

QUALITY EVALUATION OF KERNELS OF DIFFERENT CASHEW VARIETIES

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THESIS

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requirement for the degree of**

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2001

DECLARATION

I hereby declare that this thesis entitled "**Quality evaluation of kernels of different cashew varieties**" 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, associateship, fellowship or other similar title, of any other University or Society.

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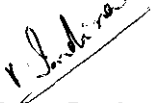
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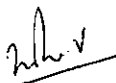
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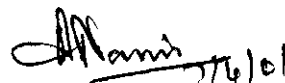
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DEDICATED TO MY
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Introduction

INTRODUCTION

Cashew, (*Anacardium occidentale*) is one of the most important dollar earning crops of India. Unlike other foodstuffs both the fruit as well as kernels are edible and nutritious.

India still remains the largest producer, processor and exporter of cashew. The production of cashew nut in the country is estimated to be 4.5 lakh tonnes (Salam, 1999).

Commercial interest in cashew is for production and utilization of cashew nuts (Narayanankutty, 2000). Cashew nuts along with other nuts, have been a vital source of nutrients for centuries. They are unique and possess flavour and textural properties that set them apart from all the other nuts (Phipps, 1999).

Cashew is nutritious having a substantial amount of quality proteins of high digestability and biological value, a fat with low saturated fat content contributing notable quantities of fat soluble vitamins and precious mineral matters. Cashew nut is a zero cholesterol nut as 82 per cent of the fat content in cashew nut is unsaturated fatty acids. Cashew with a high content of good quality proteins is nutritionally on par with milk, egg and meat without the disadvantages of the food of animal origin (Mahendru, 1990a).

Cashew is a versatile nut with many health advantages. Its regular use is beneficial in the treatment of gastric, chest, urinary and liver disorders. As part of a low fat, high fibre diet cashew nuts can help to reduce the risk of certain types of heart diseases, cancer and birth defects (Rainey and Nygiust, 1998).

Besides its nutritional benefits, cashew kernel is a good appetiser, an excellent nerve tonic, a steady stimulant and a body builder. With its rare combination of fats, carbohydrates, proteins and minerals cashew kernel makes a

food of great taste, especially for people on fast track of life which provides health, vigour and vitality.

The process of roasting and toasting of cashew kernels assists in increasing the enzymatic and bioregulative activities and can be eaten, digested and assimilated even by those suffering from senility and obesity (Mahendru, 1990b).

Efforts have been carried out in our country to enhance the production of cashew nuts by evolving high yielding cashew types and their popularization among cultivators. Evolution of productive types which exhibit better grade and nutritional qualities in addition to other attributes like yield and pest resistance are essential in any successful crop improvement programme.

Information with respect to the quality of kernels of different cashew varieties especially the nutritional qualities are scanty and hence the present investigation was carried out to study the variation in nutritional characteristics of the kernels in the cashew varieties available at Cashew Research Station, Kerala Agricultural University, Madakkathara and to assess the changes in the nutrient content due to processing.

Review of Literature

REVIEW OF LITERATURE

Literature relevant to the study entitled “Quality evaluation of kernels of different cashew varieties” is reviewed in this chapter under the following sections.

- 2.1 Nutritional importance of nuts and oilseeds
- 2.2 Composition and nutritional importance of cashew kernel
- 2.3 Processing aspects of cashew nuts
- 2.4 Physical and processing characters of cashew nuts

2.1 Nutritional importance of nuts and oilseeds

Tree nuts which include oil seeds enjoy world wide acceptance and are valued for their sensory and nutritional attributes (Sathe, 1994).

Nuts like grains and legumes are seeds filled with nutrients that are designed by nature to direct and enhance the development of life (CEPC 1998a).

Nuts and oilseeds are the most important and the most potent of all foods and contain all the important nutrients needed for human growth. They contain the germ, the reproductive power which is of vital importance for the health of human beings (Bakhru, 1997).

All nuts usually pack high amounts of proteins, minerals, vitamins, fats and carbohydrates (Swaminathan, 1986). Nuts form an important constituent of balanced diet especially in the diets of children and adolescents (Vijayapushpam and Kumari, 1998).

Tree nuts are complex multi dimensional plant food. They are high in all useful elements essential for germination and growth (Narayanan, 1998). Eaten alone or added to salads, baked goods, and desserts tree nuts provide wonderful taste and flavour (Phipps 1999).

According to Manay and Shadaksharaswamy (1987) nuts are very nutritious and supply for a given weight twice the amount of protein than any other food. The superior quality of nut protein renders them good substitutes for animal foods. Vegetable proteins, especially oilseed proteins find a place in meat products mainly because of their properties like high water binding capacity which prevents the formation of fat in cooked meat (Venkataraghavan, 1998).

Protein content of nuts and oilseeds ranged from about 6 to 25 per cent (Gopalan *et al.*, 1989 and Vijayapushpam and Kumari, 1998). Groundnuts had the highest amount (25%) followed by almond (20.8%), cashew nut (21%), walnut (15.6%) and pistachio nut (19.8%).

Sathe (1994) reported that the protein content of nuts varied from 20 to 25 g 100 g⁻¹. The crude protein content of soyabean, groundnut and of melon seeds were found to be between 34 to 41 per cent (Gbenle and Onyekachi, 1995). According to Lal (1997) walnut contained 15.03 per cent of protein. Srilakshmi (1999) observed 19 per cent proteins in nuts and oilseeds.

Nuts are typically high in fat (45-70% w/w) and are considered as energy rich foods (Sathe, 1994).

Saleem *et al.* (1991) observed 27.82 per cent and 65.78 per cent of total lipids in ground nut and walnut respectively.

Onyejebu and Oguntunde (1993) found that groundnut is very rich in fat (48.5%) while locust bean and soyabean are moderately rich in fat. Gbenle and Onyekachi (1995) found that soyabean, groundnut and melon seeds contain 18.6%, 42% and 45% of crude oil respectively. Lal (1997) reported 71.03 per cent of fat in walnut.

Nuts are also found to be an excellent natural source of essential unsaturated fatty acids necessary for growth (Bakhr, 1997). Although both nuts

and animal foods are fatty the type of fat in these two foods is different. The ratio of unsaturated over saturated fat indicates that the nuts have a greatly higher proportion of unsaturated fat as compared to animal foods (Fraser, 1999).

Nuts in general are very different from animal food group by having considerable amounts of dietary fibre that decreases the blood cholesterol and probably helps to prevent diabetes and aids in proper bowel function (Fraser, 1999).

The fibre content of different varieties of nuts varied from about 0.8 to 2.8 per cent (Saleem *et al.*, 1991).

Cardozo and Li (1994) analysed eight varieties of nuts for their fibre content and reported that the total fibre content varied from 3.6 per cent in cashew nut to 14.9 per cent in macadamia with the other nuts having values between 6.2 per cent and 10.5 per cent.

Nuts and oilseeds are also rich in carbohydrates. The carbohydrate content of soyabean and ground nut are 30.41 and 21.85 per cent respectively (Onyejegbu and Oguntunde, 1993).

Nuts and oilseeds are good sources of minerals and B-vitamins. Gingelly seed is particularly rich in calcium (Swaminathan, 1986). They are also good sources of certain B-vitamins, Vitamin E and minerals like phosphorus and iron (Begum, 1991). According to Bakhru (1997) and Vijayapushpam and Kumari (1998) nuts are important sources of a number of minerals like magnesium, potassium and copper.

The folic acid content of nuts may help to lower homocysteine levels, the levels of which have been linked to increased coronary heart diseases (Vijayapushpam and Kumari, 1998).

Apricot, an oil seed is a good source of vitamin A and contain appreciable amounts of thiamine and iron (Lal, 1997). According to the author walnut contained about 1.34 per cent minerals.

Ayurveda extensively discussed the medicinal value of nuts. Almonds were used for eye problems. Indian walnut was considered as a brain tonic and sesame seed was prescribed for infertility. Peas and nutmeg were given in cases of genital complaints (CEPC, 1998b).

Frequent nut consumption was associated with a reduced risk of both fatal coronary heart disease and non fatal myocardial infarction (Fraser, 1994).

2.2 Composition and nutritional importance of cashewnuts

Cashew in India is an introduced crop of nearly 500 years of processing and export. It was only from the early part of the current century its commercial value for export and foreign exchange earnings were realised (Balasubrahmanian, 1998).

Cashew crop is mainly grown for its nuts which is basically the raw material for processing out kernels (Rao *et al.*, 1962). India is the largest producer of cashew nut and it accounts for 43 per cent of the total production (CEPC, 1998b).

To sustain cashew industry and to keep India's prestigious position in the world trade of cashew kernels it is necessary to develop varieties with better quality nuts (Singh, 1991). According to Nayar (2000), cashew is a versatile nut with many health advantages.

Cashew nut is a good food of high nutritive value, having a substantial amount of proteins of good quality with high digestability and biological value, a

fat with low saturated fat content contributing notable quantities of fat soluble vitamins and precious mineral matters (Balasubramanian, 1979).

Cashew kernels have been known for their sweet, pleasant and bland palatability but little has been reported about its latent and benign properties as a medicine (Mahendru, 1978a).

Indian cashewnuts are distinct in taste and flavour, slightly salty and sweet at the same time, this delicate nut is a mouthful of delicacy (Manay and Shadaksharaswamy, 1987, CEPC, 1998a). Among the different nuts, cashewnut is an oilseed with excellent consumer acceptance and therefore has a great potential for increased utilization in foods.

Food and Agricultural Organisation (FAO, 1997) indicated that cashew compares well with other tree nuts in its nutritive value and the growing conditions and variety of cashew influences the composition of kernels.

Saleem *et al.* (1991), Minifie (1997) and Melo *et al.* (1998) reported that the moisture content of cashew nut kernels varied between 4 to 6 per cent. According to Balasubramanian (1998) cashewnuts immediately after harvest have a moisture content of 17 to 20 per cent and during drying the moisture content decreases to 8 to 9 per cent to increase their storage life. According to Shivasankar *et al.* (1998) during processing moisture content of kernels is kept below 5 per cent. According to Jisha *et al.* (1999) organoleptic and kernel quality of nuts deteriorates with increase in humidity.

Cashew nut has the highest protein content among the tree nuts (Woodroof, 1970). Cashew kernels of different varieties were evaluated by Mohapatra *et al.* (1972) and indicated that the protein content varied from 13.13 to 25.03 per cent with wide variation among varieties. Aravindakshan *et al.* (1986) analysed some varieties of cashew nuts and indicated that protein content of varieties ranged from 26.47 per cent in (K-28-2) to 43.01 per cent in (H-4-7).

Nagaraja (1989) reported that the protein content of defatted kernel flour of some cashew varieties varied from 32.1 to 43.7 per cent. The protein content of cashew nuts varied according to variety and locality from 20 per cent to 28 per cent (Anon, 1989). Mahendru (1990 b) and Soman (1990) reported that cashew kernels contain 20.8 per cent proteins which are readily assimilated. Manoj *et al.* (1994) observed that the protein content of cashew kernels varied from 20.03 per cent to 28.94 per cent.

Joseph (1978) reported that the thicker and broader portions of the nuts contain more protein than that of the narrow and tip portion of the kernel.

