosquito bug attack, P_2=Thrips attack, P_3=non infected nuts

V_1=Madakkathra-1, V_2=Kanaka, V_3=Priyanka

(90%, 86.03% and 88% respectively) in the varieties Madakkathra-1, Kanaka and Priyanka. The recovery of white whole kernels was low in the TMB infected nuts.

Percentage kernel pieces

In general, the kernel pieces were lowest (7.84%) in the non infected nuts and highest (16.83%) in the TMB infected nuts.

The effect of pest attack was similar when individual varieties were considered separately.

Percentage kernel rejects

In all the three varieties : Madakkathra-1, Kanaka and Priyanka, the lowest kernel rejects (2.05%, 2.1% and 1% respectively) were observed in the non infected nuts, and the highest rejects were observed in the TMB infected nuts (Table19).

4.5.3 Biochemical characters of kernels

The biochemical characters of nuts analysed in relation to pest attack are presented in Table 20:

Table 20. Effect of Tea mosquito bug and thrips attack on biochemical constituents of kernels of different cashew varieties

Pest attack	Biochemical constituents of kernels			
	Sugar (%)	Carbohydrates(%)	Protein (%)	Fat (%)
P_1	8.31	13.36	11.52	46.89
P_2	8.62	13.10	12.96	46.79
P_3	9.52	18.89	19.95	45.90
CD (0.05)	0.57	0.72	0.59	NS
SEm±	0.19	0.24	0.20	0.29
Varieties				
V_1	8.57	15.76	14.16	46.88
V_2	8.01	15.38	14.99	47.75
V_3	9.86	14.21	15.28	44.95
CD(0.05)	0.57	0.72	0.59	0.86
SEm±	0.19	0.24	0.20	0.29
Pest attack X Varieties				
P_1V_1	8.67	14.34	10.05	46.95
P_1V_2	7.93	13.16	12.14	48.10
P_1V_3	8.35	12.57	12.37	45.62
P_2V_1	8.59	13.65	13.71	47.59
P_2V_2	7.82	13.27	13.74	47.05
P_2V_3	9.44	12.38	11.43	45.72
P_3V_1	8.46	19.30	18.72	46.10
P_3V_2	8.30	19.70	19.10	48.10
P_3V_3	11.80	17.68	22.03	43.50
CD (0.05)	0.98	NS	1.01	1.49
SEm±	0.33	0.42	0.34	0.50

P_1=Tea mosquito bug attack, P_2=Thrips attack, P_3=non infected nuts

V_1=Madakkathra-1, V_2=Kanaka, V_3=Priyanka

Sugars

High sugar content (9.52%) was observed in the non infected kernels. Kernels from nuts affected by TMB and thrips had significantly less sugars (8.31% and 8.62%).

In the varieties Madakkathra-1 and Kanaka, significant variation was not observed in the sugar content between the pest infected and the non infected kernels. In variety Priyanka the non infected nuts had 11.8% sugars compared to 8.35% in TMB infected ones.

Carbohydrates

Carbohydrate content in non infected kernels were higher (18.89%) compared to pest infected samples. The kernels from thrips infected nuts had 13.10 % carbohydrates while those from TMB infected ones had 13.36% carbohydrates.

Significant reduction in the content of carbohydrates was also observed in the pest infected nuts when the varieties were studied separately (Table 20).

Proteins

The pest attack on the nuts resulted in reduction of protein content in all the varieties studied. Protein content was highest in the non infected nuts

(19.95%). The protein content in the TMB and thrips infected nuts ranged only between 11.52% and 12.96%.

Fats

The fat content did not vary significantly between the kernels from pest infected nuts and the non infected nuts.

In varieties Madakkathra-1 and Priyanka, fat content was less in non infected nuts (46.1% and 43.5% respectively). The thrips infected nuts had more fat content (47.59% and 45.72% respectively).

In variety Kanaka, the fat content in the kernels from pest infested nuts did not vary significantly from the non infected kernels.

4.6 GRADE OF CASHEW KERNELS IN RELATION TO DIFFERENT SOURCES OF NUTS

The grade and colour of cashew kernels of nuts of different agroecological regions, different flowering behaviour of varieties, different maturity stages, different size groups and that attacked by different pests are given in Table 21.

When the kernel grades of the four varieties collected from the different agroecological regions were considered, kernels from the nuts of the variety Dhana from FSRS, Kotttarakkara were found to be bolder and acquired superior

Table 21. Kernel grade and colour chart

Nuts from different agroecological regions

Location X Varieties	Count/454gms	Grade designation	Kernel colour
L_1V_1	251.00	W280	Pale Ivory
L_2V_1	258.00	W280	Light ash
L_3V_1	239.00	W240	Light ash
L_4V_1	262.40	W280	Light ash
L_1V_2	275.15	W280	Light ash
L_2V_2	206.36	W210	Light ash
L_3V_2	267.00	W280	Light ash
L_4V_2	270.24	W280	White
L_1V_3	275.15	W280	White
L_2V_3	300.66	W320	White
L_3V_3	229.30	W240	White
L_4V_3	258.00	W280	Pale Ivory
L_1V_4	227.00	W240	Pale ivory
L_2V_4	159.30	W180	Pale ivory
L_3V_4	206.36	W210	White
L_4V_4	231.60	W240	Light ash

Nuts of three crop phases of different varieties

Location X Varieties	Count/454gms	Grade designation	Kernel colour
S_1V_1	267.00	W280	White
S_1V_2	275.15	W280	White
S_1V_3	211.16	W210	Light ash
S_2V_1	233.00	W240	Light ash
S_2V_2	280.00	W280	White
S_2V_3	209.20	W210	Light ash
S_3V_1	234.00	W240	Light ash
S_3V_2	295.00	W320	Light ash
S_3V_3	223.65	W240	Pale ivory

Table 21. continued

Nuts of varying maturity stages

Location X Varieties	Count/454gms	Grade designation	Kernel colour
M_1V_1	179.40	W180	Light ash
M_1V_2	215.16	W240	Pale ivory
M_1V_3	230.50	W240	Pale ivory
M_1V_4	302.66	W320	Pale ivory
M_1V_5	295.00	W320	Pale ivory
M_2V_1	176.65	W180	White
M_2V_2	234.02	W240	Light ash
M_2V_3	220.40	W240	Light ash
M_2V_4	302.66	W320	Light ash
M_2V_5	273.50	W280	Pale ivory
M_3V_1	168.77	W180	White
M_3V_2	215.16	W240	Pale ivory
M_3V_3	203.58	W210	Light ash
M_3V_4	291.03	W320	Light ash
M_3V_5	270.24	W280	Pale ivory

Nut of varying sizes from different harvest phases

Location X Varieties	Count/454gms	Grade designation	Kernel colour
W_1S_1	270.24	W280	Light ash
W_1S_2	255.00	W280	Light ash
W_1S_3	261.00	W280	Light ash
W_2S_1	211.16	W210	Light ash
W_2S_2	209.20	W210	White
W_2S_3	223.65	W240	Pale ivory
W_3S_1	169.40	W180	Light ash
W_3S_2	168.15	W180	White
W_3S_3	177.30	W180	Light ash

Table 21. continued

Nuts of different varieties attacked by pests

Location X Varieties	Count/454gms	Grade designation	Kernel colour
P_1V_1	324.30	W320	Pale white
P_1V_2	324.30	W320	Pale white
P_1V_3	203.60	W210	Pale white
P_2V_1	319.70	W320	Pale white
P_2V_2	300.60	W320	Pale white
P_2V_3	197.40	W210	Pale white
P_3V_1	252.00	W280	White
P_3V_2	267.06	W280	White
P_3V_3	172.60	W180	White

grade (W180) and were of pale ivory colour. The kernels of variety Madakkthra-1 collected from CRS, Anakkayam could be grouped under the comparatively higher grade (W240) than the samples from other regions.

The kernels of the nuts of variety Kanaka from FSRS, Kottarakkara had 206 kernels per pound and are graded as W210. Among the four samples of K-22-1, kernels of nuts from CRS, Anakkayam acquired a comparatively higher grade of W240.

Among the early, mid and late crop phases of the varieties Madakkathra-1 , Kanaka and Madakkthara-2, the kernels of nuts from early and mid harvest phases of variety Madakkthra-2 were found to possess a higher grade of W210. The kernels were of light ash colour.

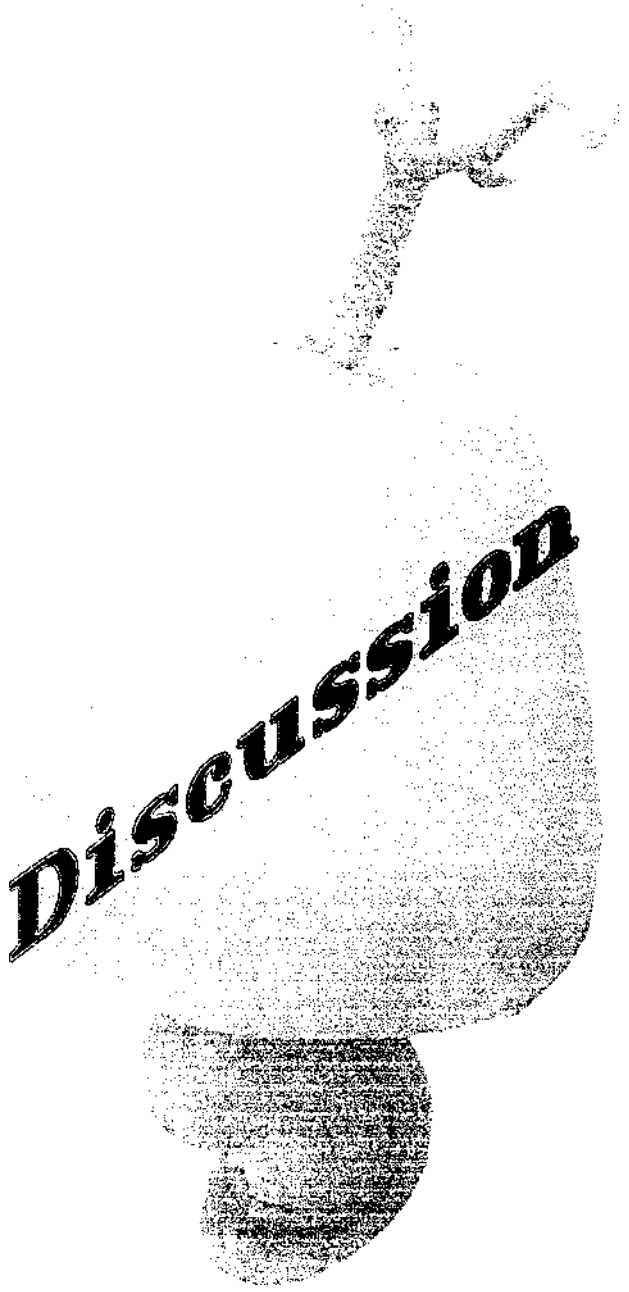
The kernel grade showed some different between the three maturity stages in the varieties Madakkathra-2 and Kanaka.

In the variety Madakkthara-2, the fully matured nuts 55-60 days after nut set gave kernels of grade W210 and they were light ash in colour, while the kernels from the nuts which were processed 45-50 and 50-55 days after set were graded under W240.

In case of the variety Kanaka the nuts at 45-50 days after set gave kernels of the lower grade W320, compared to the other two maturity stages.

It was observed that the size of nuts have relation with size of kernels. The nuts of size group 9.1-11g collected from all the three crop phases gave kernels of W180 grade on processing while the kernels from nuts of smaller size acquired lower grades.

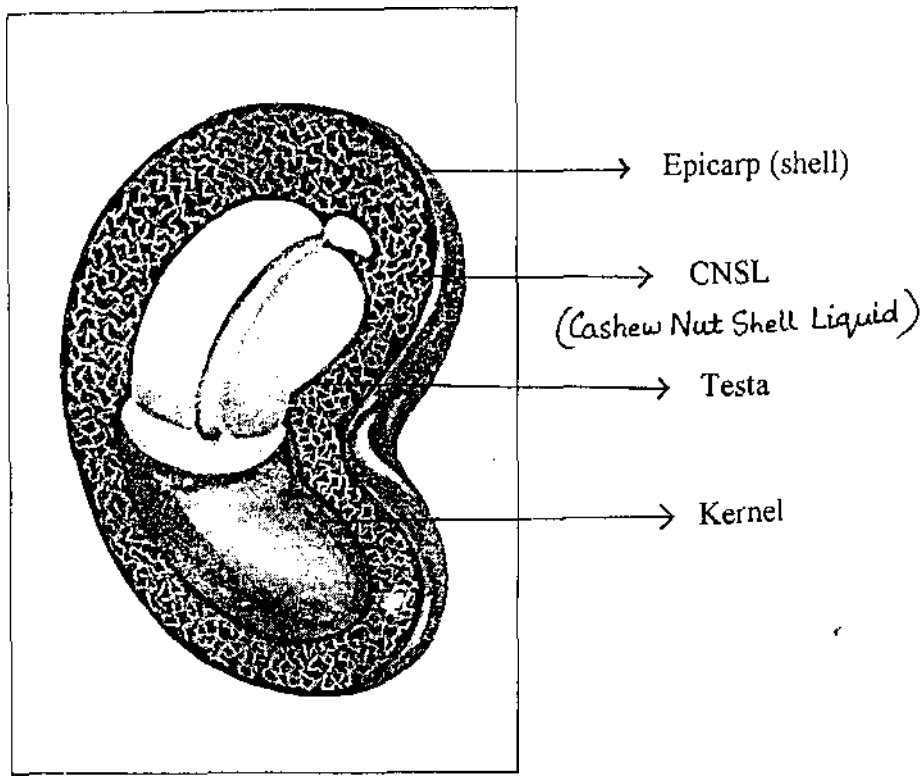
In the all the varieties, the kernels from pest infected nuts acquired lower grades, and the kernels were pale white in colour.


Discussion

DISCUSSION

The real fruit of cashew is called the nut. It is a kidney or heart shaped achene composed of the kernel and pericarp or shell.

Structure of a raw cashewnut



The shell consists of a leathery outer skin (epicarp) and thin hard inner skin (the endocarp). Between these two walls of the shell is a honey comb structure which contains the phenolic compounds, commercially known as the cashew nut shell liquid (CNSL). The cashew kernel inside the shell, wrapped in a thin brown skin, known as the testa.

Processing of cashew nut is meant for recovering the delicious and nutritious kernels. The quality of kernel is the sum total of its physical as well as biochemical characters. Good kernels can be obtained from raw nuts having desirable processing qualities. Desirable processing qualities include higher nut weight, shelling percentage, percentage yield of white whole kernels (of W180, W210 and W240 sizes), kernel size and less number of pieces and rejects (Salam, 1998). Hence the raw nut quality is of prime concern in the processing sector (Rao, 1998).

A number of variables can influence the raw nut quality which influences kernel quality as well. In the present investigation, the relationship between factors like agroecological conditions and phenological conditions of the crop, maturity stages of nuts, size of nuts as well as pest infestation on nut and kernel quality was studied.

5.1 INFLUENCE OF AGROECOLOGICAL REGIONS ON QUALITY OF RAW NUTS

Inorder to bring out the influence of agroecological conditions on kernel quality, variation in quality attributes of same variety in different locations were monitored. Nuts of same variety were collected from FSRS, Kottarakkara representing cashew growing region in the southern part of Kerala, CRS, Madakkathra representing cashew growing region in Central zone, CRS, Anakkayam and RARS, Pilicode representing cashew growing region in northern part of Kerala. The varieties selected for the study include Madakkathra-1, Kanaka, Dhana and K-22-1.

5.1.1 Physical characters

Nuts collected from the FSRS, Kottarakkara representing in the southern region was found to have better size compared to nuts from other regions (Fig.1). Among the physical characters studied, the nut length, breadth and weight of nuts collected from FSRS, Kottarakkara was found to be higher. At the same time the shell thickness was low. Husk rejects was comparable with those from other regions (Table1). The length and breadth of nuts are the biometrics that contribute to size of raw nuts and correlation had been reported between nut size and kernel size (Manoj, 1992., Swamy *et al.*, 1998). The nut weight and kernel weight of different varieties selected for the study was found to vary significantly in relation to the agroecological regions they were grown (Fig.2).

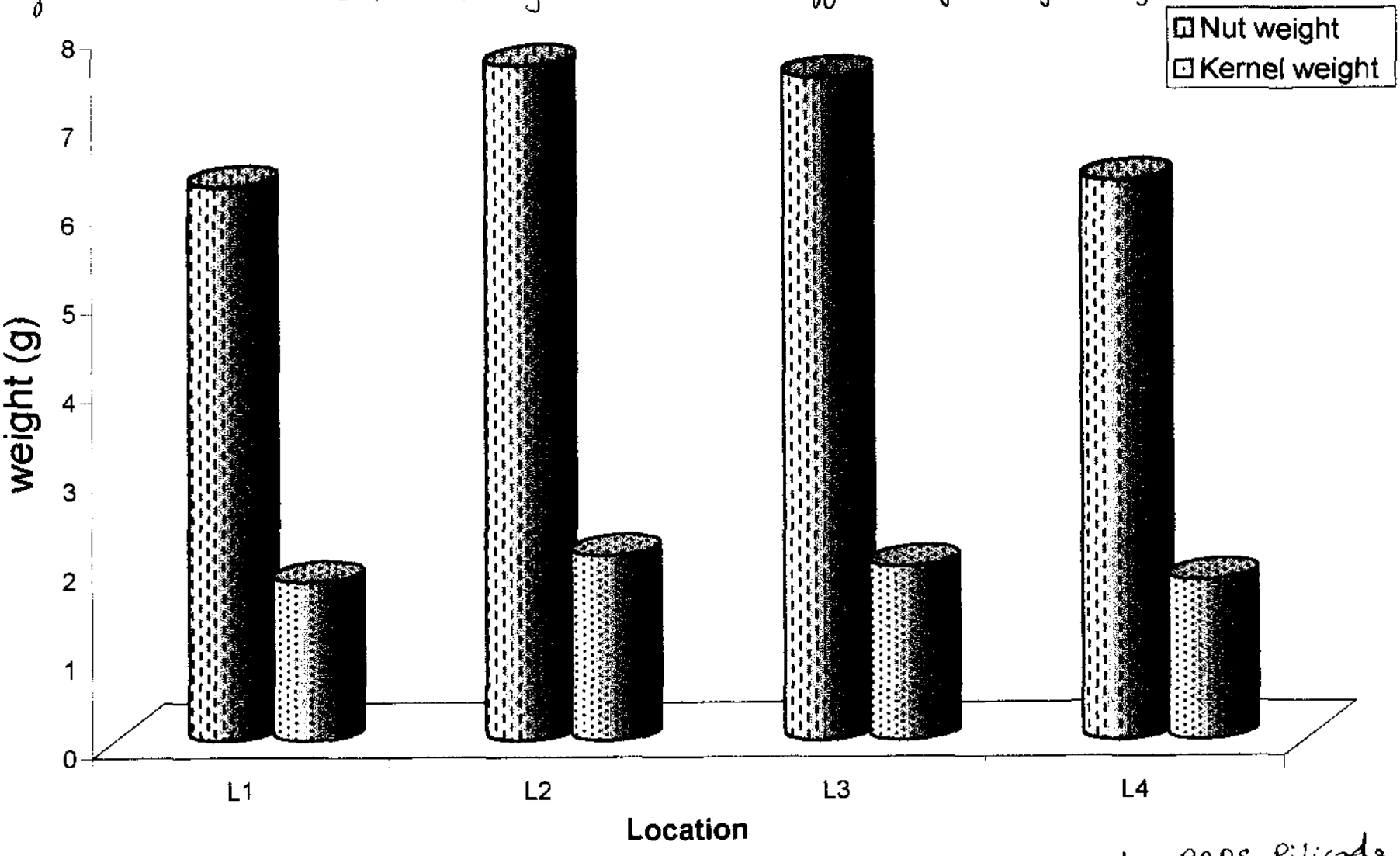
Though shell thickness also contributes to nut weight it ought to be negatively correlated with kernel weight. Thus the nuts which have more weight and low shell thickness, should give heavier kernels. The kernels obtained from nuts collected from FSRS, Kottarakkara were found to have comparatively more weight (Table2) compared to those from other regions.

Nuts collected from CRS, Madakkathra were of smaller size and had low kernel weight. The shell thickness of nuts from this region was similar to those collected from other regions.

The overall shelling percentage of all the varieties collected from CRS, Madakkathra was found high (Fig.3). Shelling percentage is an important

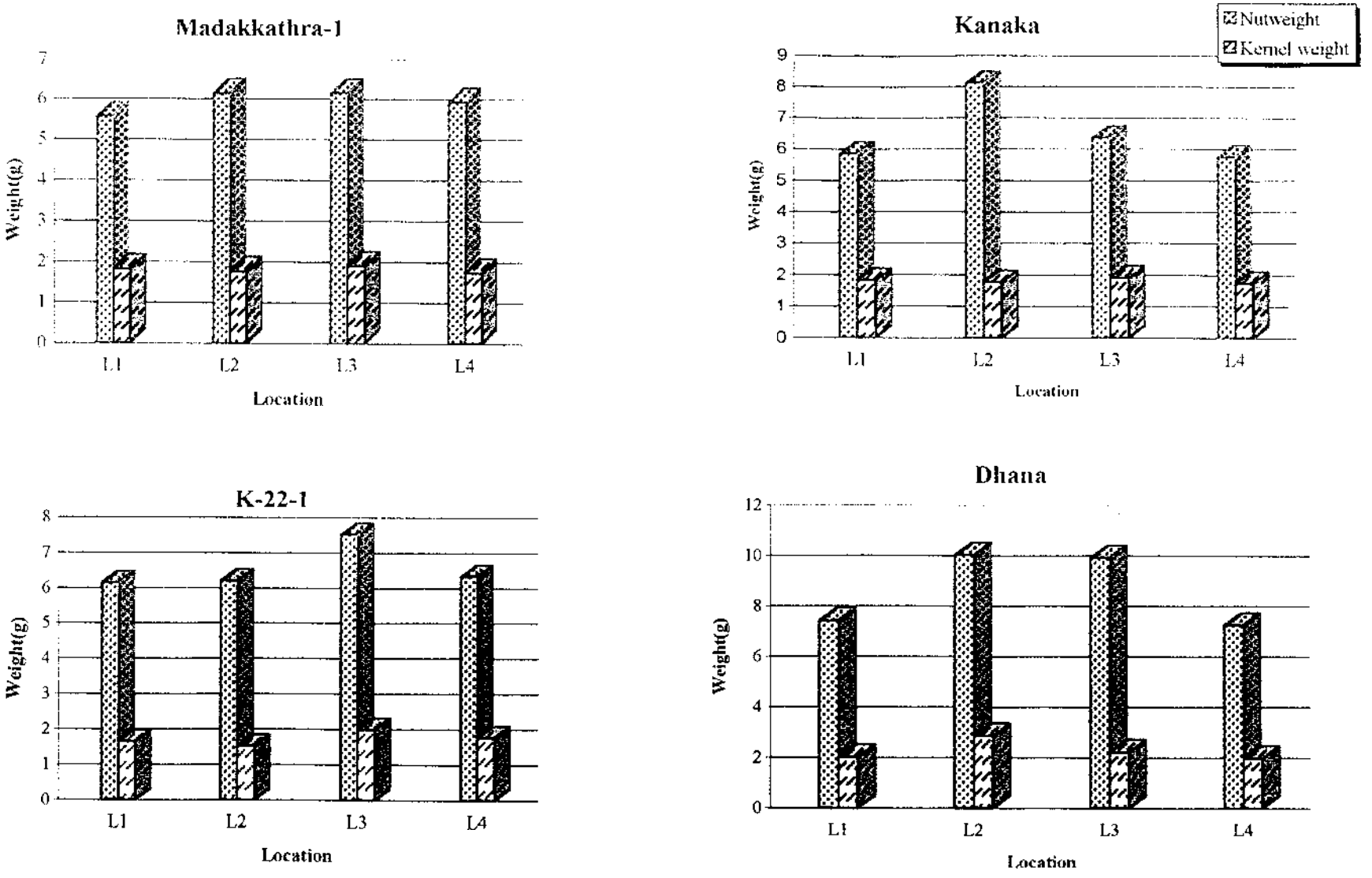
Fig. 1 Variation in nut and kernel weight in relation to different agroecological regions

Fig. 1. Variation in nut and kernel weight in relation to different agroecological regions



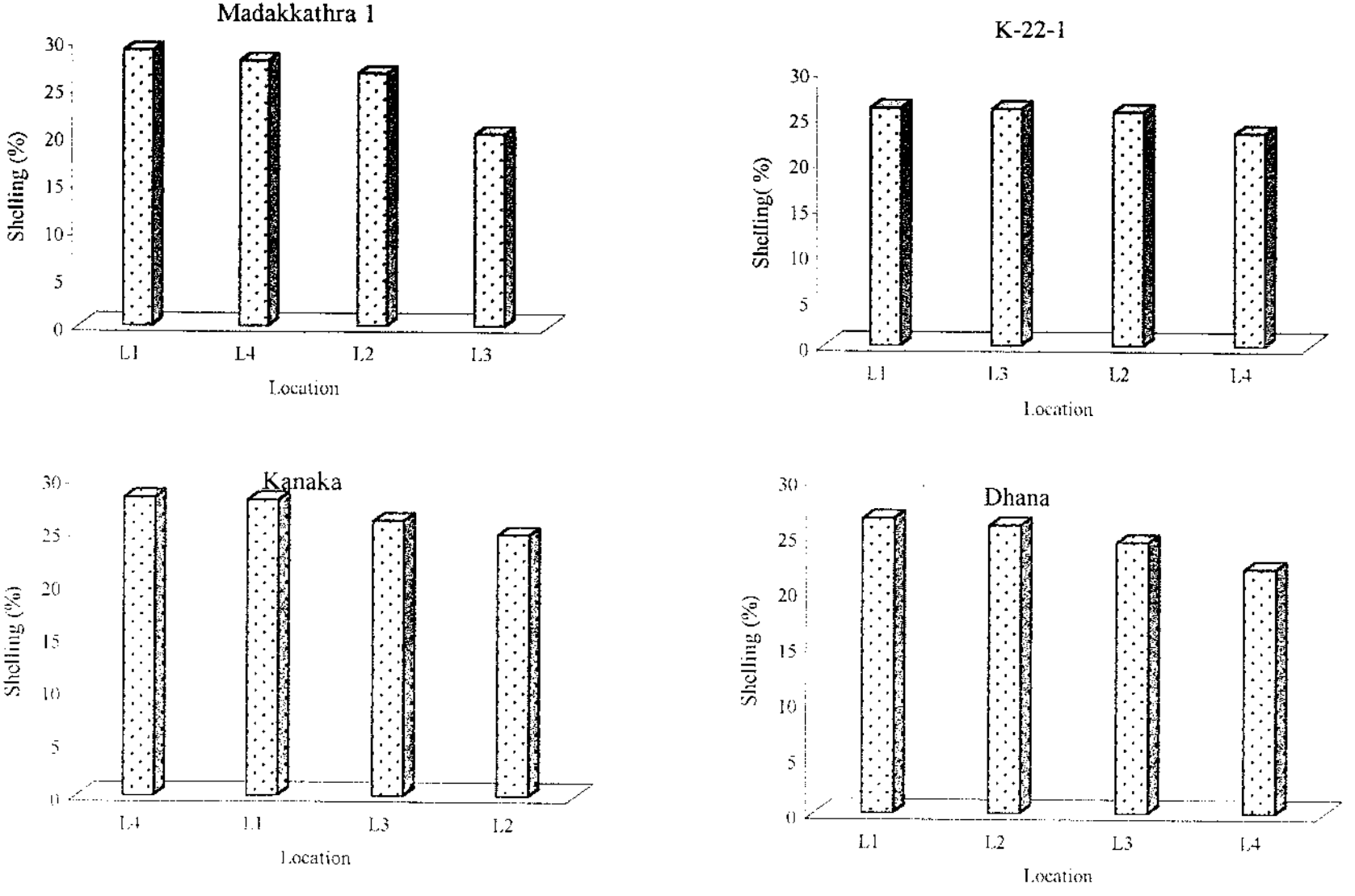
L1 = CRS, Madakkathra L2 = FSRS, Kottarakkara L3 = CRS, Anakkayam L4 = RARS, Pilicode

Fig. 2 Variation in nut and kernel weights of different cashew varieties in relation to agroecological regions



L1- CRS, Madakkathra - L2 -FSRS,Kottarakkara L3- CRS Anakkayam L4- RARS,Pilicode.