Singh (1991) indicated that better quality nuts should have a protein level over 35 per cent. According to Vijayapushpam and Kumari (1998) cashew nut have a high protein content of which 50 per cent is readily assimilable.

While comparing cashew nut and kola nut for their proximate composition and functional properties, Arogba (1999) observed a crude protein content of 36 per cent in dried samples of cashew nut. According to Nayar (2000) cashew is a versatile nut with 21.1 per cent protein and with right combination of amino acids.

Nagaraja and Nampoothiri (1986) evaluated 16 high yielding varieties of cashew kernel without testae and reported that protein content varied from 32.1 to 43.8 per cent. According to Renganayaki and Karivarathuraju (1993) cashew nut had 28.34 per cent protein.

Panda and Pal (1993) analysed cashew kernels and observed a protein content of 14.27 to 14.33 per cent.

The food value of cashew nut protein was found to be the highest in the vegetable kingdom (Piva and Santi, 1985).

Cashew kernels had a very high level of amino acids which are qualitatively equal to those of milk, meat and eggs (Mahendru, 1990b and Soman, 1990).

Most of the amino acids in cashew kernel was found to be greater during the early stage of development and decreases with an increase in maturity (Hariharan and Unnikrishnan, 1984). Exceptions were valine, methionine, serine and alanine which decreased initially and then increased with an increase in maturity. The authors also observed a highest concentration of tryptophan in cashew kernels followed in descending order by leucine, amino butyric acid, proline, valine, methionine, tyrosine and glutamic acid.

The major globulin in cashew nut protein is 13S globulin. Sulphur amino acids and methionine are the first and second limiting amino acid in globulin (Lercker and Pallotta, 1985).

The most exciting aspect of cashew nut is perhaps the fact about its fat content. Cashew nut contains 47 per cent of fat of which 82 per cent is unsaturated (Nayar 1985 and Soman, 1990).

Mahendru (1990 b) observed that cashew kernels are rich in fat and contain 42 per cent fat. According to Nayar (2000) cashew nut is a zero cholesterol nut.

The oil content in cashew kernels of certain cashew varieties showed a wide variability and ranged from 34.48 to 46.76 per cent (Murthy and Yadav, 1972).

About 82 per cent of fat in cashew kernel is composed of unsaturated fatty acids which actually lower the cholesterol level in blood and keep the heart devoid of cholesterol and related problems (Joseph, 1978, Soman, 1990, CEPC, 1998a and Narayanan, 1998).

The fats of the cashew nut are biologically complete, very active and easy to digest and exclude in notable quantities the vitamins known as liposolubles (Balasubramanian, 1979). According to the author cashew nut contained 73.77 per cent oleic acid, 7.67 per cent linoleic acid, 6.7 per cent palmitic acid and 11.44 per cent stearic acid. The percentage of raw fat in the cashew kernel is about the same as that found in the richer oil yielding seeds like peanuts, sesame, sunflower etc. (Lercker and Pallotta, 1985).

Nayar (1999) reported that unsaturated fatty acids of cashew kernels not only eliminates the possibility of an increase of the cholesterol level in the blood but actually balances or reduces cholesterol. According to Jisha *et al.* (1999) cashew kernels are prone to oxidative changes during its distribution and storage because of its high fat content.

Cashew kernel lipids from high yielding varieties have been characterized by Nagaraja (1987) and revealed that neutral lipids accounted for 96 per cent while glycolipid and phospholipid accounted for the remaining 4 per cent. According to the author cashew kernel lipids also contain 3.7 to 71 per cent of triglycerides.

Maia *et al.* (1975) and Maia *et al.* (1976) analysed composition of cashew kernel oil and observed palmitic, stearic, oleic and linoleic acids as the major fatty acids in the oil. Cashew nut oil contained 21 per cent saturated fatty acids, 59 per cent oleic acid and 19 per cent linoleic acid.

Renganayaki and Karivarathuraju (1993) reported that there is variation in fat content of different varieties according to maturity levels. They indicated that cashew nuts which matured 50 days after fruit set recorded the highest mean fat content of 47.57 per cent followed by 60 days with a fat content of 47.42 per cent. The nuts which matured 40 days after fruit set recorded a least mean value of 46.88 per cent.

Cashew nut oil contained significant amounts of triacylglycerols, tocopherols, sterols, triterpine alcohols etc. (Toschi *et al.*, 1993).

Cashew kernel has very low content of carbohydrates (22%) and as little as 1 per cent of soluble sugars. Such a quantity is sufficient to give a pleasant taste without creating excess energy (Narayanan, 1998).

Murthy and Yadav (1972) analysed cashew nuts of different varieties for its sugar content and observed that reducing sugars varied from 0.909 per cent (Pellerna) to 3.15 per cent (Edayanchavdi). Non reducing sugars vary widely and was lowest in Agumbe (1.28%) and maximum in Vazhisodanaipalayam (5.77%). Total sugar varied greatly from 2.43 per cent (Agumbe) - 8.72 per cent (South Aricot). Starch content ranged from 4.668 per cent (Vengurla) to 11.22 per cent (Edayanchavedi).

Cashew nuts provide about 7.76 Kcal/g of energy (Fetuga *et al.*, 1974).

Nagaraja and Nampoothiri (1986) analysed cashew kernels without testae from 16 high yielding varieties of cashew and indicated that total sugar content varied from 9.3 to 19.2 per cent and starch content from 21.3 to 33.2 per cent. Reducing sugar in all the varieties was very much less compared to total sugar content.

According to Woodroof (1967) cashew nut had a fibre content of 1 per cent.

Cardozo and Li (1994) analysed eight types of nuts for total dietary fibre content. Mean total dietary fibre values for three brands of each type of nut ranged from 3.6 per cent for cashew to 14.9 per cent for macadamia with the other nuts in between.

Cashew contained about 7 per cent dietary fibre. Introducing more fibre into diet increases the bile acid and also lowers serum cholesterol. Fibre in intestine reduces the absorption of cholesterol from food intake and cures constipation (Narayanan, 1998).

The presence of starch distinguishes cashew nuts from almonds and most other nuts. Carbohydrate content of cashew nut was found to be about 15 per cent (Chatfield and Adams, 1940). Woodroof (1967) observed a starch content of about 10.7 per cent in cashew nuts.

Since cashew kernel has very low carbohydrate content it keeps our waist trim and mouth busy. They do not add to obesity and help to control diabetes (Mahendru, 1990b).

Cashew comprise a surprising spectrum of vitamins and minerals which is very rare among nuts (CEPC, 1998a).

The fats in cashew nuts are abundant in vitamin E, A and D that are cardinal in the assimilation of fats and reinforcement of immunity function (CEPC, 1998a).

Cashew kernels have all fat soluble vitamins but the presence of 210 mg 100 g⁻¹ of vitamin E compels its mention as a potent source of this vitamin (Mahendru, 1978b). The author also pointed out that these fat soluble vitamins exert a sparing action in the B-group vitamins and assist in the metabolism of lactose and thiamine. The amount of carotene and vitamin E is quiet low (Soman 1990).

Vitamin E in cashew nuts is adequate to stabilize the unsaturated fatty acids present in them (FAO, 1994).

Cashew kernels contain 0.8 to 1.14 mg 100 g⁻¹ of thiamine and 0.58 mg 100 g⁻¹ of riboflavin (Mahendru, 1978a).

Cashew nuts provides in small quantities of most members of the B-complex group of vitamins. (Soman, 1990). According to Narayanan (1998) cashew kernel is also a rich source of riboflavin which keeps the body active, gay and energetic. Cashew nut contained about 322 I.U. of vitamin A and 46 mg of vitamin E/100 g (Anon, 1989).

Cashew nut is a good source of sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc, manganese, chlorine and even selenium. It is significant to note that cashew nut provides much more of the trace elements than other members of nut family (Soman, 1990).

Cashew nut contain about 450 mg of phosphorus, 50 mg of Ca and 5 mg of iron (Kumar, 1998)

Cashew kernel is a rich source of minerals like calcium and iron. They protect the human nervous system (Mahendru, 1990a). Cashew kernel is a good source of iron, phosphorus, magnesium and potassium (CEPC, 1998d).

The presence of large quantities of calcium, phosphorus and iron in their organic form prevent anaemia, poor nervous system and ill health (Mahendru, 1978b).

Ayurveda considered cashew nut as a good stimulant, rejuvenator, appetizer, an excellent hair tonic, aphrodisiac and restorative (CEPC, 1998a). According to Narayanan (1998) cashew kernels may be used as a medicine for loss of appetite, general depression, nervous weakness and scurvy.

Cashew kernel oil is a good mechanical and chemical antidote for irritant poisons. It is a versatile nut for lineaments and other external applications under pharmacology (Mahendru, 1990a).

The vitamins present in cashew nuts are essential in producing calcium, in protecting the well being of the mucous membrane and in strengthening the defence system against infectious diseases (Balasubramanian, 1979).

2.3 Processing aspects of cashew nuts

Cashew processing industry has made tremendous strides in recent years. Manufacturing process have also come a long way from what they were in the early years. The old methods of ground roasting and shelling by hammering the nut gave higher percentage of scorched kernels. These methods now yielded place to drum roasting and partly manual and partly mechanised shelling process. These improved methods have assured better kernel quality and yield (Zantye, 1998).

The harvesting of immature and tender nuts will affect very much the quality and weight of nuts (Nair, 1984 and Nagaraja, 1992). Most of the farmers collect the nuts along with apple. They dry the nuts for 2 days and store it for 2 to 5 months to gain additional value varying from 14 to 26 per cent (Dalvi *et al.*, 1992).

Since cashew nut has a peculiar shape and hard to break outer shell with a costic and corrosive oil within the shell, the processing has been highly labour oriented and time consuming. With each batch taking 7 to 10 days to reach the final products cashew have become a high value product (Musaliar, 1998).

The process of toasting or roasting the cashew kernels assist in increasing the enzymatic and bioregulatory activity and can be eaten, digested and assimilated even by those suffering from senility and obesity (Mahendru, 1978a).

Thirty per cent increase in the nutritional value is created due to processing of cashew nuts (Dalvi *et al.*, 1992).

Three important methods of cashew nut processing reported by Sharma (1998) are drum roasting, bath roasting and steam roasting. Steam roasting yields good quality whole kernels with natural white colour (Sharma, 1998).

Melo *et al.* (1998) observed that roasted cashew nuts contain 1.18 per cent moisture, 2.43 per cent ash, 21.76 per cent protein, 48.35 per cent lipids and 8.23 per cent sugar and starch 17.3 per cent.

Roasted cashew nuts contain moisture 4.1 per cent, protein 19.6 per cent, fat 47.2 per cent, ash 2.7 per cent, sugar 6.8 per cent and starch 10.7 per cent (Woodroof, 1967).

The processing of cashew nut involved the roasting and shelling of raw nuts and the peeling, grading and packing of cashew kernels. Processing for decortication is difficult because of the peculiar shape of nut, its varying size and brittleness of the kernel (Balasubramanian, 1979).

Processing of immature nuts results in lower shelling percentage (25.4%), peeling outturn (16.9%) and per cent wholes recovered (14.2%) and higher per cent kernel rejects (10.6%) (Nagaraja, 1998). According to the author processing by steam roasting helps in the recovery of higher percentage of whole kernels.