Fig.3 Shelling percentage of different varieties in relation to agroecological regions



L1-CRS, Madakkathra L2-FSRS,Kottarakkara L3-CRS,Anakkayam L4-RARS,Pilicode.

character that governs the processing qualities of cashew nuts. It is the percentage recovery of kernels from one 'kg' of raw nuts. As the size of nuts from CRS, Madakkathra was low compared to other regions, the number of nuts per 'kg' was more. As such, there were more number of kernels from one 'kg' of nuts. The increase in number contributed to increase in total weight of kernels recovered from one 'kg' of nuts resulting in increased shelling percentage. It will be more clear when we compare the varieties Kanaka with Priyanka and Akshaya released by KAU. The nut weight of variety Kanaka is low(6.80) and its shelling percentage is 30.58. Priyanka and Akshaya posses bolder nuts (10.80 and 11.00g respectively) among the varieties released by KAU, but their shelling percentage (26.57 and 28.36% respectively) is less compared to Kanaka.

The reduction in kernel weight should not be so grave to affect the shelling percentage and another important processing quality, the kernel grade. If the size of kernels are low, they will be categorised under inferior grades. Kernel grade will be assigned to a variety by calculating the number of kernels per pound.

The kernels of nuts of variety Madakkathra-1 from all locations were bolder and graded as W 280. Owing to the good weight the kernels of nuts of variety Kanaka from FSRS, Kottarakkara was graded as W 210. The kernels of nuts from other regions acquired the grade W 280 only. Similarly the kernels of Dhana from FSRS, Kottarakkara were also superior (W180) compared those collected from other regions. The higher weight recorded by nuts of location FSRS, Kottarakkara of southern region (Fig.1)also reflected on kernel weight of all the varieties studied.

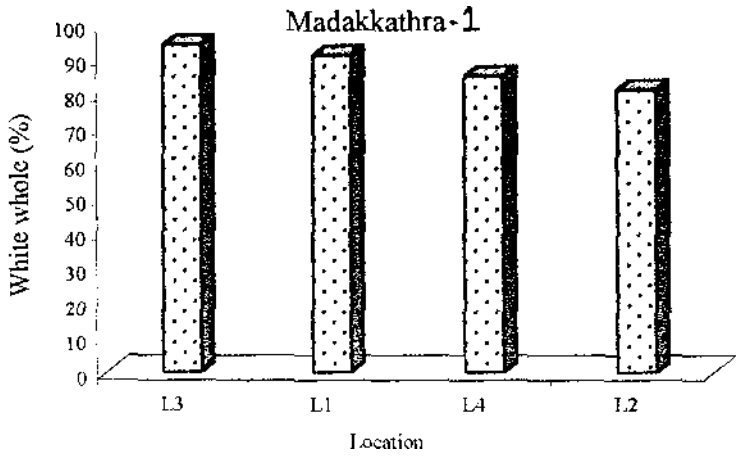
The processing characters of nuts in terms of white wholes (Fig.4), kernel pieces and kernel rejects were better for the nuts collected from CRS, Anakkayam. The kernels of nuts from this region of different varieties resulted in the recovery of more white wholes (93.14%), less kernel pieces (5.24%) and rejects (1.45%).

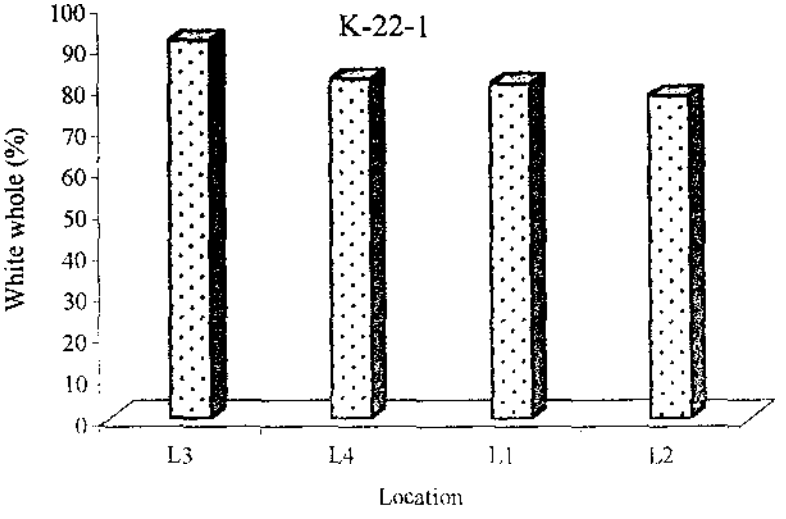
Among the four varieties studied, the variety Madakkathra-1, released from CRS, Madakkathra could be ranked as a more or less stable variety with respect to physical characters of the nuts. It was found to retain its nut characters through out the different agroclimatic zones of Kerala. Variation in physical characters between regions was negligible.

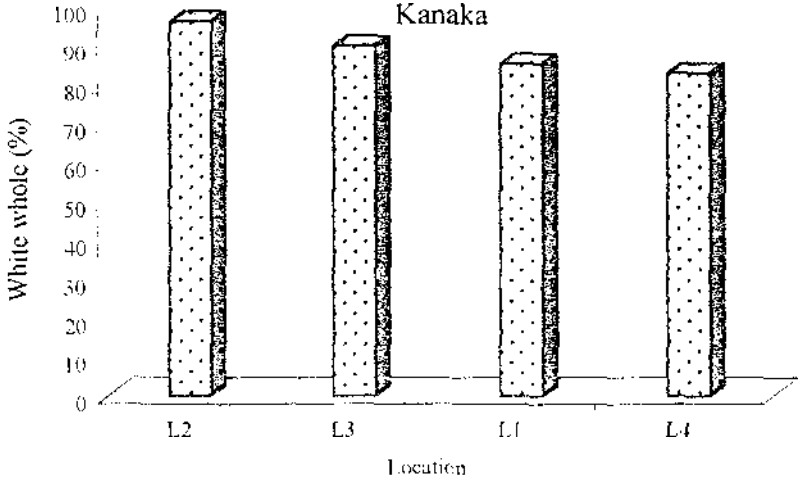
In varieties Kanaka and Dhana best quality nuts were obtained from FSRS, Kottarakkara and that of K-22-1 from CRS, Anakkayam.

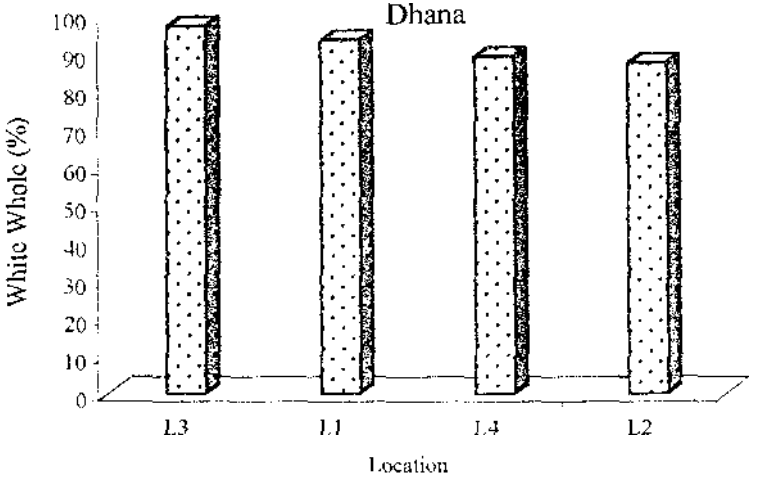
Kanaka and Dhana are the hybrids of the cross between Anakkayam-1 X H.3-13 and ALGD-1-1 X K-30-1 respectively. These parents have shown their superiority across the regions of Kerala. Now, the hybrids evolved through the crossing of these parents were also found to perform well in terms of quantity and quality at FSRS, Kottarakkara. Thus these two varieties can be recommended to Kottarakkara region to assemble nut quality with quantity. In the present study it was observed that in terms of processing quality, the nuts of Kanaka and Dhana from RARS, Pilicode is comparatively inferior.

Fig 4. White whole (%) of nuts in relation to different agroecological regions









L1-CRS, Madakkathra L2-FSRS,Kottarakkara L3-CRS,Anakkayam L4-RARS,Pilicode.

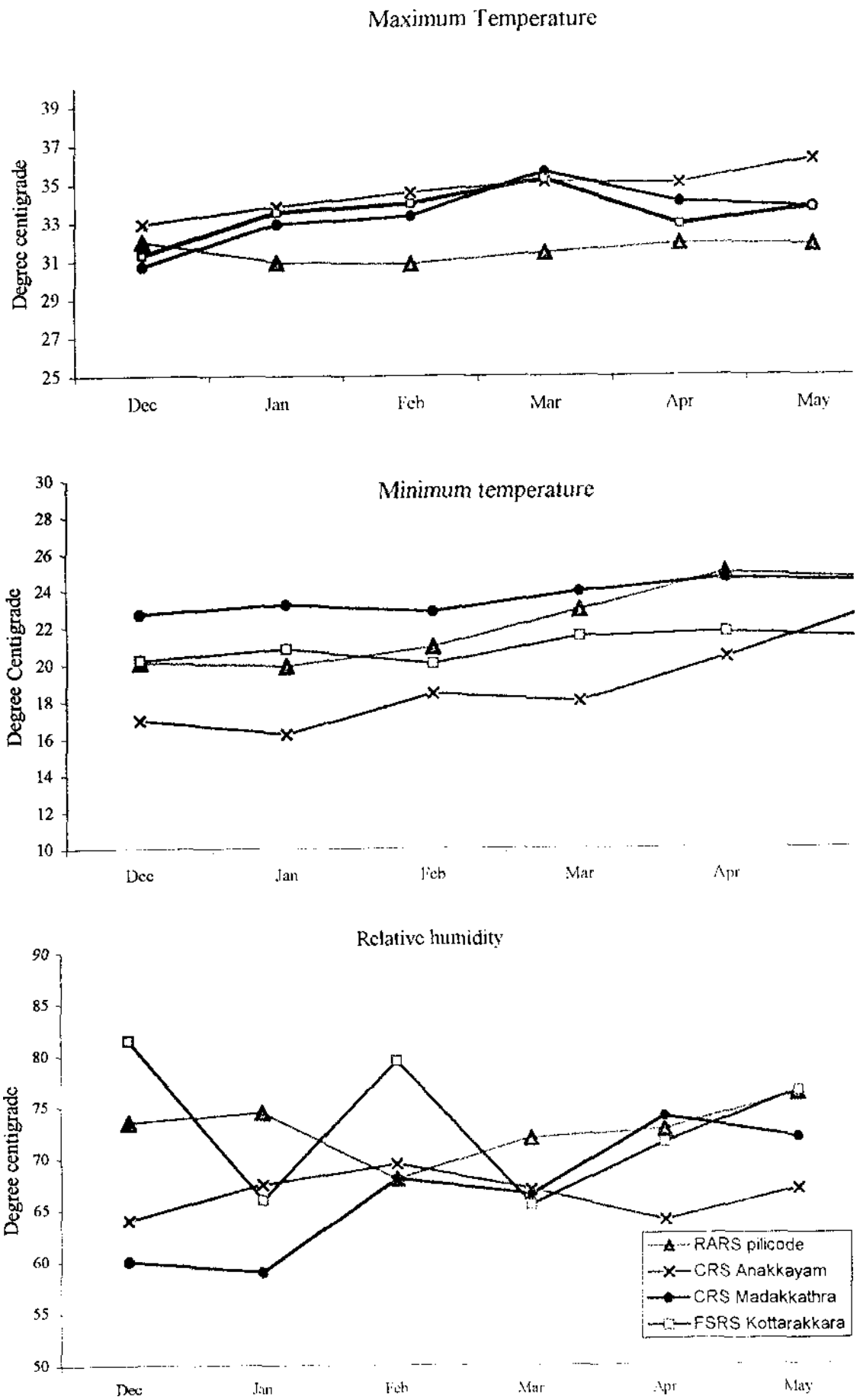
The regional variation in nut quality observed in varieties Kanaka, Dhana and K-22-1 indicates that location specific recommendations of varieties could be ideal for realising higher returns.

The regional influence on productivity of cashew was studied by Rao *et al.*, (1999). They reported that among different weather elements, air temperature appears to be vital factor which influences chronology of cashew phenology. Similarly the rainfall distribution and cloud also influence the phenology. Similarly the quality of nuts and kernels were also found affected as evidenced through the present study.

The weather parameters prevailing in a region may be a factor influencing the quality of nuts. The weather parameters pertaining to different centres for the period of investigation are given in Tables 5, 6 and 7.

During the nut set and development period, (December to January), the day temperature prevailing at FSRS, Kottarakkara and CRS, Anakkayam was more, whereas the night temperature was comparatively low (Fig 5). This might have favoured the production of big nuts having good kernel size with ideal consistency and colour. The testa was found loosely attached with the kernels of nuts from this region and peeling was also felt easy during processing. The high temperature prevailing during harvesting time may be a factor contributing to low adherence of the testa by way of reducing moisture content of kernels. In this context the moisture content recorded for different samples collected from different centres are given below as a support to this statement.

Fig. 5 Temperature and humidity prevailing at different agroclimatic regions



Moisture content (%) in kernels of nuts from different agroecological regions

Location	Varieties			
	Madakkathra-1	Kanaka	K-22-1	Dhana
CRS, Madakkathra	5.9	6.1	6.0	5.8
FSRS, Kottarakkara	5.6	5.4	5.1	4.8
CRS, Anakkayam	5.3	5.4	4.9	5.6
RARS, Pilicode	5.8	5.9	6.2	6.2

The less adherence of testa to kernels resulted in recovery of more white wholes, less kernel pieces and kernel rejects, especially for the nuts from CRS, Anakkayam. Dasarathi (1958) and Dorajeerao *et al.* (2000) reported the favourable effects of cool nights on flowering and nut set of cashew.

Another factor that might have favoured kernel quality of nuts of CRS, Anakkayam may be the temperature condition prevailing during nut maturity time. It was identified as crucial factor in governing processing quality of nuts. For all the varieties studied, the harvest came between February to March. Again, higher temperature was found prevailing at CRS, Anakkayam and nights were comparatively cooler. At the centre RARS, Pilicode, the day temperature was very low during nut maturity time and night temperature was high compared to other centres. This resulted in poor quality nuts in general.

The more humid condition prevailing at FSRS, Kottarakkara during flowering and nut set might be another factor positively contributed to increased kernel size through nut size. But after nut set, low humidity was found better, as noticed at FSRS, Kottarakkara and CRS, Anakkayam. Rao *et al.* (1999) reported that high humidity during reproductive phase adversely affect nut set and development through pest and disease incidence. This will naturally affect nut quality as well. During harvesting time the humidity was not found to have a say on quality.

5.1.2 Biochemical characters:

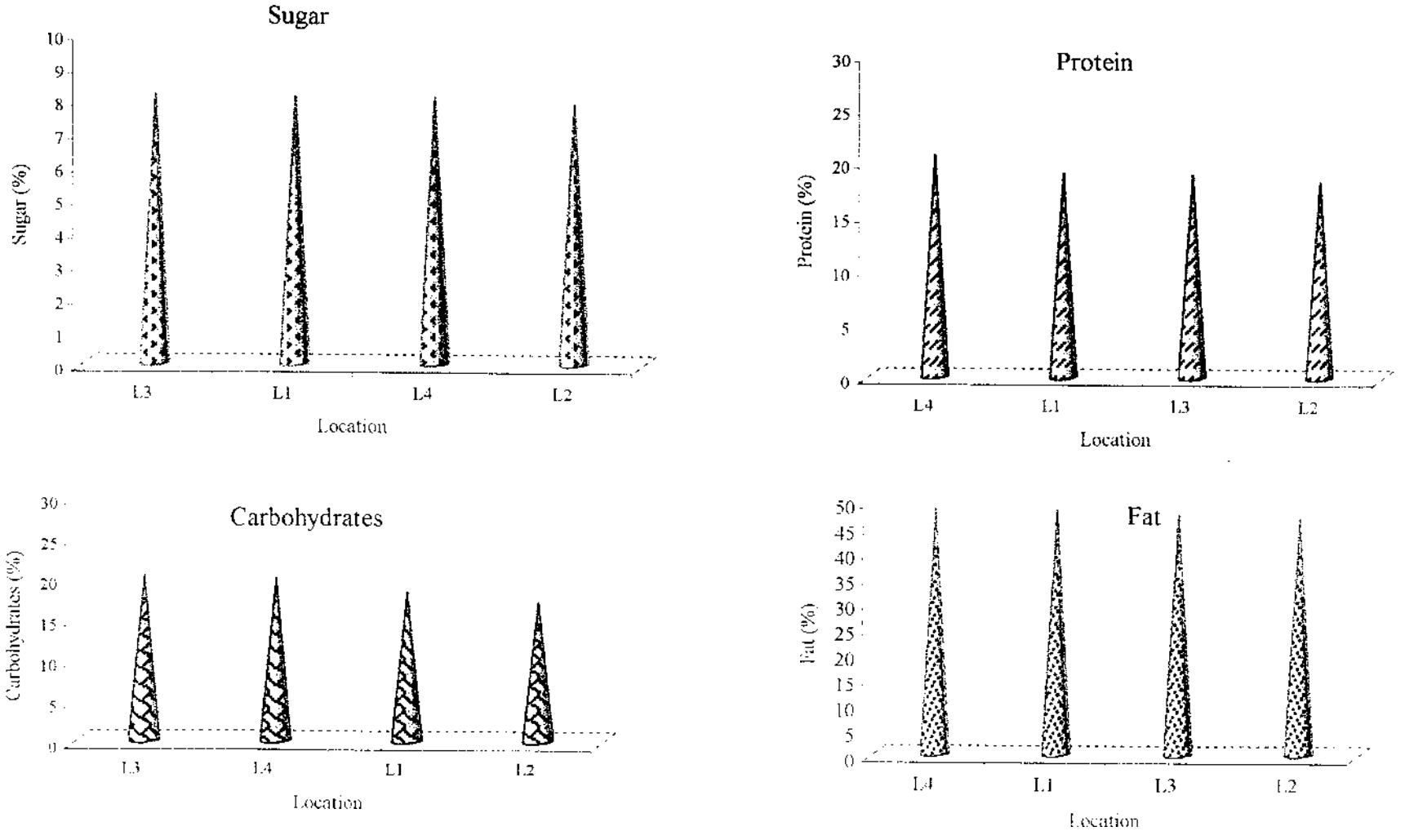
Biochemical characters of kernels that influence the quality include sugar, carbohydrates, protein and fat content (Narayanan, 1998).

The biochemical constituents of kernels showed variation with respect to the agroclimatic regions from where the nuts were collected (Fig.6).

Among the different constituents, sugars impart sweetness to kernels, carbohydrates and proteins are highly valuable from health point of view. Low fat content is also considered as a desirable attribute. (Nagaraja, 1998).

Intravarietal variation in crop performance at different climatic zones was observed by many workers previously. This was also true with the quality parameters of the kernels from nuts of different varieties. Regional intravarietal variation in quality parameters was also evident.

Fig. 6 Variation in biochemical components in relation to agroecological regions



L1-CRS, Madakkathra L2-FSRS,Kottarakkara L3-CRS, Anakkayam L4-RARS,Pilicode.

The average of the sugar content in kernels of nuts collected from different locations did not vary significantly (Fig.6). Carbohydrates, proteins and fats recorded significant variation in relation to the location of nuts collected. The average protein content was found high in kernels of nuts collected from RARS, Pilicode of northern region. The soil characters of this location is favourable for producing more proteins in the kernels. Compared to other regions available nitrogen as well as potassium content was very high (306kgha^{-1}) in the soil collected from RARS, Pilicode. Availability of more nitrogen might have favoured more protein in the kernels of nuts from this location. Kumar and Sreedharan (1987) and Latha *et al.* (1996) reported that kernel protein content was increased by nitrogen application in the soil. They also opined that rich potassium content in the soil help in mobilising precursors responsible for synthesis of proteins and translocating it to kernels. A detailed chart depicting the processing and nutritive characters of the cashew nuts generated from different agroecological regions will be a much useful tool to the producers, processors and consumers. For this the relation between the soil characters of different regions and biochemical characters of cashew kernels requires detailed study.

Data collected from the present study eventhough indicated variation in biochemical characters of kernels in relation to varieties and agroecological conditions, the extent of variation could not be derived. How far these variations could be attributed to variations such as atmospheric factors, soil factors, genetic factors or rootstock effect is also not clear. A detailed study on the factors which influence the kernel quality have to be conducted.

5.1.3 Comparison of different characters of nuts collected from six agroecological regions

The nuts collected from Southern, Northern and central regions were compared with nuts from Wynad and Alappuzha regions for their processing characters (Table 22). Except for the white whole recovery, the physical characters of nuts collected from Alappuzha and Wynad region did not differ much with that collected from other regions. Compared to other regions the white whole recovery percentage was low with nuts collected from Alappuzha region while it was high with nuts from Wynad region.

Among the biochemical constituents analysed, the sugars and protein content was very low with kernels of nuts collected from Wynad and Alappuzha regions. The kernels of nuts from Alappuzha region was observed to contain very low amount of fat. As low fat content is a favourable character, the nuts of Alappuzha regions can not be under rated for having low fat content. A comprehensive package of practices recommendation is to be evolved for cashew cultivation at this sandy area which will suit production of quality nuts.

5.2 FLOWERING BEHAVIOUR OF VARIETIES

5.2.1 Physical characters

Variation in flowering behaviour between cashew varieties/types had been observed. Pushpalatha (2000) classified 67 genotypes into three categories viz., early

Table 22 Comparison of different characters of nuts collected from six agroclimatic zones of Kerala

Location	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
L_1	3.55	2.39	6.24	3.02	27.38	72.63
L_2	4.18	2.52	7.61	2.95	25.70	74.30
L_3	4.06	2.56	7.48	3.27	24.31	75.71
L_4	3.69	2.39	6.30	3.07	25.37	74.65
L_5	4.06	2.30	6.86	2.88	26.70	73.30
L_6	3.56	2.27	6.23	3.12	26.40	73.60

Physical characters of kernels

Location	Weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
L_1	1.78	87.71	9.95	1.70
L_2	2.08	85.65	7.63	6.88
L_3	1.95	93.14	5.24	1.45
L_4	1.79	84.78	13.04	2.16

L_5	1.89	79.50	12.58	8.01
L_6	1.77	95.00	4.62	0.73

Biochemical characters of kernels

Location	Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
L_1	8.05	18.13	18.88	48.09
L_2	7.82	16.95	18.13	46.84
L_3	8.13	20.05	18.71	47.37
L_4	8.02	19.81	20.43	48.24
L_5	7.76	18.05	17.35	39.57
L_6	6.98	17.45	17.45	46.71

L_1 - CRS, Madakkathra , L_2 - FSRS, Kottarakkara , L_3 – CRS, Anakkayam, L_4- RARS,Pilicode, L_5 – Alappuzha region , L_6- Wynad region

(which attained flowering stage before mid November), mid (flowering between mid November and December) and late (flowering after mid December), based on their flowering behaviour. In cashew two or three phases of flowering is usually observed (Dorajeerao *et al.*, 2000) for the same variety. For the varieties selected for the present study three phases of flowering was noticed as reported by Parameswaran *et al.* (1984). There was early male phase, middle mixed phase and late male phase. For such varieties, the middle phase is reported to be the active productive phase. Naturally the nutrients and metabolize will be diverted more towards this phase for more nut development. In the present study, the processing qualities of early, mid and late varieties, viz., Madakkathra-1, Kanaka and Madakkathra-2 respectively were compared. Emphasis was also given to assess the quality of nuts of same variety collected at early, mid and late part of the crop phase.

Overall variation in physical characters of nuts did not show variation between the early, mid and late crops from the same variety. This indicated that length, breadth, weight and shell thickness are purely varietal characters.

Similarly, the weight of kernels from nuts of early, mid and late crop phases of different varieties studied did not differ significantly.

However the shelling percentage of nuts of early crop phase was high compared to that of other crop phases, while the husk rejects was less. Without detailed studies on pattern of partitioning of metabolites among kernels and shells at different crop phases, the results obtained in the present study is difficult to interpret.

The nuts of late crop phase of all varieties were superior with respect to recovery of white wholes and production of kernel pieces was observed to be less in them. Similarly the nuts of late variety was found to produce more percentage of white wholes and less kernel pieces.

5.2.2 Biochemical characters in kernels in relation to flowering behaviour

Variation in sugar, carbohydrates, protein and fat content in kernels of same variety was observed with respect to the three crop phases studied (Table 11). The sugar, carbohydrates and protein content was observed to be high in kernels of mid phase nuts of all varieties studied, where as fat content was significantly low. The possibility is that during early and mid production phase of the same tree, the factors responsible for conversion of sugars to carbohydrates and proteins may be more active and storage of metabolites might be more in such forms. In late nuts, the conversion of sugar may be more in the form of fat. This could be one of several reasons for the production of more white wholes and less pieces when nuts of late crop was processed. Fats are reported to import wholesomeness and palatability to produce by way of reducing breakage (Nagaraja, 1998).

Intravarietal variation in biochemical constituents was also evident. The late variety, Madakkathra-2 was found to contain comparatively more sugar (9.46%), carbohydrates (22.32%) and protein (20.54%) than the early variety Madakkathra-1 and mid season variety Kanaka. The fat content (39.97%) in Madakkathra-2 was low. This observation once again indicates that synthesis and storage if fats are inversely related to that of sugar, carbohydrates and proteins in

quantitative terms. As discussed earlier, the low fat content of the kernels of late nuts might have adversely affected the wholesomeness of kernels, resulting in recovery of less white wholes.

As the present trend in cashew production technology is to promote varieties with high carbohydrates and protein and low fat content, the assembly of biochemical constituents in kernels of varieties with different flowering behaviour need immediate attention of processors and dieticians.

5.3 INFLUENCE OF NUT MATURITY STAGES ON QUALITY OF NUTS

5.3.1 Physical characters

The physical characters of nuts viz., length, breadth, fresh nut weight and kernel weight were not found to vary significantly between stages of nut maturity studied for the different varieties. Developmental physiology of cashew nut amply justify this observation noted in the present study.

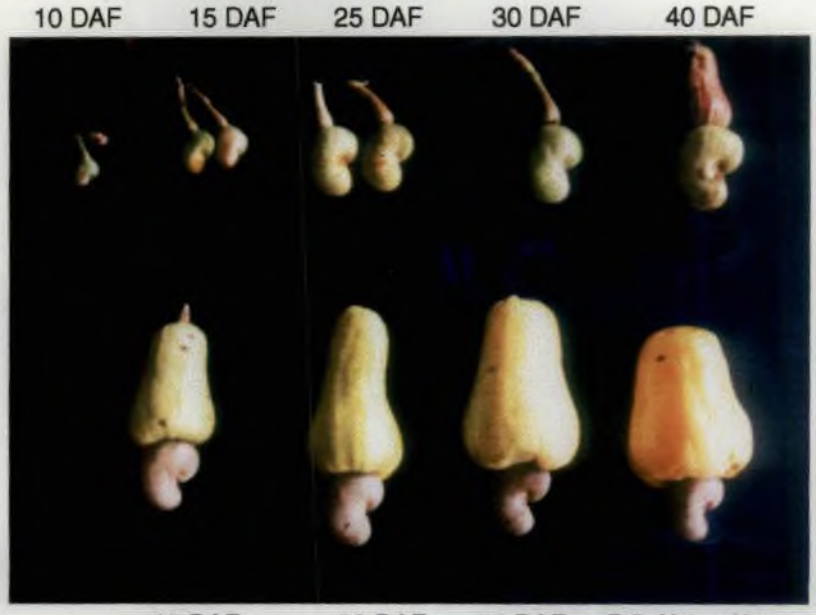
Kutty (2000) reported the development pattern of cashew nut. During the initial stage of development of nut, the relative growth rate was low but increased rapidly and maximum fresh weight was found at 35 to 40 days after fruit set stage. There were two peaks in its growth, the first peak correspond to development of shell and the second peak at 40 days after nut set stage, corresponding to the filling and dry weight increase of the nut.

Thus the full development of nut (Plate 6.) and kernel take place with 35-40days after nut set. This might to be the reason for recording almost same length, breadth and weight for nuts when analysed at different maturity stages after 45 days after nut set. In a study conducted by Renganayaki and Karivaratharaju (1993) the nut weight was low for nuts at lower maturity stages (below 40 days after fruit set) and the weight was found maximum with nuts at fully matured stages. The fresh kernel weight was not found varying significantly among nuts at different maturity stages studied. As the nuts mature, the moisture content of kernels decreased and metabolite status increase as evidenced through biochemical studies. Because of this the fresh weight of kernels at different maturity stages may remain same but the dry weight will increase as nuts mature. Kutty(2000) observed that the dry weight of kernels increase upto 55-58 days after nut set. During drying and processing the kernels of immature nuts lose more moisture, resulting in low dry weight. Thus processing of nuts which have not attained proper maturity stages have paramount effect on processing industries which look for quality raw nuts. Recovery of quality kernels could be highest when fully matured nuts are available for processing (Fig.7).