Study conducted by Salam (1998) to identify varieties with higher nut yield coupled with desirable processing characteristics revealed that the varieties H-1598, M-26/2 and H-1608 are the best among 18 varieties tested for their high productivity, higher shelling percentage, white whole yield and more kernels of key size.

2.4 Physical and processing characters of cashew nuts

Cashew nut is a kidney-shaped nut with greenish grey colour. It has an oleogenous shell or pericarp which is hard, smooth and shiny (Manay and Shadaksharaswamy, 1987).

According to Rao *et al.* (1962) cashew nuts reach the maximum size in 30 days and apple in 40 days. Augustin and Unnithan (1983) reported that the best stage for harvesting nuts is when they are crisp and tight with fully developed colour.

A study on physico-chemical aspects of 13 types of kernels was conducted by Aravindakshan *et al.* (1986) and revealed significant difference in quality attributes of different varieties with respect to length, breadth, thickness etc. Nut quality depends upon the size, shape, kernel weight, shelling percentage, sugar and protein content in kernels (Nalini *et al.*, 1994a).

Nandini and James (1985) evaluated 16 cashew types at Cashew Research Station, Anakkayam and found that weight of nuts varies from 8.7 to 9.4 g per nut between types. The highest weight of 9.4 g was observed with cashew type K-10-2. Reddy *et al.* (1986) evaluated 15 cashew selections in Karnataka and highest nut weight was found to be 6.59 g. While evaluating 10 cashew types at Cashew Research Station, Anakkayam, Nalini and Santhakumari (1991) observed variation in nut size from 5.1 to 8.9 g with the highest nut weight in K-16-1. Swamy and Mohan (1991) compared the average nut weight of 6 varieties and reported that the nut weight ranged from 3.5 to 7 g. Two varieties developed from Kerala Agricultural University namely Madakkathara-1 and Madakkathara-2 had a nut weight of 6.02 g and 7.5 g respectively (Veeraraghavan *et al.*, 1991). Ullal-3, a selection identified from the germplasm at Agricultural Research Station, Ullal had a nut weight of 6.99 g (Kumar and Hegde, 1994). A study conducted by Manoj *et al.* (1994) in cashew varieties it was found that all yield attributes had a higher degree of variability especially in the nut weight, which varied from 4.81 to 13 g. Priyanka a high yielding cashew hybrid released from Kerala Agricultural University had a nut weight of about 10.8 g (KAU, 1995).

A study was conducted by Salam (1998) to evaluate the processing characteristics and production potential of cashew varieties at Cashew Research

Station, Madakkathara. The study reported a higher nut weight of above 8 g among varieties like T 2/16, H 1610, H 1608. The nut weight of M 33/3, V-4, T 2/15, VTH 59/2, M 26/2, V-3, V-2, H 1600, H 1598, Anakkayam-1, T-40, VTH 30/4 and T 129 varied from 6 to 8 g and that of varieties V-5 and M-44/3 were found to be less than 5 g.

Nut weight had significant positive association with nut length, breadth and thickness (Anitha *et al.*, 1991). Varieties developed from K.A.U. namely M-1 and M-2 had a nut length of 2.98 cm and 3.12 cm respectively (Veeraraghavan *et al.*, 1991).

Pattannur-1-1 a special type of cashew nut which has no shell liquid had a nut weight of 3.55 g, nut length 3.55 cm, breadth 1.8 cm and thickness 1.35 cm (Nalini *et al.*, 1994b).

Weight of cashew kernels varied from 1.41 to 2 g in 13 varieties tested and the highest weight was observed with cashew selection NDR-21 (Aravindakshan *et al.*, 1986). George *et al.* (1991) compared the kernel weight of nine cashew selections like BLA-139-1, BLA-39-4, K-22-1, NDR-2-1, H-3-17, H-1598, H-1608, H-1010 and H-1602 from Cashew Research Station, Anakkayam and found that the kernel weight varied from 1.6 g in K-22-1 to 2.76 g in H 1602. Kernel weight varied from 1.64 to 2.76 g in 14 hybrids tested at Cashew Research Station, Madakkathara and highest kernel weight of 2.76 g was noticed with the hybrid H 1602 (Salam *et al.*, 1991). Manoj *et al.* (1994) observed a variation of 1.42 to 3.08 g in kernels of different cashew varieties.

Shelling percentage of cashew nuts was found to differ with variety (Nandini and James, 1985). Among the varieties evaluated by Manoj *et al.* (1994) shelling percentage was found to vary from 23.69 to 37.55 per cent. While evaluating F₁ hybrids of cashew at CRS Anakkayam the highest shelling percentage of 31.56 per cent was observed for H-419 (Manoj *et al.*, 1995). In the

study conducted by Salam (1998) the author observed that the shelling percentage of the cashew varieties ranged from 28.1 in 59/2 per cent to 37 per cent in Anakkayam. Among the varieties evaluated by Pushpalatha (2000) shelling percentage varied from 18.38 - 36.25.

Shelling percentage is an important determinant of the quality of nut (Ghosh, 1995). Highest shelling percentage was observed in varieties receiving water at 50 days interval i.e. 31.3 per cent followed by those receiving water of 10 days interval i.e. 29.8 per cent.

Ohler (1979) reported that shelling percentage of cashew kernels varied from 22 to 24 per cent.

In a study conducted by Salam (1998) the percentage of white whole kernels varied with variety and it ranged from 33.9 (M 44/3) to 86.3 (V4). The percentage of white wholes were above 70 in varieties like V4, VTH 59/2, H 1608, VTH 30/4, T 40, T 2/16, V2, V3 and M-26/2.

Materials and Methods

MATERIALS AND METHODS

3.1 Experimental materials

Following varieties of cashew nuts available and maintained at Cashew Research Station (CRS), Madakkathara, Trichur were selected for the study. The details of the cashew varieties selected for the study are given in Table 1.

Table 1. Selected varieties of cashew nuts

Varieties	Source
1. Anakkayam	Madakkathara
2. Madakkathara 1	Madakkathara
3. Madakkathara 2	Madakkathara
4. Kanaka	Madakkathara
5. Dhana	Madakkathara
6. Priyanka	Madakkathara
7. Amrutha	Madakkathara
8. Sulabha	Anakkayam
9. Dharasree	Anakkayam
10. H-1600	Madakkathara
11. H-1610	Madakkathara
12. H-2/15	Bapatla
13. H-2/16	Bapatla
14. Tree No. 129	Bapatla
15. Tree No. 40	Bapatla
16. VTH-30/4	Vittal
17. VTH-59/2	Vittal
18. Hybrid-4/5	Vengurla
19. Vengurla-2	Vengurla
20. Vengurla-4	Vengurla
21. M-26/2	Vrindhachalam
22. M-33/3	Vrindhachalam
23. M-44/3	Vrindhachalam

From each of the selected varieties nuts were collected from apples which were crisp and tight with fully developed colour as suggested by Augustin and Unnithan (1983).

3.2 Experimental methods

The methods used to evaluate the quality of selected cashew kernels are given under the following headings.

- 3.2.1 Evaluation of nut characters
- 3.2.2 Processing of cashew nuts
- 3.2.3 Evaluation of processing characters of kernels
- 3.2.4 Nutrient analysis of raw nuts and kernels
- 3.2.5 Statistical analysis

3.2.1 Evaluation of nut characters

Cashew nuts were evaluated for the following physical characters.

3.2.1.1 Weight

Average weight of three nuts of each variety was taken and expressed in gram.

3.2.1.2 Length

The distance between apex and the base was measured and expressed in cm.

3.2.1.3 Breadth

The breadth was measured using standard vernier callipers and expressed in cm.

3.2.1.4 Thickness

The thickness was measured using vernier callipers and expressed in mm. All the above observations were taken in triplicate samples.

3.2.2 Processing of cashew nuts

Fully matured nuts of different varieties were collected and subjected to steam processing to extract the kernels. Processing was done at 121°C and 15 Psi for 415 minutes.

3.2.3 Evaluation of processing characters of kernels

Following processing characters of the kernels were evaluated.

3.2.3.1 Kernel weight

Average weight of three kernels of processed nuts were taken and expressed in g.

3.2.3.2 Shelling percentage

Shelling percentage was worked out as the ratio of weight of kernels to the weight of raw nuts and expressed in percentage.

3.2.3.3 Percentage yield of whole kernels

The weight of whole kernels in one kg of processed nuts was taken and expressed as percentage.

3.2.3.4 Kernel count

The number of kernels in one kg of processed kernels was taken and expressed as kernel count.

3.2.4 Nutrient analysis of raw nuts and kernels

The selected kernels were analysed for different nutrients. All the analysis were conducted in triplicate samples.

3.2.4.1 Moisture

Moisture content of the selected cashew kernels was estimated using the method of A.O.A.C. (1980).

About 10 g of the kernel was weighed and dried in an oven at 90°C for 8 hours and cooled in a desiccator. The moisture content of the sample was calculated from the loss of weight during drying and expressed as percentage.

3.2.4.2 Protein

The nitrogen content was estimated using the method suggested by Snell and Snell (1983). 0.2 g of the kernel was taken and digested in concentrated sulphuric acid for about 10 minutes. After digestion 2-3 ml of H₂O₂ was added till the sample solution become colourless. The solution was made upto 100 ml. From the made up solution 5 ml was taken and 4 ml of salicylic acid and 1 ml of NaOH were added and made upto 25 ml. 1.6 ml of Nessler's reagent was added and the orange red colour developed was read colorimetrically at 410 nm. The nitrogen content was calculated and multiplied by a factor of 6.25 and the protein content was expressed as g 100 g⁻¹ of the fresh sample.

3.2.4.3 Fat

The fat content of the sample was estimated using the method of A.O.A.C. (1955).

The dry sample (10 g) was weighed accurately into a thimble and plugged with cotton. The material was extracted with anhydrous ether for about 4 hours in a Soxhlet apparatus. The washings were transferred from the flask and ether was removed by evaporation. Fat content was calculated from the residue remaining in the flask and expressed as g 100 g⁻¹ of the fresh sample.

3.2.4.4 Carbohydrate

The total carbohydrate content was estimated by following the method suggested by Sadasivam and Manikam, (1992).

0.1 g of the sample was taken in a boiling tube and hydrolysed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N HCl. The solution was neutralised with Na_2CO_3 until effervescence ceases and made up to 100 ml. 10 ml of hydrolysed sample was taken and again made up to 50 ml. From that 0.5 and 1 ml aliquots were taken and made up to 1 ml. Then added 4 ml of anthrone reagent and heated for 8 minutes. The dark green colour was read at 630 nm. Carbohydrate content was calculated from standard graph and expressed in $\text{g } 100 \text{ g}^{-1}$ of the fresh sample.

3.2.4.5 Sugar

The total sugar content was estimated by phenol sulphuric acid method suggested by Sadasivam and Manikam (1992).

0.1 g of the sample was taken and extracted using methanol. The supernatant was collected and made up to 100 ml with methanol. From that 0.2 ml and 1 ml aliquots were taken and made up to 1 ml. To the aliquotes 1 ml of 5 per cent phenol and 5 ml of sulphuric acid were added. An orange red colour was developed and read at 490 nm. Glucose content was found from standard graph and expressed as $\text{g } 100 \text{ g}^{-1}$ of the sample.

3.2.4.6 Fatty acid

The free fatty acid in oil was estimated by titrating it against KOH in the presence of phenolphthalein as suggested by Sadasivam and Manikam (1992). From the titre value fatty acid content was calculated and expressed as percentage of oleic acid.

3.2.4.7 Free amino acid

The total free amino acid was estimated by colorimetric method suggested by Sadasivam and Manikam (1992). 2 g of the sample was taken and extracted with 10 ml of boiling 80 per cent ethanol. To 1 ml of extract 1 ml of ninhydrin solution was added and made upto 2 ml. The tube was heated in a boiling water bath for 20 min and about 5 ml of diluent was added. Purple colour developed was read at 570 nm. Amino acid content was calculated from the graph and expressed as g 100 g⁻¹ of the fresh sample.

3.2.4.8 Calcium and Iron

For estimating the calcium and iron contents of the samples, diacid extract of the sample was prepared by adding nitric acid and sulphuric acid in the ratio 3:1. The solution was made upto 100 ml. Iron and calcium contents were estimated directly from the solution using Atomic Absorption Spectrophotometer (Perkin-Elmer, 1982). Calcium and Iron contents were expressed as mg 100 g⁻¹ of the fresh sample.

3.4.9 Phosphorus

It was estimated by colorimetric method using diacid extract. 5 ml of the extract was taken in a 25 ml volumetric flask and 5 ml of HNO₃-Vanadate-Molybdate reagent was added and made upto 25 ml. Read the colour after 10 minutes at 470 nm (Jackson, 1973). Phosphorus content is expressed as mg 100 g⁻¹ of the fresh sample.

3.2.5 Statistical analysis

Analysis of data was conducted using statistical techniques such as Analysis of Variance, Duncan's Multiple Range Test (DMRT), Paired 't' test and cluster analysis.

Results

RESULTS

The results pertaining to the study entitled “Quality evaluation of kernels of different cashew varieties” are presented under the following headings.

- 4.1 Physical characters of cashew nuts
- 4.2 Nutritional composition of raw nuts and kernels
- 4.3 Processing characters of cashew kernels
- 4.4 Comparison of nutrients of raw nuts and kernels
- 4.5 Cluster analysis of cashew nuts

4.1 Physical characters of raw nuts

Twenty three varieties of cashew nuts available and maintained at CRS, Madakkathara were evaluated for their physical characters like weight, length, breadth and thickness. The results are presented in Table 2.

4.1.1 Nut weight

The weight of cashew nuts varied from 4.24 g to 11.4 g with a mean weight of 7.1 g (Table 2). The highest mean weight was observed for cashew variety H-1600 and the lowest for Hybrid 4/5.

Analysis of variance indicated that there is significant variation between varieties of cashew nuts with respect to their weight at one per cent level (F value = 793.5).

The different varieties of cashewnuts were categorised into 16 groups based on their mean weight on the basis of DMRT (Duncan’s Multiple Range Test). Majority of the varieties were found to be significantly different from each other on the basis of mean weight except seven groups namely kl, f, i, g, c, k and n which contained two varieties in each group.

Table 2. Physical characters of raw nuts

Varieties	Weight (g)	Length (cm)	Breadth (cm)	Thickness (mm)
Amrutha	5.3 ⁿ	3.10 ^{hij}	2.39 ^{ghij}	18.05 ^{efg}
Anakkayam	6.0 ^k	3.67 ^{fg}	2.40 ^{ghij}	17.93 ^{efg}
Dhana	8.6 ⁱ	3.77 ^{efg}	2.67 ^{de}	20.87 ^{abc}
Dharasree	5.69 ^{lm}	3.37 ^{ghi}	2.44 ^{ghi}	19.07 ^{def}
Kanaka	5.5 ^{mn}	3.10 ^{hij}	2.30 ^{ijkl}	18.71 ^{defg}
Madakkathara-1	5.35 ⁿ	3.10 ^{hij}	2.45 ^{ghi}	18.47 ^{defg}
Madakkathara-2	6.97 ^l	3.66 ^{fg}	2.35 ^{hijk}	18.68 ^{defg}
Priyanka	10.8 ^b	4.40 ^{ab}	3.04 ^a	21.11 ^{ab}
Sulabha	8.02 ^g	3.53 ^g	2.64 ^{def}	19.41 ^{bcde}
H-1600	11.4 ^a	4.16 ^{abcd}	2.65 ^{de}	18.40 ^{efg}
H-1610	9.99 ^c	4.16 ^{bode}	2.48 ^{fgh}	18.55 ^{defg}
H-2/15	9.0 ^e	3.76 ^{defg}	2.87 ^{bc}	22.01 ^a
H-2/16	9.25 ^d	4.13 ^{abcde}	2.96 ^{ab}	21.85 ^a
Hybrid 4/5	4.24 ^o	3.00 ^{ij}	2.20 ^{kl}	17.19 ^g
M-26/2	7.19 ^h	3.96 ^{odef}	2.65 ^{de}	18.55 ^{defg}
M-33/3	8.4 ^f	4.50 ^a	2.54 ^{efg}	17.51 ^{fg}
M-44/3	6.22 ^j	3.56 ^g	2.52 ^{efg}	21.19 ^a
Tree No.40	5.8 ^{kl}	2.96 ^j	2.27 ^{kl}	18.30 ^{efg}
Tree No.129	6.0 ^k	4.00 ^{odef}	2.73 ^{cd}	20.29 ^{abcd}
Vengurla 2	5.79 ^{kl}	3.13 ^{hij}	2.41 ^{ghij}	19.15 ^{cdef}
Vengurla 4	8.0 ^g	4.03 ^{bodef}	2.55 ^{efg}	19.11 ^{cdef}
VTH 30/4	6.9 ^t	3.40 ^{gh}	2.73 ^{cd}	19.37 ^{cdef}
VTH 59/2	9.87 ^c	4.30 ^{abc}	2.14 ^l	21.47 ^a
Mean ± S.E.	7.1±0.18	3.68 ±0.06	2.54 ±0.03	19.35±0.19

Values having different alphabets as superscripts are significantly different at 5% level

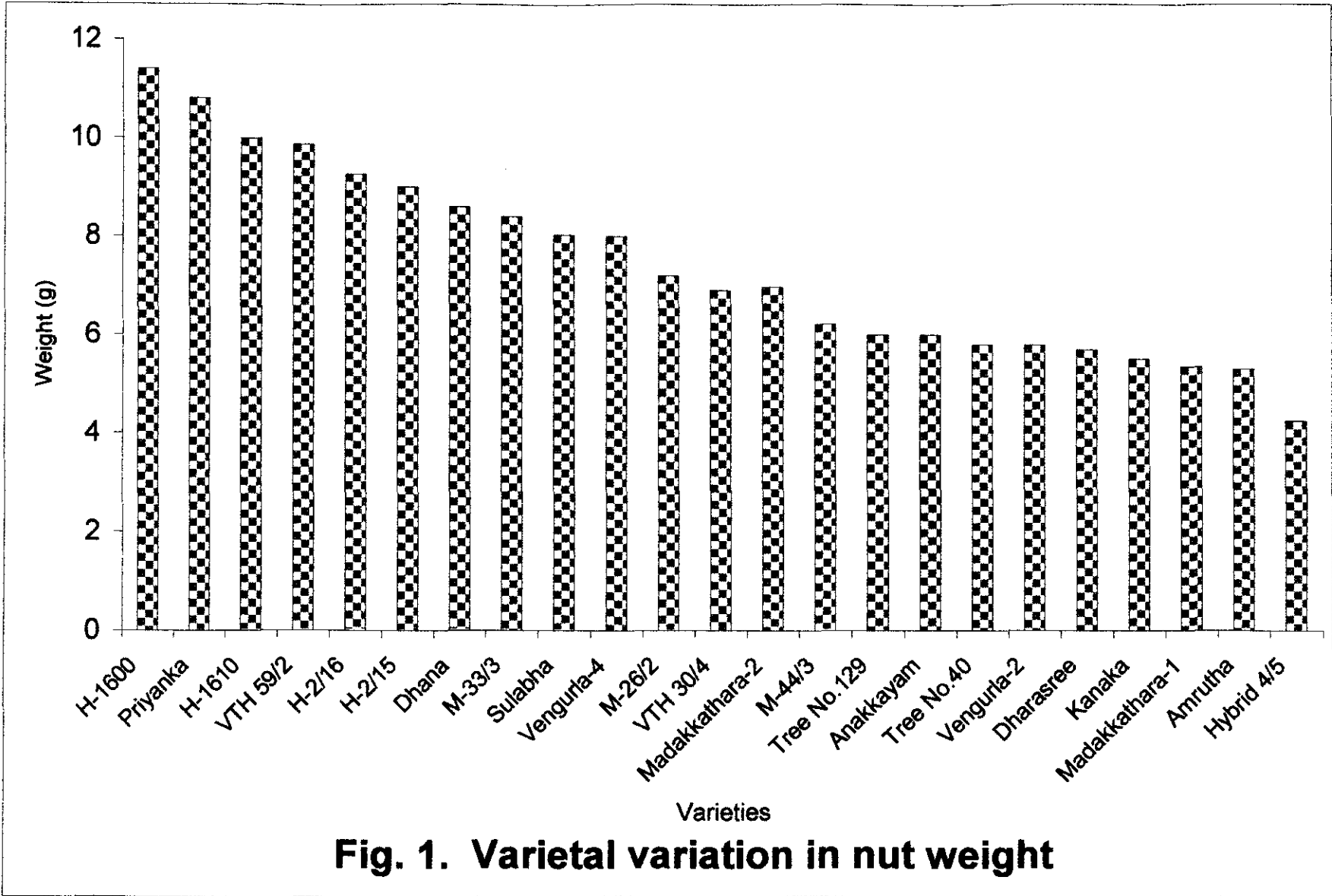


Fig. 1. Varietal variation in nut weight

Weight of 23 varieties of raw nuts is shown in Fig.1.

4.1.2 Length

The length of raw nut varied from 2.96 cm to 4.5 cm with a mean length of 3.68 cm (Table 2 and Fig.2). The highest and lowest values were observed in M-33/3 and Tree No.40 respectively.

Analysis of variance indicated that there is significant variation between cashew varieties with respect to their nut length at one per cent level (F value = 15.056).

On the basis of statistical analysis different varieties of cashew nuts were classified into 17 groups based on their length. Among the different categories hij category contained four varieties namely Vengurla 2, Kanaka, Madakkathara-1 and Amrutha. This indicates that there is no significant variation in the length of these varieties but they are significantly different from other varieties. M-44/3 and Sulabha were included in the same group (g). The group fg also contained two members namely Anakkayam and Madakkathara-2. M-33/3 with the highest length was included as a sole variety in the first group (a) indicating that this variety is statistically different from all other varieties with respect to length. The variety Priyanka was included in the second group (ab).

4.1.3 Breadth

The breadth of cashew nuts varied from 2.15 cm (VTH 59/2) to 3.04 cm (Priyanka). The mean breadth of raw nuts was found to be 2.54 cm (Table 2 and Fig.3).

Analysis of variance indicated significant variation within varieties of cashew nuts with respect to their breadth (F value = 19.856) at one per cent level.