Balasubramanian (1998) stated the importance of procurement of quality raw nuts. Raw nuts of inferior quality lead to kernels of poor quality. This is especially true in the case of nuts which do not attain proper maturity stage as evidenced once again through this study. It is difficult to sort nuts which have not reached full maturity from the harvested lots by visual means especially when large quantities are handled. Methods of harvest followed also contribute for this.

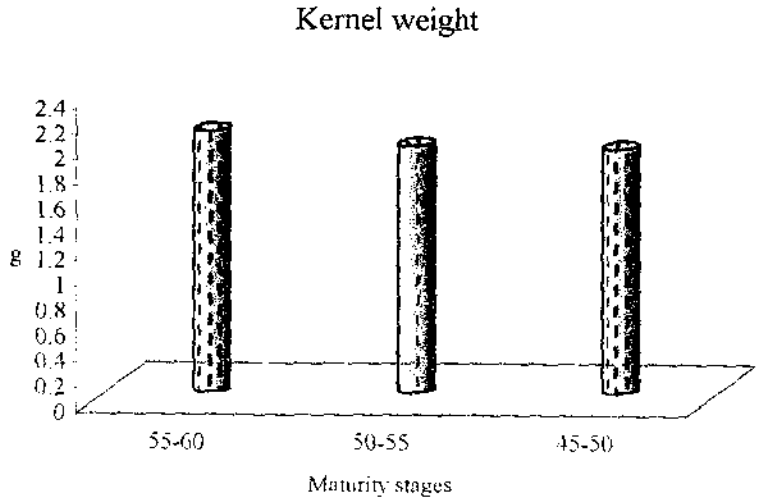
Plate 6. Stages of nut maturity

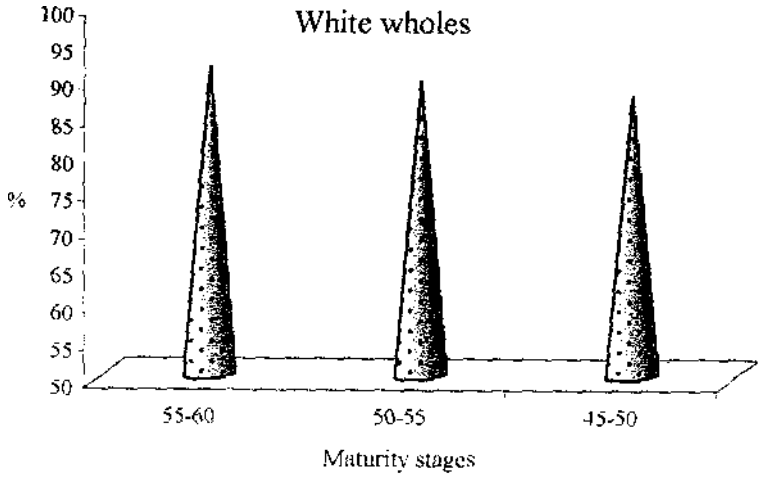
KANAKA

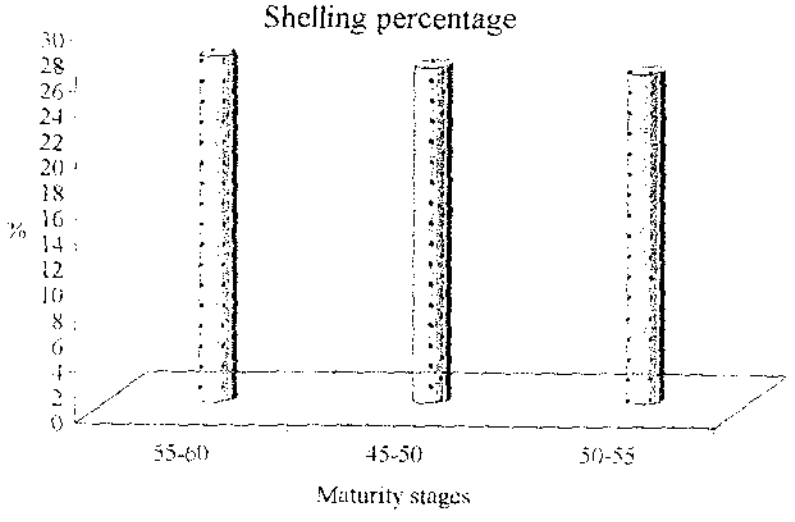


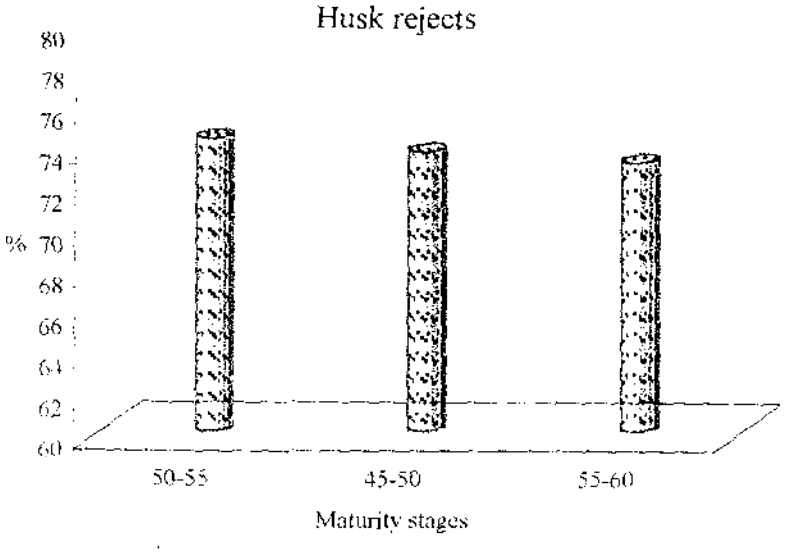
PRIYANKA

Fig. 7 Kernel characters in relation to maturity stages of nuts









Defective methods of harvest are being commonly practiced by the farmers even today, that is thrashing and collection of nuts. Also due to problems of pilferage, farmers have a tendency to harvest the nuts before they are fully mature. This results in poor out turn when processed In the present study more recovery of white wholes, less pieces and rejects were observed with nuts at 55-60 days maturity stage. Nagaraja (1998) reported lower shelling percentage, peeling out turn and percent wholes recovered and higher percent kernel rejects with nuts of lower maturity stages. This report conforms to the present study with nuts of different maturity stages.

To over come this difficulty, methods for sorting and raw nut grading at the procurement site is highly essential (Rao, 1998).

It is a fact that quality of kernels from a spoilt, nut harvested from the field cannot be improved by processing methods. This problem is also encountered when raw nuts are imported from other countries (Balasubramanian, 1998). At present no standard methods are available to identify quality nuts.

The study revealed that maximum shelling percentage could be obtained only from fully matured nuts. Due to the low dry weight of kernels of immature nuts, their shelling percentage is low.

5.3.2 Biochemical characters in relation to maturity stages of nuts

The importance of harvesting nuts at correct maturity stage was once again revealed through biochemical analysis of kernels collected from nuts at different maturity levels.

The total carbohydrates was found high in nuts at lower maturity stages but decreased in matured nuts (Fig.8). The sugar content showed a reverse trend. This shows, as the nuts mature a portion of carbohydrates get converted to sugars. Sugar actually determine the taste and quality of kernels (Soman, 1990).

The protein and fat content was also highest in kernels of fully matured nuts (Fig.8). The high fat content actually imparts palatability to kernels from matured nuts. Renganayaki and Karivaratharaju (1993) also recorded highest protein content in nuts at fully matured stage.

At present the emphasis is given for developing varieties with kernels having high protein and low fat.(Nagaraja, 1998, Rao, 1998). In this context, scarifying the protein content due to the simple reason of harvest at improper stage is detrimental to the actual health concern of cashewnut consumption. When nuts mature from 45-50 days to 55-60 days the protein content recorded 3.86% increase.

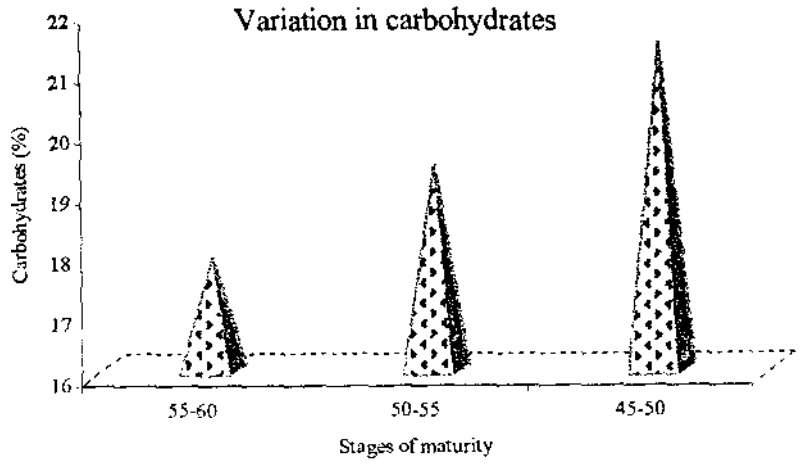
This study insists the necessity of creating awareness about the importance of harvest at right stage among the growers, which also will be rewarding for ensuring good kernel quality.

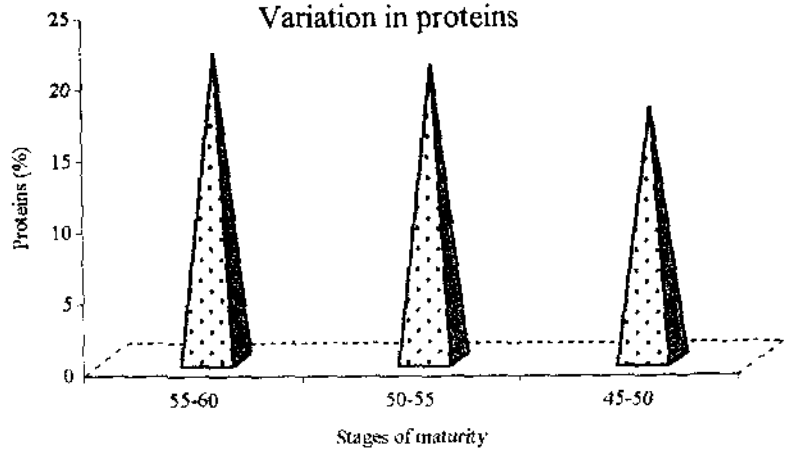
5.4 NUT QUALITY IN RELATION TO MARKET ARRIVAL OF NUTS

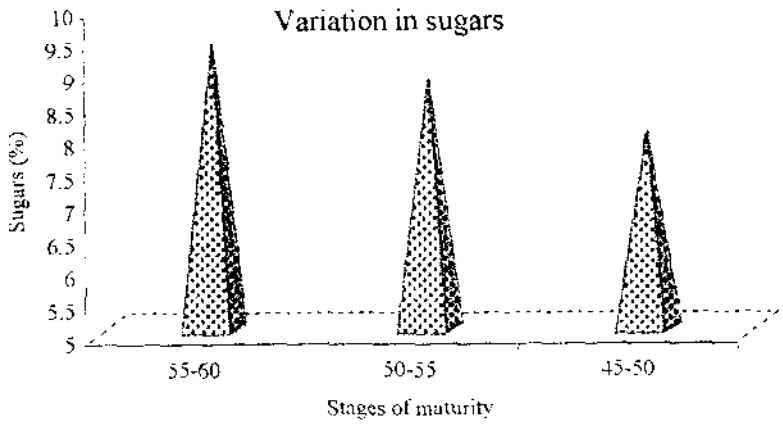
5.4. 1 Physical characters

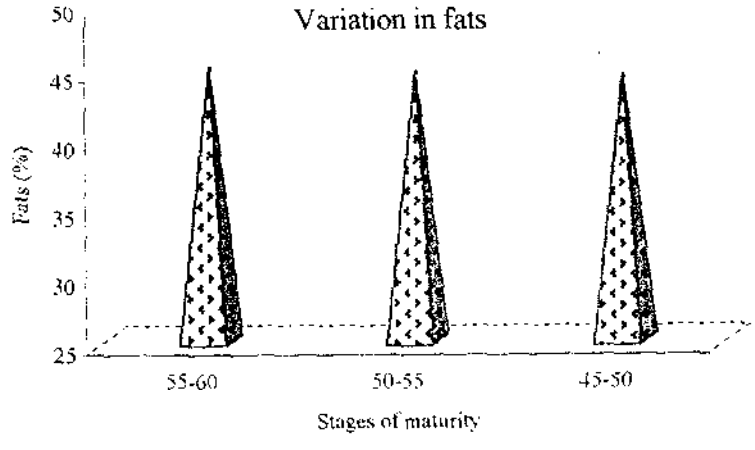
In the present study, the processing characters of cashewnuts were analysed in relation to nut size and season of harvest. As discussed elsewhere in this chapter,

Fig.8 Variation in biochemical constituents of kernels due to maturity levels of nuts









there are three flowering and harvesting seasons for cashew which could be denoted as early, mid and late. Nuts arrive in the market from different places and the lots will consist of nuts of different sizes. In the processing industries the raw nuts are usually sorted based on the size. This itself is an indication that the processing characters of nuts will vary depending on their size. However, the extend of variation has not been quantified. The difference in nut set and development is mostly governed by genetic parameters and to a certain extent by weather parameters. Anyway the variation in nut quality will reflect on their processing quality.

The study had shown that the season of harvest had negligible influence in modifying the physical characters of each category of nuts grouped based on their size. The length, breadth, nut weight, shelling percentage and husk rejects (%) recorded for small, medium and big size nuts during early cropping season did not vary significantly with that recorded during mid and late cropping season. Obviously, the nut size govern the processing qualities in terms of physical characters of nut. In the earlier part of present study (5.2) viz., analysing the processing qualities of nuts in relation to flowering behaviour of varieties, the difference in processing characters in relation to season of harvest was observed. This was because distinct varieties were chosen for the study, representing early, mid and late flowering and harvesting season. But when selection was imposed on nut size, the difference in processing characters over different season of harvest can be minimised.