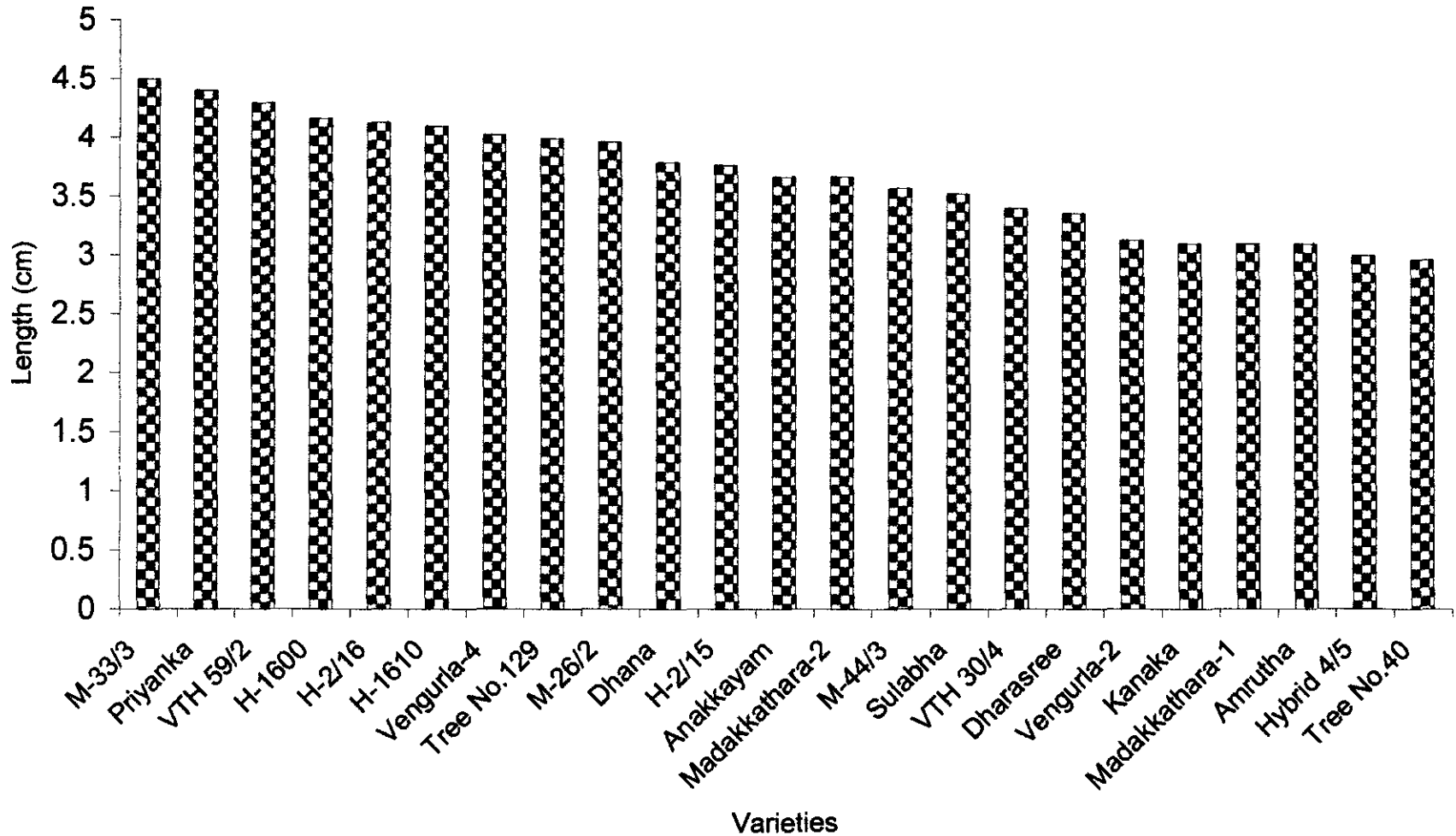


Fig. 2. Varietal variation in length of raw nuts

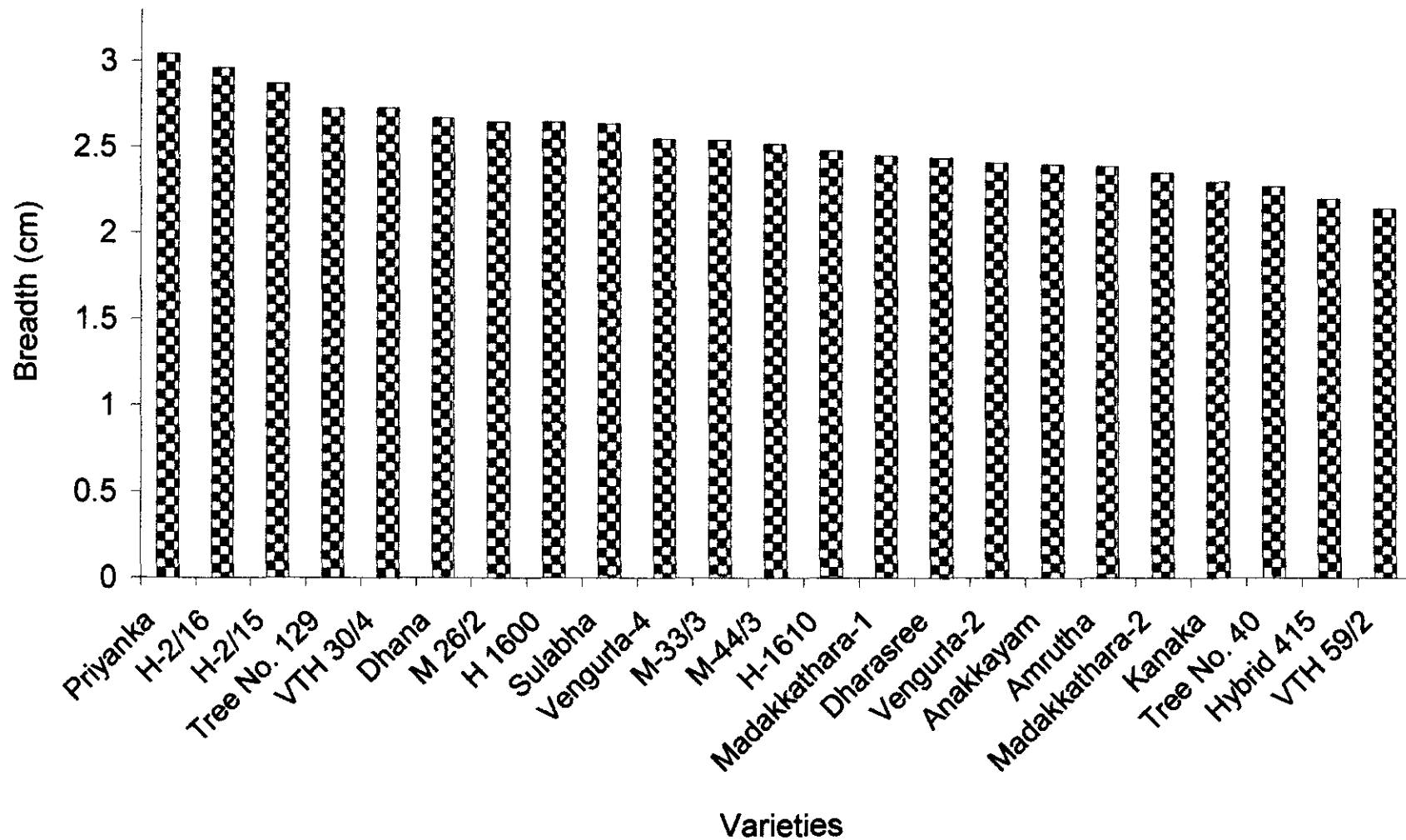


Fig. 3. Varietal variation in breadth of raw nuts

On the basis of DMRT, the varieties of nuts were classified into 16 groups. Priyanka was included in the first group (a) as a single entity which indicated that it had significant difference from all other cashew varieties with respect to breadth of nuts. The groups ghij, efg and de had three members each. They are Vengurla-2, Anakkayam and Amrutha in ghij, M-44/3, M-33/3 and Vengurla-3 in efg and M 26/2, Dhana and H-1600 in category de.

The breadth of twenty three varieties of cashew nuts is shown in Fig.3.

4.1.4 Thickness

The thickness of raw nuts ranged from 17.19 mm for Hybrid 4/5 to 22.01 mm for H 2/15 with a mean thickness of 19.35 mm (Table 2).

Analysis of variance indicated significant variation within varieties of cashew nuts with respect to their thickness (F value = 6.638) at one per cent level.

Statistically, the different cashew varieties were classified into 11 groups. The variety with highest thickness namely H-2/15 was included in the first group (a) along with other three varieties namely H-2/16, M-44/3 and VTH-59/2 indicating that these varieties are statistically similar with respect to their thickness but different from all other varieties. The group defg contained five varieties namely Kanaka (18.71 mm), Madakkathara-2 (18.68 mm), M-26/2 (18.55 mm), H-1610 (18.55 mm) and Madakkathara-1 (18.47 mm). Priyanka (21.11 mm) was included as the sole member of the second category ab. VTH-30/4, Vengurla-2 and Vengurla-4 were included in the same class cdef.

The thickness of twenty three varieties of raw nuts is shown in Fig.4.

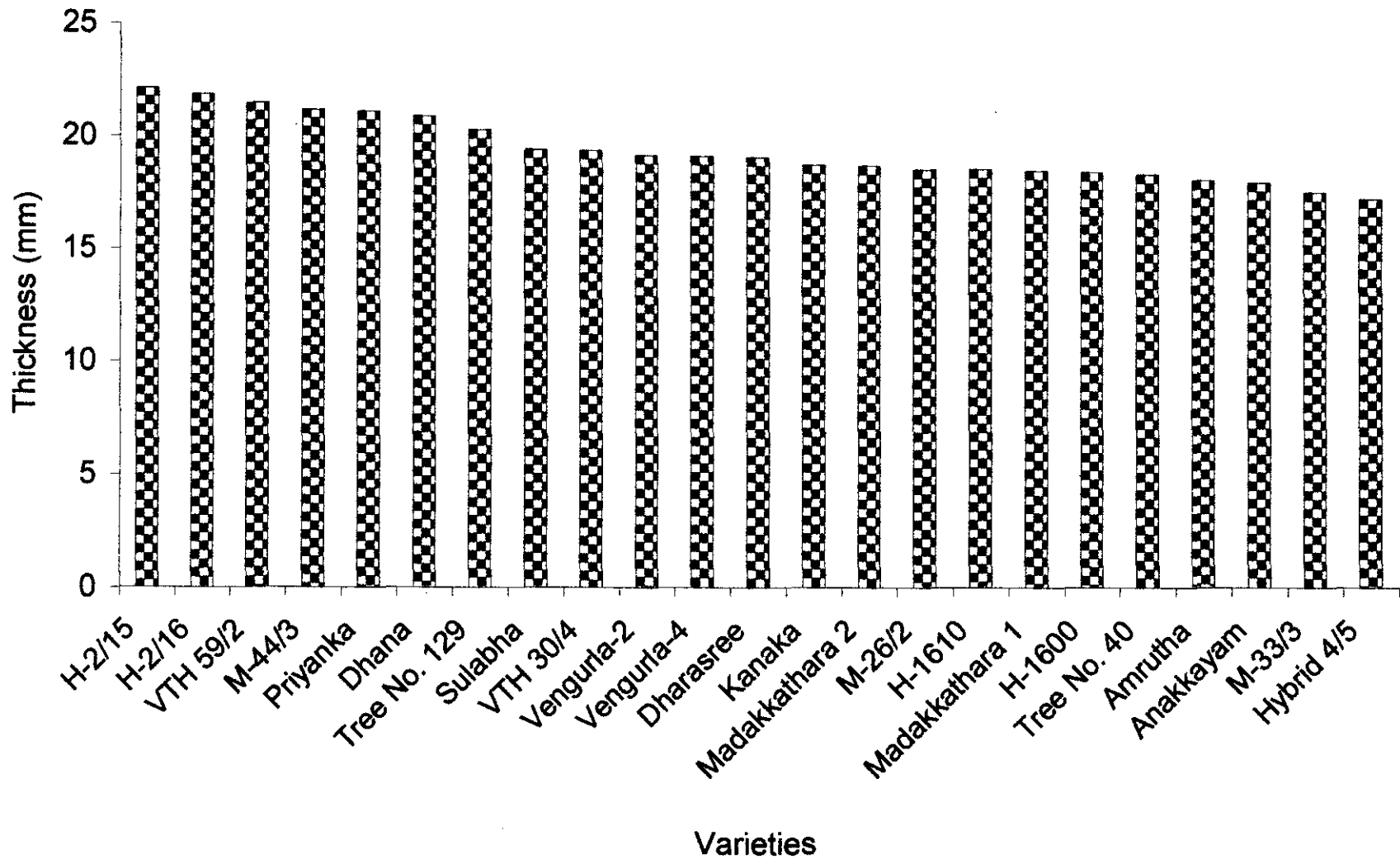


Fig. 4. Varietal variation in thickness of raw nuts

4.2 Nutritional composition of raw nuts and kernels

The selected varieties were analysed for ten nutrients which are moisture, protein, fat, carbohydrate, total sugar, total free fatty acid, free amino acid, calcium, iron and phosphorus before and after processing.

4.2.1 Moisture

The moisture content of raw nuts and kernels varied from 4.9 per cent to 7.9 per cent and from 4.78 per cent to 8.03 per cent respectively (Table 3 and Fig.5). The mean moisture content of raw nuts and kernels of 23 cashew varieties was found to be 7.04 per cent and 7.14 per cent respectively. The highest mean moisture content was found in VTH-59/2 variety before and after processing. The lowest mean moisture content before and after processing was observed in H-1610 and M-26/2 respectively.

Significant variation within cashew varieties was observed both before (F value = 3.272) and after (F value = 11.017) processing at one per cent level.

On the basis of DMRT cashew varieties were differentiated into 6 groups with respect to their moisture content before processing. VTH-59/2 with the highest moisture content was grouped in category a along with H-1600 indicating that they are not significantly different from each other but different from varieties of other categories statistically. The group bcd had 7 members in it which are H-2/15 (7.4%), Tree No.40 (7.21%), Anakkayam (6.87%), Vengurla-2 (6.8%), Vengurla-3 (6.76%), Hybrid 4/5 (6.63%) and Dharasree (6.43%). The group cd also had seven members. The members of different groups had significant difference between themselves.

The cashew varieties after processing were grouped into seventeen classes based on their moisture content. The first group a had three varieties

Table 3. Varietal variation in moisture content ($\text{g } 100 \text{ g}^{-1}$) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	6.33 ^{cd}	5.87 ^{hijk}
Anakkayam	6.87 ^{bcd}	7.73 ^{bcd}
Dhana	7.56 ^{abc}	7.79 ^{abc}
Dharasree	6.43 ^{bcd}	5.93 ^{hijk}
Kanaka	5.83 ^{cd}	6.30 ^{efghij}
Madakkathara-1	7.80 ^{ab}	7.91 ^a
Madakkathara-2	7.75 ^{abc}	7.85 ^{ab}
Priyanka	7.71 ^{abc}	6.26 ^{efghij}
Sulabha	7.60 ^{abc}	7.62 ^{bcde}
H-1600	7.87 ^a	7.93 ^a
H-1610	4.90 ^d	5.33 ^k
H-2/15	7.40 ^{bcd}	6.76 ^{defghij}
H-2/16	5.70 ^{cd}	5.50 ^{ijk}
Hybrid 4/5	6.63 ^{bcd}	6.93 ^{defghi}
M-26/2	6.06 ^{cd}	4.78 ^k
M-33/3	5.19 ^d	6.86 ^{defghi}
M-44/3	6.06 ^{cd}	6.16 ^{ghijk}
Tree No.40	7.21 ^{bcd}	7.46 ^{defg}
Tree No.129	6.23 ^{cd}	7.20 ^{defgh}
Vengurla 2	6.80 ^{bcd}	6.23 ^{efghij}
Vengurla 4	6.76 ^{bcd}	6.53 ^{defghij}
VTH 30/4	6.13 ^{cd}	7.54 ^{cdet}
VTH 59/2	7.90 ^a	8.03 ^a
Mean \pm S.E.	7.04 \pm 0.21	7.14 \pm 0.19

Values having different alphabets as superscripts are significantly different at 5% level

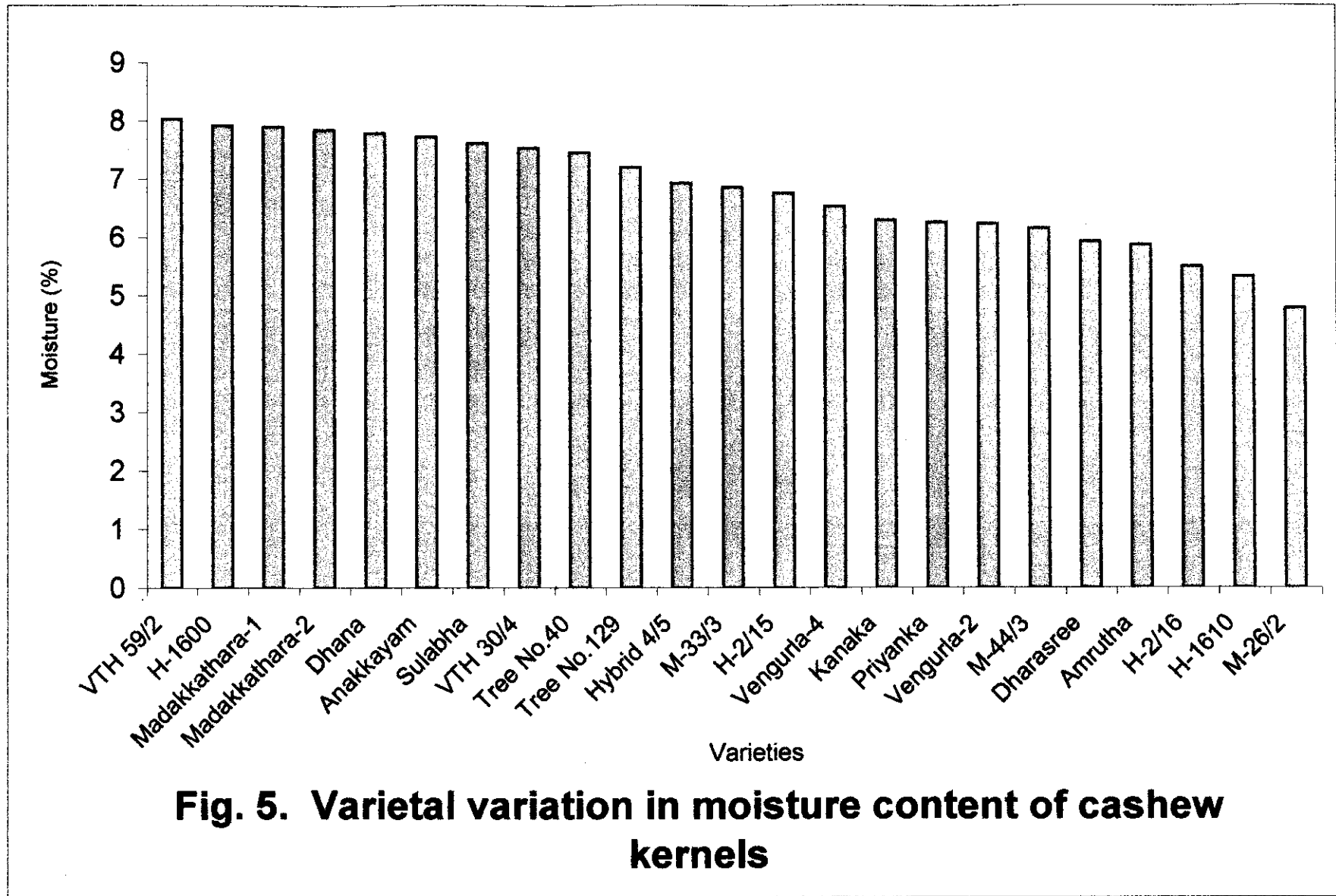


Fig. 5. Varietal variation in moisture content of cashew kernels

namely VTH-59/2 (8.03%), H-1600 (7.93%) and Madakkathara-1 (7.91%). All other groups had two or less than 2 members.

The moisture content of cashew kernels is shown in Fig.5.

4.2.2 Protein

The protein content of raw nuts varied from 19.69 g in H-1600 to 22.31 g 100 g⁻¹ in H-2/16 with significant variation between varieties (F value = 24.407) (Table 4). The mean protein content of raw nuts was found to be 21.26 per cent.

Statistically, the cashew nuts before processing were divided into 15 classes based on their protein content. H-2/16 with the highest protein content was categorised as a single member indicating that the protein content of H-2/16 was significantly different from all the other varieties. The variety (M-33/3) with the second highest protein content (22.15%) was also categorised as a single member in group ab.

The protein content of cashew kernels varied from 19.32 g to 22.11 g 100 g⁻¹ with significant variation between varieties (F value = 18.128) (Table 4). The highest and lowest values were observed in H-2/16 and Vengurla-2 respectively. The mean protein content of cashew kernels was found to be 21.1 per cent.

On the basis of Duncan's Multiple Range Test the cashew kernels were divided into 13 groups. The groups bcde and ab had three members each. The first group a had two members namely H-2/16 and M-33/3 with a protein content of 22.11 and 22.09 per cent protein respectively.

The protein content of cashew kernels is shown in Fig.6.