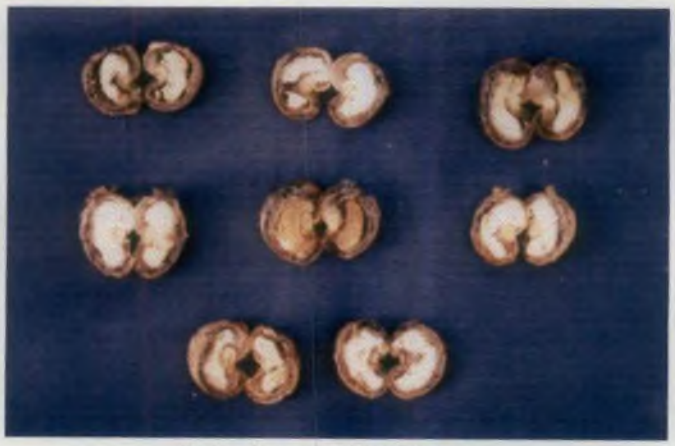
The kernel weight of the nuts of 9.1 to 11 g group was high (Plate 7.) and they acquired superior grade W 180. This is because of the strong correlation

Plate 7. Variation in Kernel Size in relation to nut size.

Kernels from nuts of 5-7g | Kernels from nuts of 7.1-9g | Kernels from nuts of 9.1-11g

Plate 8. Cross Section of nuts damaged by pests.

Nuts damaged by tea mosquito



Nuts damaged by Thrips

between nut weight and kernel weight as reported by Manoj (1992). Pushpalatha (2000). That is why, the recent trend in cashew cultivation is to identify and cultivate varieties having big nut size. They will yield kernels possessing higher grades. The importing countries prefer kernels having grade below W.280.

Among the nuts of different sizes, the white whole recovery percentage was maximum for nuts of 7.1 to 9.1 g. This observation conforms to the earlier report by Salam (1998). The varieties reported to have maximum shelling percentage viz., VTH 30/4 and M 26/2 and VTH 59/2 are having medium sized nuts.

Among the three harvesting season, the nuts collected during late phase had high white whole recovery. It was observed that during shelling, peeling and cleaning, chances of breakage of kernels were more for nuts of early and mid season, while late nuts were more wholesome. In the late crop, nut set and development take place between March and May, could have reduced the moisture content of nuts, making kernels more crisp. In this context, the moisture content recovered with nuts of different sizes collected during different time is worth mentioning.

Moisture content (%) in kernels of nuts of different size groups

Size group	Crop phase		
	Early	Mid	Late
5-7g	6.2	5.8	5.4
7.1-9g	5.9	5.7	5.2
9.1-11g	6.3	5.9	5.5

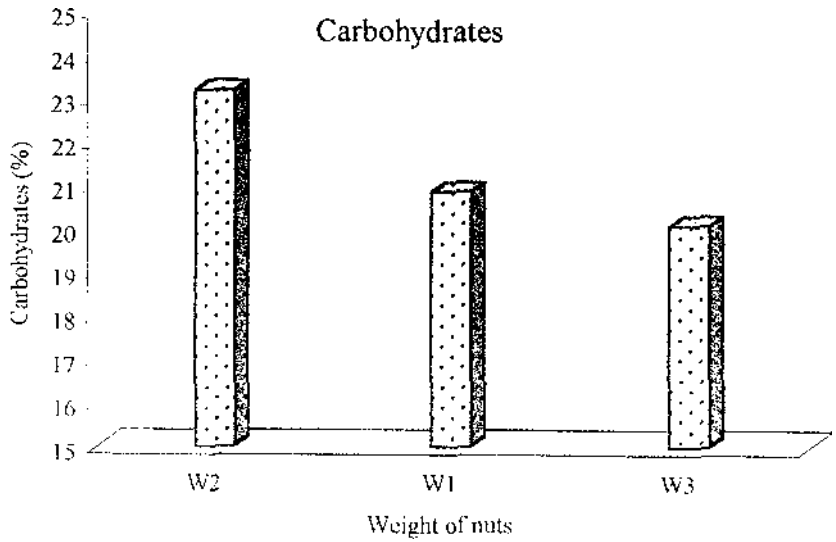
5.4. 2 Variation in biochemical characters of kernels in relation to market arrival of nuts

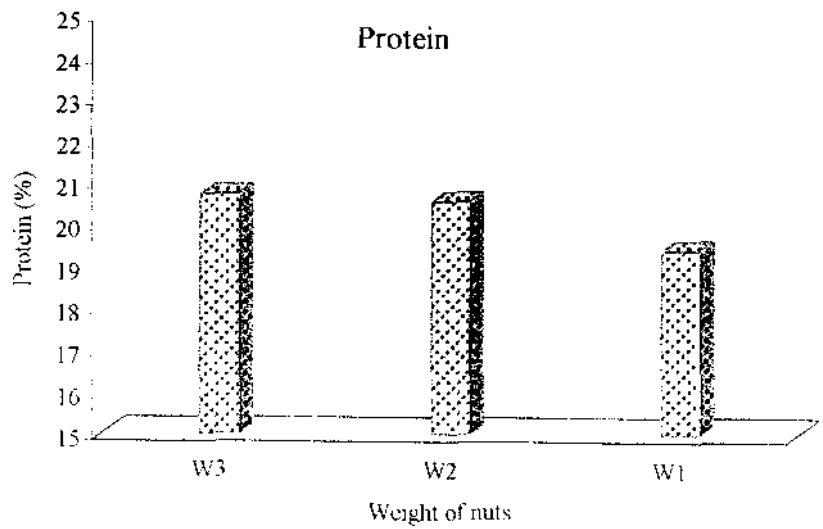
The biochemical constituents analysed viz., carbohydrates, sugar, protein and fat content was found to vary among the kernels from nuts of different sizes (Fig.9). The sugar and protein content in kernels of 9.1 to 11 g was found comparatively more than other sizes, while they were having low carbohydrate content. Season of harvest had negligible influence on sugar and protein content of kernels, when the study was done on bulk nuts (similar to those arrive in markets).

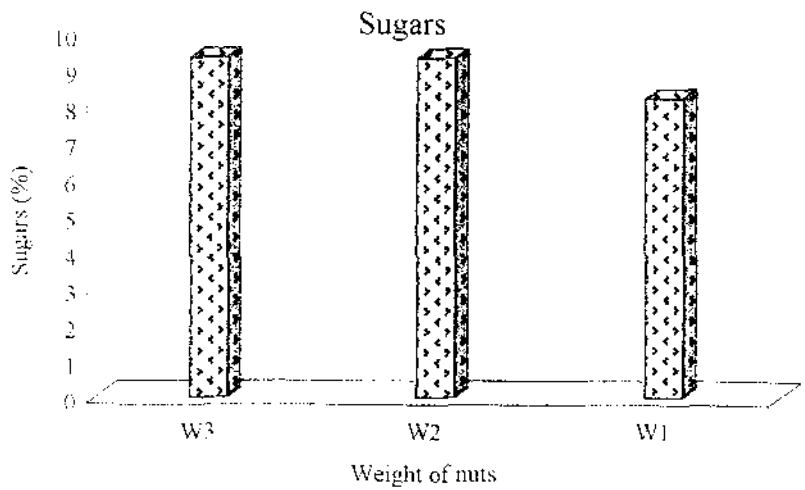
It was observed, eventhough the other constituents studied viz., carbohydrates, proteins and sugar content was high in bigger nuts, the fat content was more in kernels of smaller nuts (5-7 g). It can be inferred that among the primary metabolites stored in kernels, fats occupy a major share in smaller nuts. In them more carbohydrates might be converting to fat, resulting in low sugar and protein, as observed in the study. During storage the kernels of smaller nuts are found spoiled easily due to rancidity may be due to their high fat content. From the health point of view, big kernels are better, especially in the context of emerging trends for producing nuts with more protein and low fat content. But their high sugar content is again a challenge to dieticians.

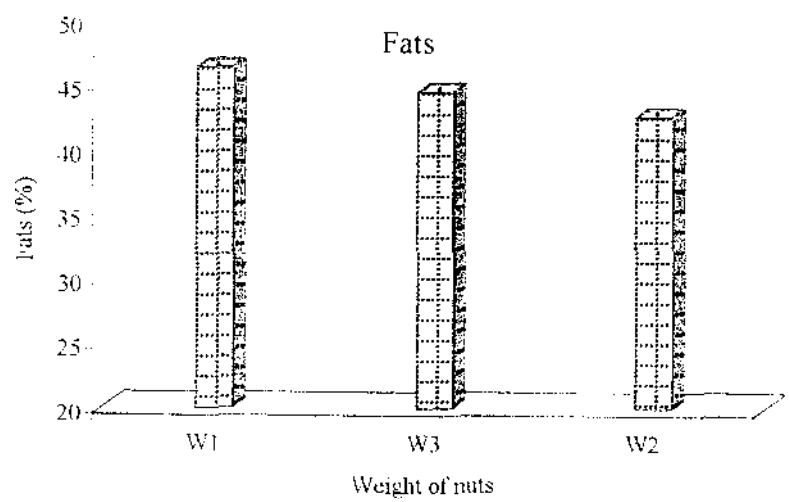
The study clearly revealed the importance of raw nut grading before processing as suggested by Rao (1998). The nuts arriving in the market during different season are equally important in processing point of view.

Fig. 9 Biochemical constituents of kernels in relation to size of nuts









W1=5-7g W2=7.1-9g W3=9.1-11g

5.5 VARIATION IN PROCESSING QUALITIES OF CASHEW NUTS DUE TO PEST DAMAGE ON NUTS

5.5. 1 Physical characters

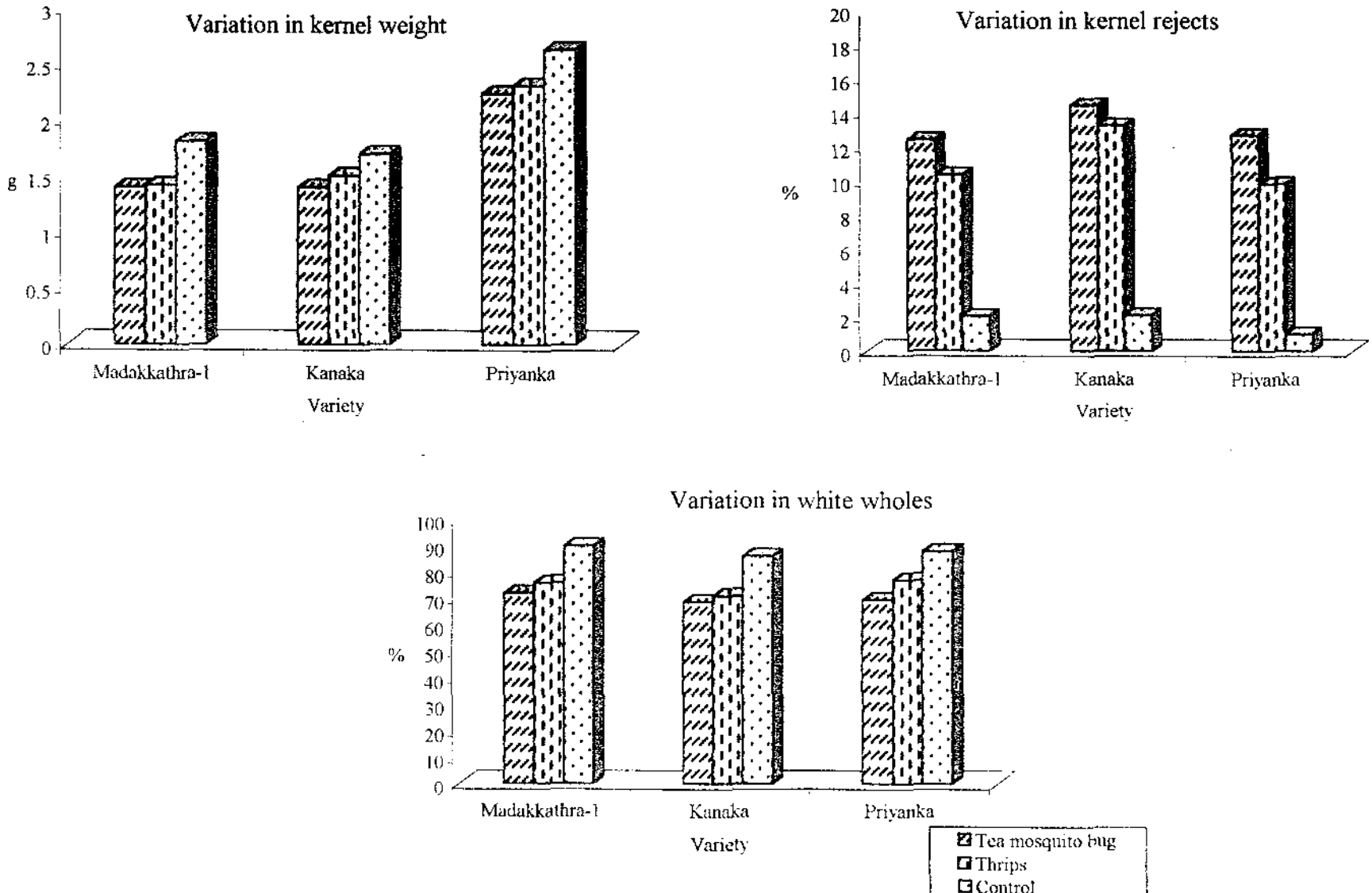
It is estimated the more than 50% of the crop is lost annually due to pests and diseases in cashew (Haribabu *et al.*, 1983). The crop is said to be infected by more than 50 different insect pests at different stages of growth and development (Pillai and Pillai, 1975). Many are attacking the plants as whole and those infecting the nuts are less in number. In the present study, two major pests of cashew viz., tea mosquito and thrips were found to infect the nuts to a substantial extent. Hence the quality deterioration of nuts due to damage these two pests were studied.

The nut length, breadth and weight were found reduced by pest attack. The shelling percentage of infected nuts was significantly low.. The husk rejects of nuts was also increased due to pest attack, especially of those infected by tea mosquito.

The tea mosquito attacks on the immature nuts result in death of infected parts of the nuts. This hampers the normal cell elongation, multiplication and smooth translocation as well as accumulation of metabolites in cells. The result is in an unhealthy growth and development of nuts. Same effect is seen in the case of thrips attack as well.

The weight of kernels from infected nuts were significantly low compared to that from non infected nuts. (Fig 10). The nuts as such could also act as sources of dry matter accumulation of kernels during the initial stages when they

Fig. 10 Variation in kernel quality due to nut damage by insect pests



have chlorophyll pigments. Pest attack could also limit the contribution from this source.

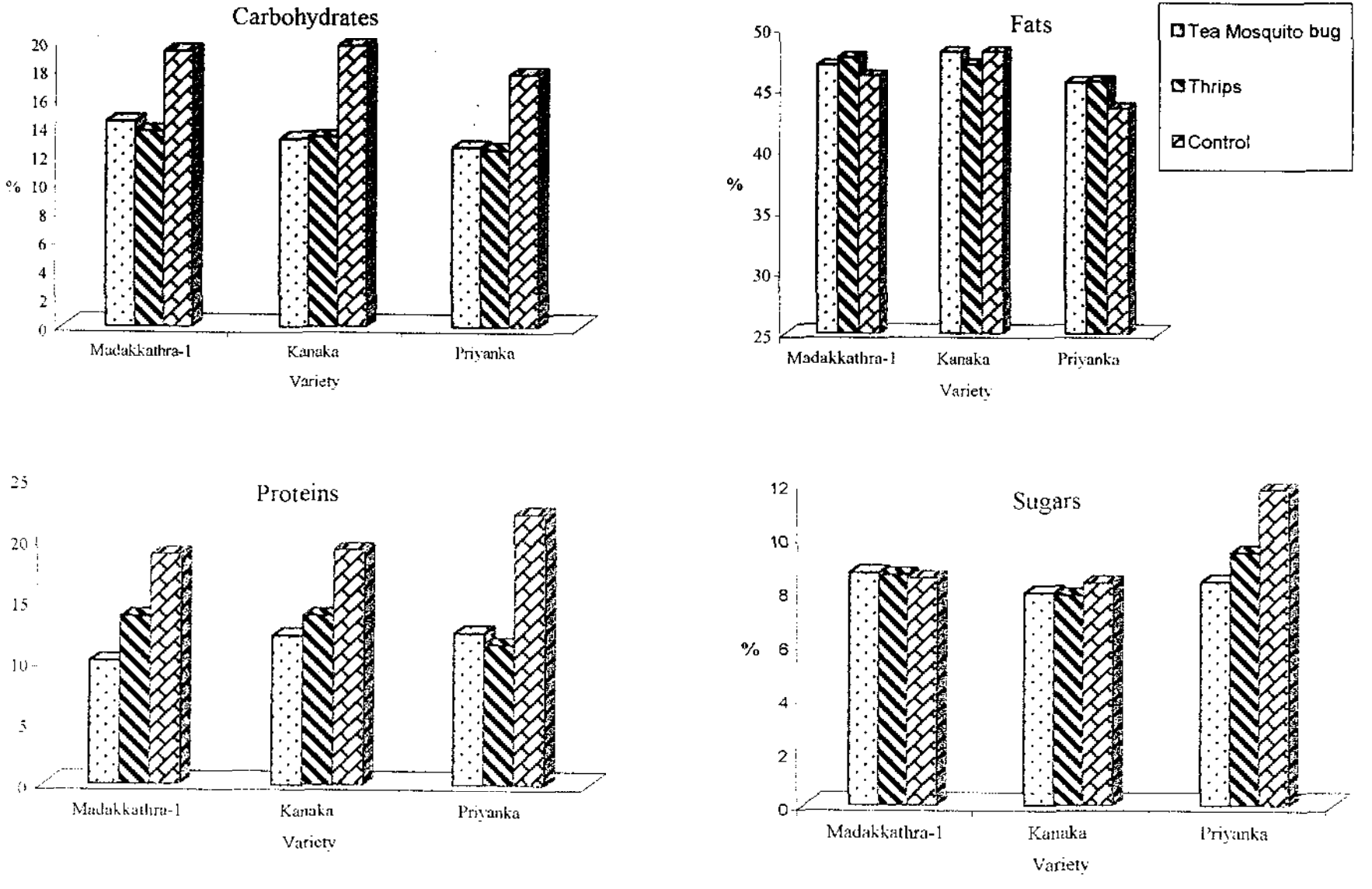
It was evident from the observations that the kernel rejects were more when the pest infected nuts were processed (Plate 8). The pest attack thoroughly shatter the normal physiological development of kernels, as mentioned earlier. They are more prone to become rancid due to fat degradation and protein coagulation. As such the kernels deteriorated has to be rejected. Nagaraja (1998) reported that any bruiscence makes the fats liable to become rancid, as such the integrity of kernels are lost

5.5.2 Biochemical characters of kernels from pest infected nuts

Studies on the biochemical characters of kernels in response to pest damage on nuts clearly revealed the inferiority of kernels from pest infected nuts (Fig.10). As discussed earlier, the pest attack affects the natural path way of synthesis, translocation and accumulation of different metabolites. This results in reduced amount of primary metabolites viz., carbohydrates, sugars and proteins in kernels of infected nuts.

Interestingly the fat content was low in kernels from non infected nuts and was more in pest infected ones (especially in thrips infested lots). The pest attack might be hampering the path way of conversion of carbohydrates to proteins. . Hence the carbohydrates synthesised beyond a particular level might have been converted to fats. The path way responsible for conversion of carbohydrates to fats may not have affected. No doubt, the pest incidence reduce not only the quantity but also the quality of nuts.

Fig. 11 Variation in biochemical components of kernels due to nut damage by insect pests




Summary

SUMMARY

The project entitled 'processing qualities of cashewnut in relation to agroecological and phenological factors' was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1999-2000. The main objectives were to evaluate the variation in processing qualities of cashewnuts in relation to agroecological factors, flowering behaviour of varieties, maturity stages of nuts, size of nuts and nut damage due to pest attack.

Significant variations in processing characters of cashewnuts exist among all the samples collected from different regions irrespective of the varieties.

The nuts from the southern region (FSRS, Kottarakkara) outstands all other regions in terms of weight, shelling percentage, kernel weight and grade, whereas maximum white whole recovery was from the nuts of northern region (CRS, Anakkayam).

Variety Madakkathra-1 was observed to be a stable variety as its physical characters throughout the different agroecological zones of Kerala remained constant.

Varieties Kanaka and Dhana performed well in terms of nut weight, shelling percentage, kernel weight and kernel grade when grown in the southern region, but K-22-1 showed better performance at CRS, Anakkayam.

The biochemical constituents like carbohydrates and sugars were high in the samples from CRS, Anakkayam of northern region, whereas protein and fat content was maximum in the samples from RARS, Pilicode, also representing the northern region.

No significant variation in physical characters of nuts was observed when the nut samples of southern, northern and Central regions were compared with the samples collected from Alappuzha and Wynad regions except for percentage recovery of white whole kernels. White whole recovery was very low for nuts from Alappuzha region where as it was high for nuts from Wynad region. Kernels of nuts from Wynad and Alappuzha region had low sugars and protein content, where as the kernels of the nuts from Alappuzha region registered very low fat content.

Regarding the influence of phases of harvest on the processing qualities, the nuts of mid harvest phase were observed to be bold with high amounts of carbohydrates and proteins and low fat content. Though the early season nuts were not bold enough, regarding the quality parameters they were on par with mid harvest phase. However, the late harvest phase yielded maximum white wholes and minimum kernel pieces.

As high fat content is not considered a desirable character, the nuts of early and mid crop phases can be considered as superior from health point of view.

Though physical characters like nut length breadth, weight etc. are fully attained by 45 days after nut set, the processing qualities are attain in its fullness only by 55-60 days after nut set.

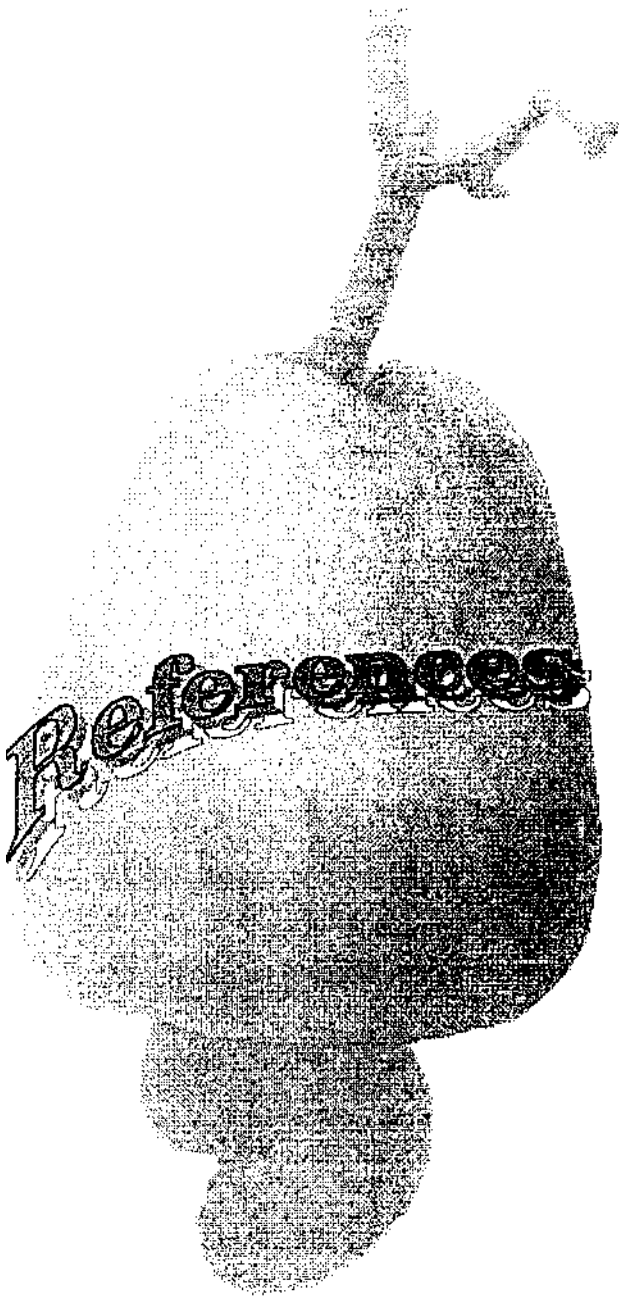
As the nuts develop in full, 45 days after nut set, and possess the same size of fully matured nuts, it is difficult to sort them from a lot by visual methods. But the nuts of lower maturity levels were found to possess less shelling percentage, kernel size and white whole recovery. They were having low protein and sugar content.

The analysis of cashew nuts of different sizes (small, medium and big) on the basis of arrival in the market at different seasons of harvest (early, mid and late) had revealed the importance of size of nuts in governing the processing characters.

Nuts of smaller size (5-7g) had more shelling percentage, while medium sized nuts had more white whole recovery. The kernels of big sized nuts were bolder and acquired a superior grade of W180. The big sized nuts recorded high amount of carbohydrate and protein, where as the kernels of smaller sized nuts recorded low protein and high fat content.

The season of harvest had negligible influence on physical and biochemical characters of the nuts when bulk quality is considered.

The pest attack (both in terms of tea mosquito as well as thrips) was found to completely shatter the normal development physiology of the cashew nuts. The pest infected nuts were found to have lost all the favourable processing characters and their kernels were shrunk and discoloured. The sugar, carbohydrate and protein content were significantly low in the kernels of pest infected nuts.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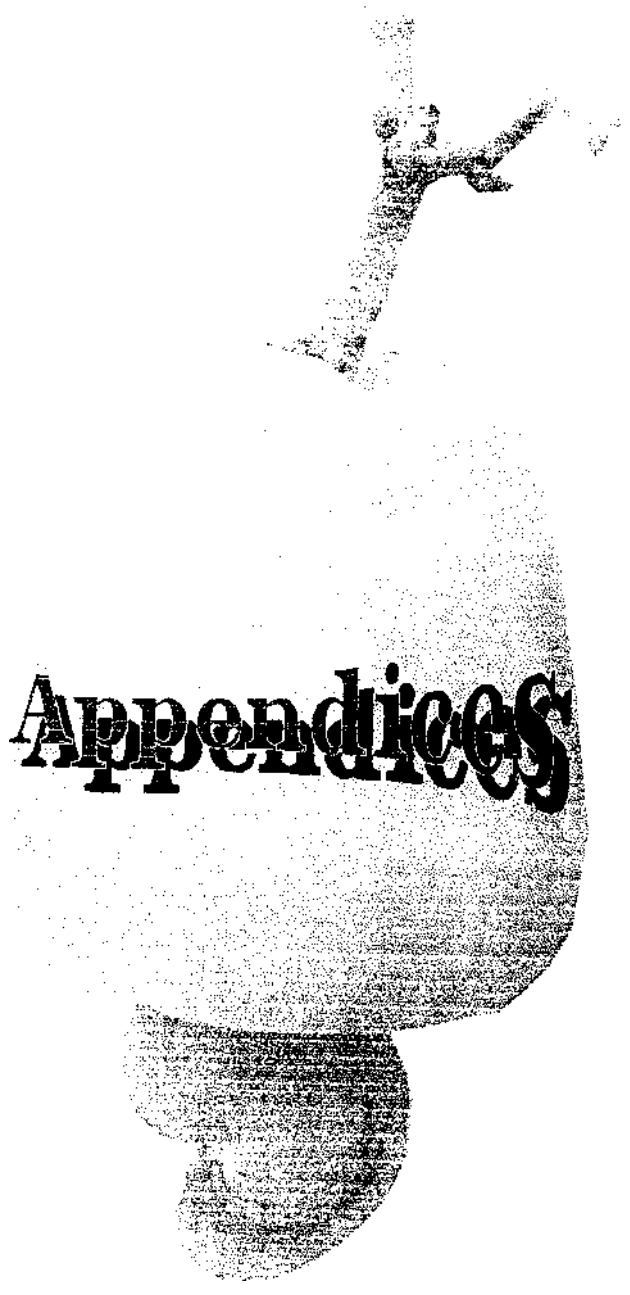


Appendices

Appendix-I

Agro-climatic zones of Kerala

Zone	Name	Area in (km^2)	Proportion in percent	Altitude	Rainfall	Soil	Topography
I	Onattukara	519	1.6	Low	Pattern I	Sandy loam	Model I
II	Coastal sandy	1564	4.8	Low	Pattern I	Sandy loam	Model I
III	Southern midland	3224	10.0	Low	Pattern I	Laterite without B-Horizon	Model III
IV	Central midland	2666	8.2	Low	Pattern I & II	Laterite	Model II a
V	Northern midland	3765	11.6	Low	Pattern II	Laterite	Model II b
VI	Northern midland	4254	13.1	Low	Pattern II	Laterite	Model II c
VII	Highland	8861	27.4	Low	Pattern I	Laterite without B-horizon	Model III
VIII	Palghat	1280	3.9	Low	Pattern II	Red loam	Model II
IX	Red loam	3170	1.0	Low	Pattern I	Red loam	Model III

Appendix I continued

X	Chittor black soil	508	1.6	Low	Pattern II	Black soil	Model II a
XI	Kuttanad	284	0.9	Low	Pattern I	Beat (Kari)	Model I
XII	River bank alluvium	-	-	Low	Pattern I	Alluvium	Model I
XIII	High ranges	5140	15.9	High	Pattern I & II	Red loam	Model III
	Total	32283	100.0				

Altitude : The entire state is divided into three types viz., low land (0-500 metres above the mean sea level), mid land (500-1000 metres above the mean sea level) and high land (above 1000 metres from the mean sea level).