Table 4. Varietal variation in protein content (g 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	20.93 ^{hij}	20.91 ^{ef}
Anakkayam	21.93 ^{abc}	21.96 ^{ab}
Dhana	21.95 ^{abc}	21.80 ^{abc}
Dharasree	19.86 ^l	19.73 ^{hi}
Kanaka	21.20 ^{fgh}	21.15 ^{cde}
Madakkathara-1	21.89 ^{abcd}	21.85 ^{ab}
Madakkathara-2	21.73 ^{bode}	21.61 ^{abcd}
Priyanka	21.89 ^{abcd}	21.79 ^{abc}
Sulabha	20.54 ^{ijk}	20.49 ^{fg}
H-1600	19.69 ^l	19.53 ⁱ
H-1610	21.42 ^{deifg}	21.32 ^{bode}
H-2/15	20.88 ^{hij}	20.93 ^{ef}
H-2/16	22.31 ^a	22.11 ^a
Hybrid 4/5	21.53 ^{odef}	21.48 ^{abcde}
M-26/2	21.01 ^{ghu}	20.99 ^{def}
M-33/3	22.15 ^{ab}	22.09 ^a
M-44/3	21.34 ^{eigh}	21.31 ^{bode}
Tree No.40	20.32 ^k	19.83 ^{hi}
Tree No.129	21.96 ^{abc}	21.96 ^{ab}
Vengurla 2	20.52 ^{jk}	19.32 ^l
Vengurla 4	20.57 ^{ijk}	20.29 ^{gh}
VTH 30/4	21.95 ^{abc}	21.39 ^{bode}
VTH 59/2	21.43 ^{defg}	21.44 ^{abcde}
Mean ± S.E.	21.26±0.09	21.1±0.11

Values having different alphabets as superscripts are significantly different at 5% level

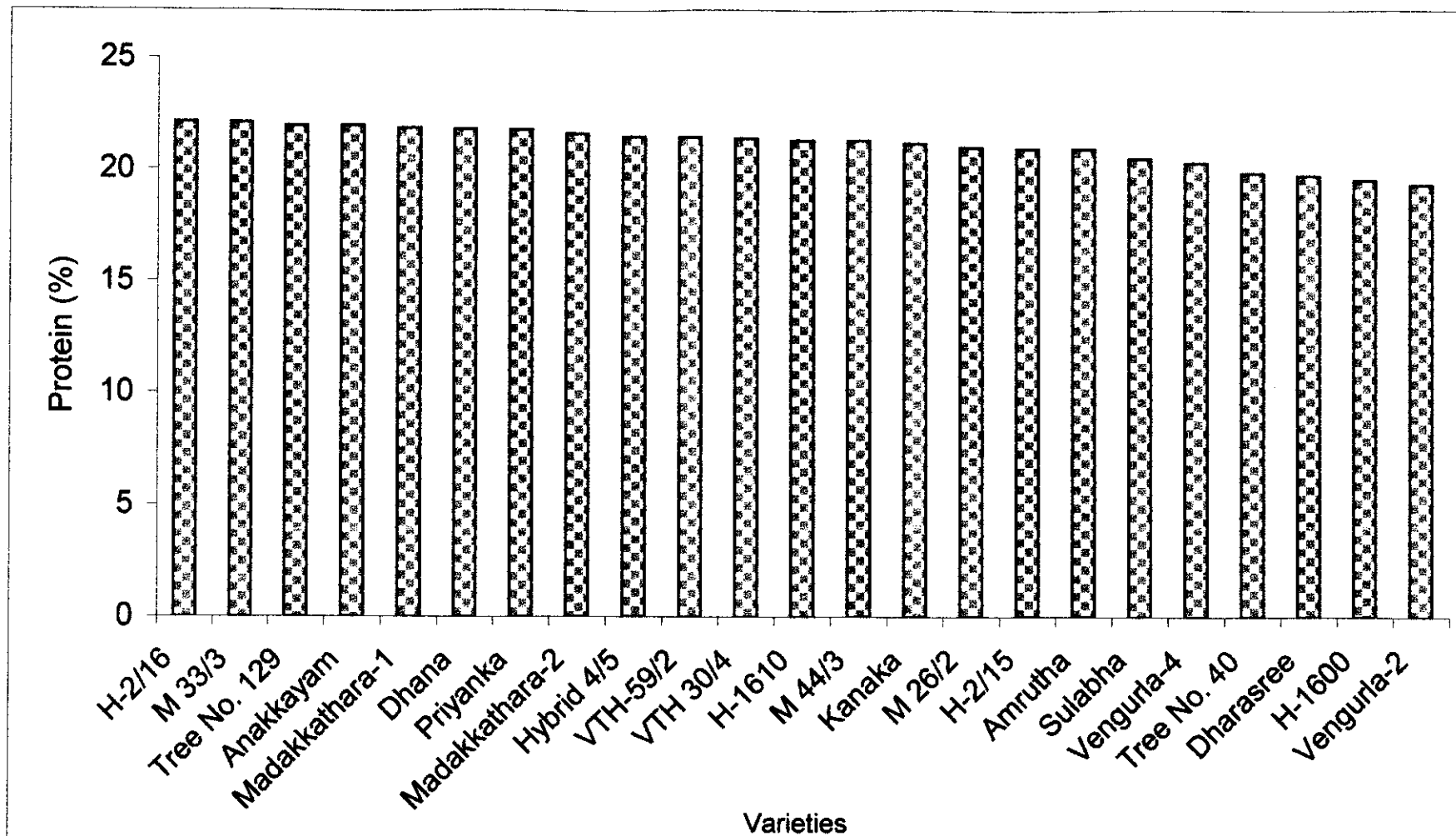


Fig. 6. Varietal variation in protein content of cashew kernels

4.2.3 Fat

The fat content of cashew nuts varied from 40.27 per cent to 46.77 per cent before processing and from 40.23 per cent to 47.17 per cent after processing. The highest and lowest values before processing were observed in Dharasree and H-2/16 respectively. After processing the highest fat content was observed in H-1600 and the lowest in Anakkayam (Fig 7). The mean fat content of raw nuts and kernels of 23 cashew varieties was found to be 43.75 per cent and 44.13 per cent respectively (Table 5).

Analysis of variance also revealed that there is significant variation in the fat content between varieties at one per cent level before (F value = 6.104) as well as after (F value = 2.865) processing.

With respect to the fat content different varieties of cashew nuts before processing were classified statistically into twelve different classes. Four varieties with a fat content in between 44.17 per cent and 44.63 per cent were included in the same group abcdef and this group included varieties like M 26/2 (44.63%), H-2/15 (44.57%), Kanaka (44.5%) and M 44/3 (44.17%). The groups efg and g contained three members each. Sulabha (45.98%) and Vengurla 2 (45.73%) were included in group abc. The groups fg, def, abcd, abcde and ab contained only one member each and they are Tree No:129 (42.13%), Priyanka (43.07%), Vengurla-4 (45.67 %), Amrutha (44.87%) and Tree No:40 (46%) respectively. The varieties included in the same class were not significantly different from each other but different from varieties of other classes statistically.

The varieties were classified into 9 groups on the basis of fat content after processing. The varieties such as VTH 30/4, M-26/2, VTH 59/2, H-1610, M-33/3 and Dhana were included in the same group abcde. The group abcd also contained 5 members such as Priyanka, Vengurla-4, H-2/15, Amrutha, M-44/3. Varieties like Kanaka, Madakkathara-2, Tree No: 129, Hybrid 4/5 were categorised

Table 5. Varietal variation in fat content (g 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	44.87 ^{abode}	44.97 ^{abcd}
Anakkayam	40.43 ^b	40.23 ^f
Dhana	42.33 ^{efg}	43.83 ^{abcde}
Dharasree	46.77 ^a	45.57 ^{abc}
Kanaka	44.50 ^{abodef}	42.97 ^{cdef}
Madakkathara-1	42.30 ^{efg}	42.03 ^{def}
Madakkathara-2	42.53 ^{efg}	42.87 ^{cdef}
Priyanka	43.07 ^{def}	45.33 ^{abcd}
Sulabha	45.98 ^{abc}	46.37 ^{ab}
H-1600	46.43 ^a	47.17 ^a
H-1610	43.67 ^{bodef}	43.87 ^{abcde}
H-2/15	44.57 ^{abodef}	45.01 ^{abcd}
H-2/16	40.27 ^b	41.53 ^{ef}
Hybrid 4/5	43.33 ^{cdef}	42.63 ^{cdef}
M-26/2	44.63 ^{abodef}	44.17 ^{abcde}
M-33/3	40.27 ^b	43.83 ^{abcde}
M-44/3	44.17 ^{abodef}	44.90 ^{abcd}
Tree No.40	46.00 ^{ab}	45.60 ^{abc}
Tree No.129	42.13 ^{fg}	42.73 ^{cdef}
Vengurla 2	45.73 ^{abc}	45.80 ^{abc}
Vengurla 4	45.67 ^{abcd}	45.17 ^{abcd}
VTH 30/4	43.30 ^{cdef}	44.37 ^{abcde}
VTH 59/2	43.43 ^{bodef}	44.13 ^{abcde}
Mean ± S.E.	43.75±0.26	44.13±0.26

Values having different alphabets as superscripts are significantly different at 5% level

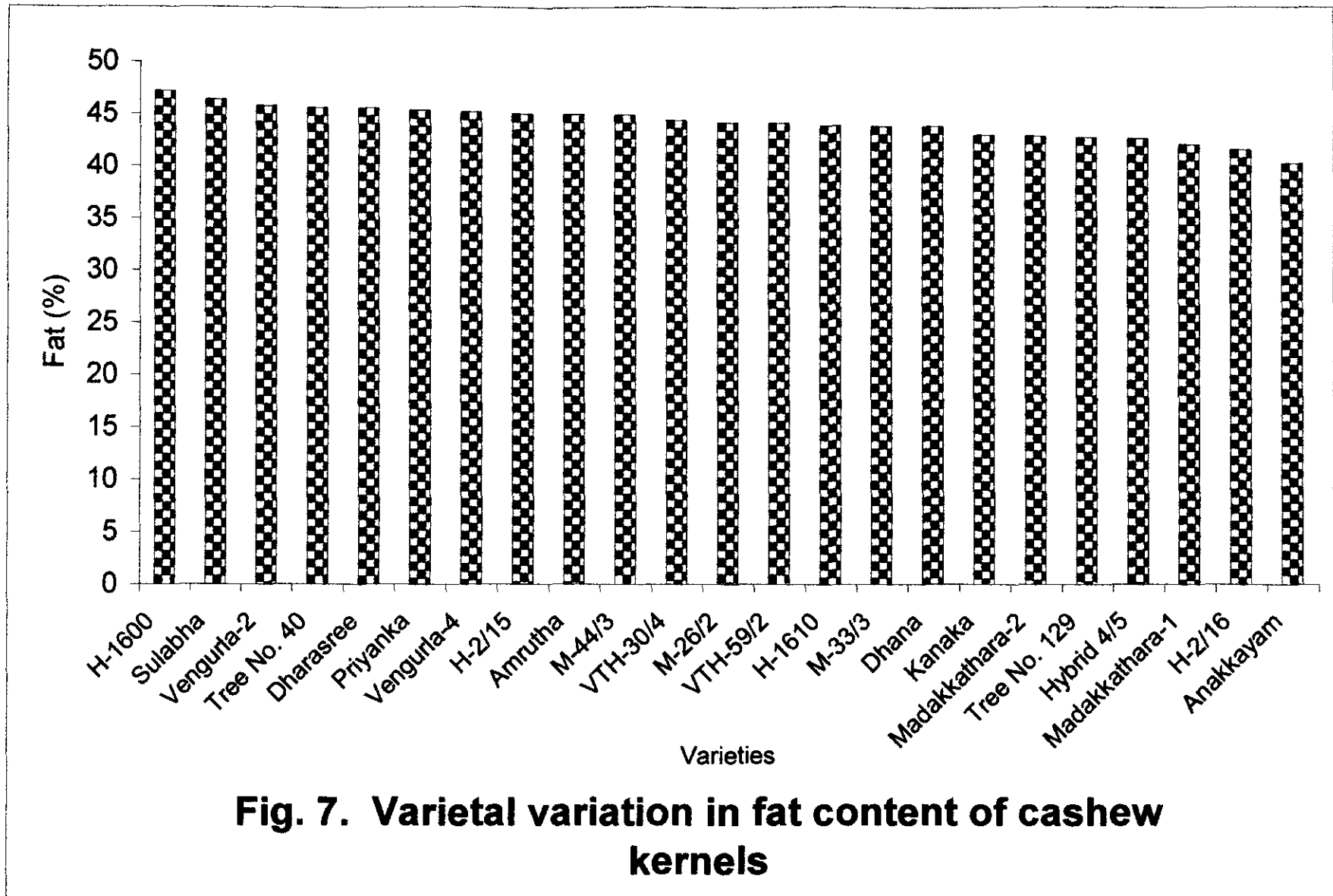


Fig. 7. Varietal variation in fat content of cashew kernels

under the group cdef. The variety H-1600 with the highest fat content was included as a sole member of group (a) which showed that it had significant difference from all other 22 varieties of cashew kernels.