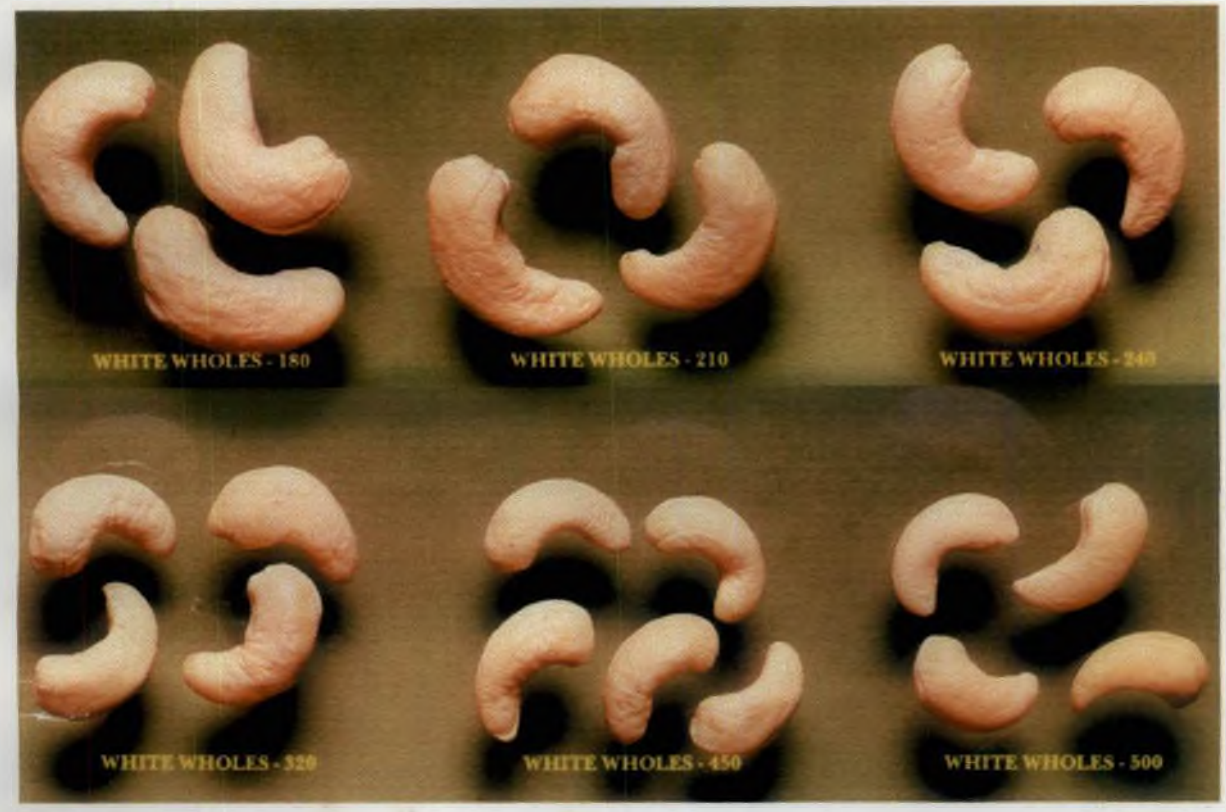
Rainfall :
Pattern I – Both the south west and north east monsoons are active and moderately distributed. South west monsoon with June maximum
Pattern II – Only South west monsoon is active with July maximum rainfall. North east monsoon is relatively weak.

Topography :
Model I – Extensive valleys with level but raised garden lands
Model II a – Valleys less extensive. Hills with moderate gradients and slopes having mild gradients
Model II b – Valleys less extensive. Hills with moderate gradients and with egg shaped hump
Model II c- Valleys less extensive. Hills with table tops. Slopes are steep
Model III – Narrow valleys and hills with steep gradients

APPENDIX - II

Specifications for Cashew Kernels

CASHEW EXPORT PROMOTION COUNCIL OF INDIA



1. **GENERAL CHRACTERISTICS** : Cashew Kernels shall have been obtained through roasting, shelling and peeling cashew nuts (*Anacardium occidentale L.*)

2. **SPECIAL CHRACTERISTICS :**

CASHEW KERNELS - WHITE WHOLES

Grade Designation	Trade Name	Colour / Characteristic VCs	Count / 454 gms Size description	Max. Mois ture %	Broken Max%	NLSG NLG max %
W-180	White Wholes	White/pale ivory/light ash. Characterisic shape	170-180	5	5	5 (NLSG & SW together)
W-210	do	do	200-210	5	5	do
W-240	do	do	220-240	5	5	do
W-320	do	do	300-320	5	5	do
W-450	do	do	400-450	5	5	do
W-500	do	do	450-500	5	5	5 (SW)

Remarks : Kernels shall be completely free from infestation, insect damage, mould, rancidity, adhering testa and objectionable extraneous matter. Scraped and partially shrivelled kernels also permitted provided such scraping / shrivelling does not affect the characteristic shape of the kernel.

Appendix - III

General analysis of variance on the influence of agroecological factors on quality of nuts and kernels

Physical characters of nuts							
Source of variation	df	Mean squares					
		Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
Factor A	3	1.43	0.30	22.41	0.76	13.41	13.24
Factor B	3	1.43	0.13	8.65	0.32	26.02	26.16
AB	9	0.20	0.03	2.46	0.24	19.92	19.82
Error	48	0.07	0.01	0.18	0.03	0.81	0.37

Physical characters of kernels					
Source of variation	df	Mean squares			
		Kernel weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
Factor A	3	0.92	200.58	229.95	12.61
Factor B	3	0.34	225.36	177.01	105.73
AB	9	0.26	86.78	22.32	37.03
Error	48	0.08	1.68	0.72	0.17

Biochemical characters of kernels					
Source of variation	df	Mean squares			
		Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
Factor A	3	14.59	11.37	6.61	8.22
Factor B	3	0.27	34.22	15.43	6.81
AB	9	4.98	8.90	8.38	46.88
Error	48	0.24	0.34	0.29	0.87

A= Varieties AB = varieties X locations B= Locations

Appendix IV

General analysis of variance on the flowering behaviour of varieties and crop phase of cashew

Physical characters of nuts							
Source of variation	df	Mean squares					
		Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
Factor A	2	1.37	0.03	8.35	0.35	0.12	0.07
Factor B	2	0.07	0.01	0.02	0.03	11.69	11.07
AB	4	0.08	0.01	0.22	0.06	6.52	6.40
Error	18	0.18	0.01	0.06	0.03	1.13	0.16

Physical characters of kernels					
Source of variation	df	Mean squares			
		Kernel weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
Factor A	2	0.59	185.94	194.27	5.18
Factor B	2	0.02	43.32	64.77	2.48
AB	4	0.04	6.53	1.45	1.88
Error	18	0.05	1.17	0.41	0.06

Biochemical characters of kernels					
Source of variation	df	Mean squares			
		Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
Factor A	2	2.50	33.65	5.76	134.44
Factor B	2	2.67	7.48	3.96	8.60
AB	4	2.78	11.96	0.56	25.22
Error	18	0.34	0.79	0.29	1.27

A= Variety B= crop phase AB= Variety X crop phase

Appendix- V

General analysis of variance on the influence of stages of maturity on the quality of nuts and kernels of different cashew varieties

Physical characters of nuts							
Source of variation		Mean squares					
	df	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
Factor A	4	3.32	0.30	24.41	0.53	22.48	22.69
Factor B	2	0.01	0.00	0.78	0.35	4.42	4.75
AB	8	0.01	0.01	0.13	0.13	0.88	0.93
Error	30	0.11	0.02	0.41	0.02	0.23	0.59

Physical characters of kernels					
Source of variation		Mean squares			
	df	Kernel weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
Factor A	4	1.65	107.37	137.08	7.13
Factor B	2	0.07	19.53	17.04	0.77
AB	8	0.01	27.98	38.81	3.93
Error	30	0.02	1.41	0.54	0.12

Biochemical characters of kernels					
Source of variation		Mean squares			
	Df	Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
Factor A	4	9.52	11.05	12.29	25.24
Factor B	2	7.24	46.95	62.02	1.32
AB	8	1.86	2.69	1.87	5.56
Error	30	0.37	0.63	0.45	0.56

Appendix- VI

General analysis of variance on the different sizes of nuts as influenced by their time of market arrival

Physical characters of nuts							
Source of variation		Mean squares					
	Df	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
Factor A	2	3.29	0.27	41.04	0.60	40.65	40.69
Factor B	2	0.01	0.01	0.02	0.01	2.41	2.37
AB	4	0.02	0.01	0.08	0.05	1.81	1.87
Error	18	0.02	0.02	0.32	0.03	1.08	0.43

Physical characters of kernels					
		Mean squares			
Source of variation	Df	Kernel weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
Factor A	2	1.91	107.61	89.98	0.75
Factor B	2	0.03	13.50	20.66	1.98
AB	4	0.01	10.26	5.70	1.47
Error	18	0.03	1.51	0.50	0.06

Biochemical characters of kernels					
		Mean squares			
Source of variation	Df	Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
Factor A	2	3.47	23.51	4.69	31.01
Factor B	2	1.66	17.19	3.75	3.09
AB	4	0.72	1.82	0.29	15.13
Error	18	0.63	1.13	0.85	1.17

A= Nut size B= Phase of harvest

AB= Nut size X Phase of harvest

Appendix- VII

General analysis of variance on the influence of pest attack on quality of nuts and kernels of different cashew varieties.

Physical characters of nuts							
		Mean squares					
Source of variation	Df	Length (cm)	Breadth (cm)	Weight (g)	Shell thickness (mm)	Shelling %	Husk rejects (%)
Factor A	2	4.05	0.37	51.56	0.06	2.25	2.34
Factor B	2	0.36	0.08	2.83	0.38	83.76	84.09
AB	4	0.01	0.01	0.41	0.15	4.52	4.58
Error	18	0.09	0.02	0.12	0.01	0.75	0.20

Physical characters of kernels					
		Mean squares			
Source of variation	Df	Kernel weight (g)	White wholes (%)	Kernel pieces (%)	Kernel rejects (%)
Factor A	2	2.17	40.83	13.75	10.87
Factor B	2	0.34	786.16	194..07	335.11
AB	4	0.01	6.26	7.88	2.01
Error	18	0.05	1.39	0.61	0.26

Biochemical characters of kernels					
		Mean squares			
Source of variation	Df	Sugars (%)	Carbohydrates (%)	Proteins (%)	Fats (%)
Factor A	2	8.07	5.88	3.05	18.53
Factor B	2	3.54	96.40	182.97	2.67
AB	4	3.02	0.63	8.49	2.41
Error	18	0.33	0.53	0.35	0.75

A= Variety B= Pest attack

AB= Variety X Pest attack

APPENDIX -VIII

Level of organic carbon, nitrogen, phosphorous and potassium in relation to soil fertility classes of Kerala

Soil fertility class	Organic carbon		Available N_2 kg/ha	Available P kg/ha	Exchangeable K kg/ha
	Sand	Clay loam			
Low	0.00-0.30	0.00-0.50	0.00-250	0.00-10.00	0.00-115
Medium	0.31-0.90	0.51-1.50	250-500	10.1-24.00	116-275
High	0.91-1.50	1.51-2.50	>500	24.1-34.5	276-395

PROCESSING QUALITIES OF CASHEWNUT IN RELATION TO AGROECOLOGICAL AND PHENOLOGICAL FACTORS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The project entitled 'Processing qualities of cashewnuts in relation to agroecological and phenological factors' was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara during 1999-2000.

The study revealed that the variation in agroecological factors modify the processing qualities of cashew nuts. The nuts from southern region were observed to be much bolder and found to possess high shelling percentage, kernel size and kernel grade compared to nuts from northern and central regions. In terms of biochemical constituents of kernels, the nuts of northern region excel than the nuts of southern and central regions. When the processing characters of the nuts of selected cashew varieties collected from four different locations were compared, the variety Madakkathra-1, was observed to be a stable variety. It's nut characters remained almost same in all the agroecological regions. The nuts of varieties Kanaka and Dhana were better when they were grown is southern region where as for the variety K-22-1, northern region was found better.

The physical characters of nuts from Alappuzha and Wyanad regions did not vary significantly from that of the nuts from other regions, where as the biochemical constituents, sugars and proteins were very low in them. The kernels of nuts from Alappuzha region registered comparatively low fat content.

Regarding the influence of phases of harvest on processing qualities, the nuts of early and mid phases can be considered as superior. The nuts of the same variety, collected during these two phases were observed to be bolder and kernels in them recorded comparatively high amounts of carbohydrates and proteins and low fat.

Analysis of cashew nuts at different maturity levels revealed that all favourable processing qualities are assembled only in fully matured nuts and nuts at lower maturity levels are significantly inferior.

The nut quality was found to differ with size of nuts. The big and medium sized nuts were found to possess good kernel size with high protein and carbohydrate content compared to nuts of smaller size. So varieties with bolder nut size are to be promoted for cultivation. The time of market arrival was found to have negligible influence on quality of nuts.

The pest infected nuts were considerably inferior to the non infected nuts. They had lost all the favourable processing qualities. Apart from visual distortions and malformations of such nuts, the kernels in them were found shrunken and discoloured. The important biochemical constituents carbohydrates and proteins were significantly low in them.

A spoiled nut can never be improved by processing.