4.2.4 Carbohydrate

The carbohydrate content of cashew nuts before processing ranged from 17.69 per cent in Madakkathara-1 to 24.02 per cent in Anakkayam, with a mean content of about 20.62 per cent (Table 6). Significant variation was noticed within the varieties with respect to carbohydrate content of raw nuts (F value = 4.675).

DMRT classified the varieties before processing into 16 categories. The group ab and abc contained two members each which are M-33/3 (23.3%) and Amrutha (23.11%) and H-2/16 (22.87%) and Kanaka (22.79%) respectively. M-26/2 (22.28%) and H-1600 (22.1%) were included in the same group (abcd). The first group a had only one member Anakkayam which was significantly different from all other varieties.

The carbohydrate content of cashew kernels after processing varied from 17.18 per cent (Madakkathara-1) to 23.26 per cent (Anakkayam) with significant variation within varieties (F value = 3.225). The mean carbohydrate content of kernels was found to be 20.45 per cent (Table 6).

The different cashew kernels were grouped into 10 groups according to their carbohydrate content after processing on the basis of DMRT. Both the groups ab and bcdef had 6 members each. M-26/2, H-2/16, Hybrid 4/5, Amrutha, VTH 30/4, and H 1600 were included in the same group ab with a carbohydrate content varying from 21.49% to 22.1 per cent. Madakkathara-2, H-2/15, M-33/3, M-44/3, VTH 59/2 and H-1610 were included in one group (bcdef) with a lower carbohydrate content ranging from 19.04 to 19.96 g 100 g⁻¹. It showed that varieties included in these two groups are not significantly different from each

Table 6. Varietal variation in carbohydrate content (g 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	23.11 ^{ab}	21.57 ^{ab}
Anakkayam	24.02 ^a	23.26 ^a
Dhana	20.91 ^{bcd^{efg}}	21.06 ^{abcd}
Dharasree	18.63 ^{efghi}	18.27 ^{cd^{ef}}
Kanaka	22.79 ^{abc}	23.11 ^a
Madakkathara-1	17.69 ⁱ	17.18 ^f
Madakkathara-2	21.63 ^{abcde}	19.96 ^{bcde^f}
Priyanka	18.02 ^{ghi}	18.12 ^{de^f}
Sulabha	18.25 ^{fghi}	21.02 ^{abcd}
H-1600	22.10 ^{abcd}	21.49 ^{ab}
H-1610	18.08 ^{ghi}	19.04 ^{bcde^f}
H-2/15	19.36 ^{defghi}	19.94 ^{bcde^f}
H-2/16	22.87 ^{abc}	21.92 ^{ab}
Hybrid 4/5	19.82 ^{cdefghi}	21.62 ^{ab}
M-26/2	22.28 ^{abcd}	22.10 ^{ab}
M-33/3	23.30 ^{ab}	19.92 ^{bcde^f}
M-44/3	21.30 ^{abcde^f}	19.70 ^{bcde^f}
Tree No.40	17.75 ^{hi}	17.99 ^{ef}
Tree No.129	20.42 ^{bcd^{efghi}}	20.29 ^{abcde}
Vengurla 2	21.60 ^{abcde}	20.55 ^{abcde}
Vengurla 4	20.83 ^{bcd^{efgh}}	21.34 ^{abc}
VTH 30/4	20.58 ^{bcd^{efghi}}	21.55 ^{ab}
VTH 59/2	18.96 ^{efghi}	19.56 ^{bcde^f}
Mean ± S.E.	20.62±0.28	20.45±0.25

Values having different alphabets as superscripts are significantly different at 5% level

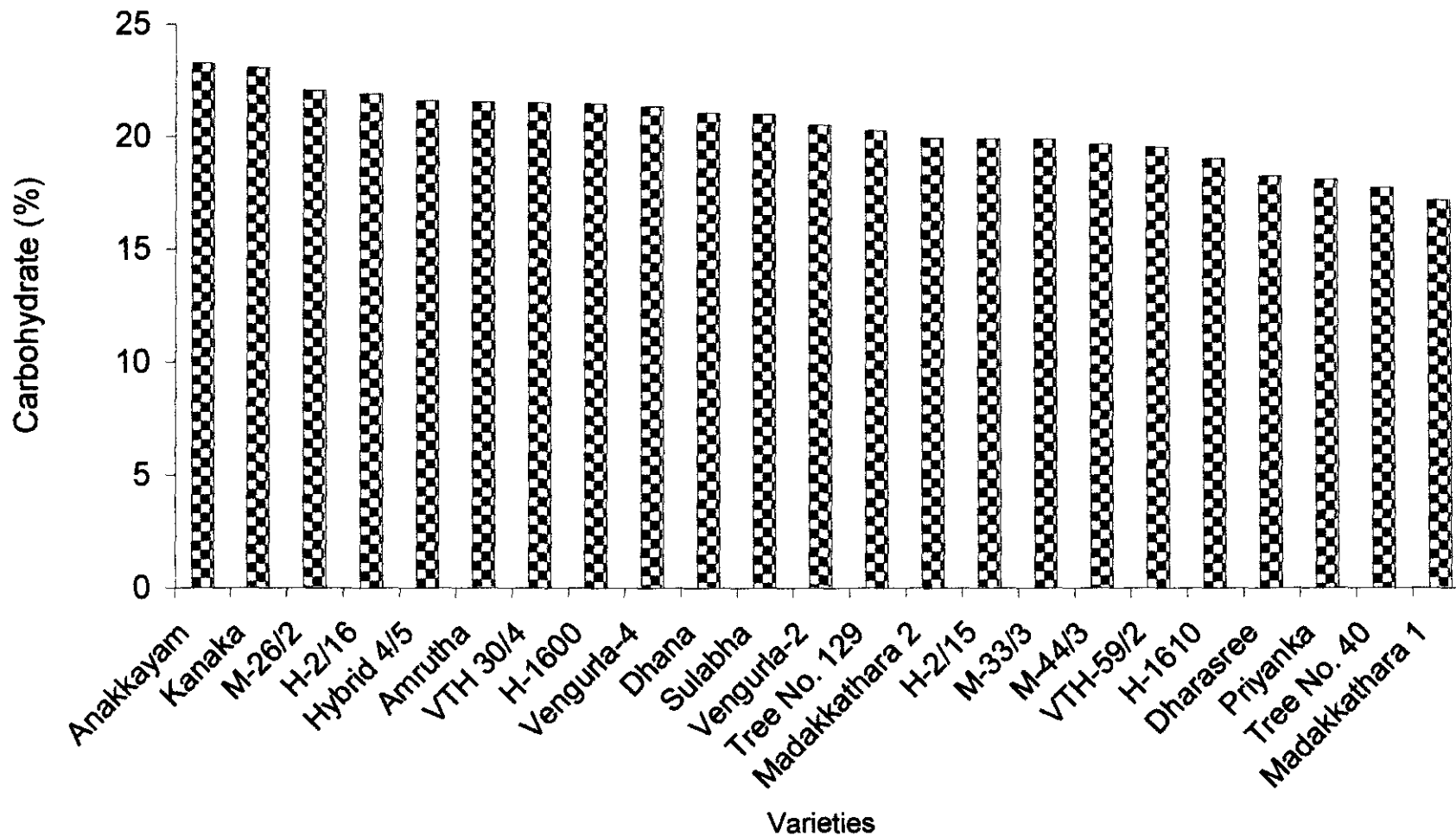


Fig. 8. Varietal variation in carbohydrate content of cashew kernels

other within the group but are different between the groups with respect to carbohydrate content.

The carbohydrate content of kernels of different cashew varieties is given in Fig.8.

4.2.5 Sugar

The sugar content of different varieties of cashew nuts varied from 4.81 per cent to 10.15 per cent. The highest and lowest values were observed in Sulabha and Tree No.129 respectively. The sugar content after processing varied from 3.91 per cent in Tree No.129 to 9.96 per cent in H-1600. The mean sugar content of raw nuts and kernels was found to be 7.25 per cent and 7.29 per cent respectively (Table 7). Significant variation was observed among the varieties with respect to sugar content of raw nuts (F value = 6.684) and kernels (F value = 2.895).

Statistically the varieties were differentiated into 16 classes on the basis of sugar content before processing. The class fghij had the greatest number of members and they were VTH-30/4 (6.06%), VTH-59/2 (6.06%) and Tree No.40 (5.83%). The variety having the highest value namely Sulabha was included in a separate group (a) and was significantly different from all other varieties in sugar content. The groups ab, bcde, bcdefg, efghi and efghij had two members each. Tree No.129 with the lowest sugar content was included in separate group (j) as a single entity indicating that the variety is significantly different from all the other cashew varieties in its sugar content before processing.

Cashew kernels after processing were also classified into 11 groups on the basis of sugar content. The varieties such as Hybrid 4/5 (8.71%), Tree No.40 (8.01%), M-33/3 (7.91%), M-26/2 (7.77%), VTH-59/2 (7.57%), H-1610 (7.47%) and Dhana (7.35%) were in the same group (abcde). The group cdef contained four varieties which were Amrutha (6.56%), H-2/16 (6.36%), Vengurla-4 (6.35%) and Madakkathara-2 (6.29%). The cashew varieties with the highest and lowest sugar

Table 7. Varietal variation in sugar content (g 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	6.58 ^{efghij}	6.56 ^{cdef}
Anakkayam	7.23 ^{defghi}	6.07 ^{def}
Dhana	8.66 ^{abcd}	7.35 ^{abcde}
Dharasree	5.51 ^{hij}	6.03 ^{ef}
Kanaka	6.60 ^{efghij}	6.03 ^{ef}
Madakkathara-1	9.33 ^{ab}	7.07 ^{bode}
Madakkathara-2	7.63 ^{bodefg}	6.29 ^{odef}
Priyanka	7.64 ^{bdefg}	8.88 ^{abcd}
Sulabha	10.15 ^a	9.77 ^{ab}
H-1600	9.44 ^{ab}	9.96 ^a
H-1610	8.30 ^{bode}	7.47 ^{abcde}
H-2/15	7.67 ^{bodef}	8.99 ^{abc}
H-2/16	5.40 ^j	6.36 ^{odef}
Hybrid 4/5	9.16 ^{abc}	8.71 ^{abcde}
M-26/2	6.71 ^{efghi}	7.77 ^{abcde}
M-33/3	8.20 ^{bode}	7.91 ^{abcde}
M-44/3	7.35 ^{cdeigh}	7.17 ^{bode}
Tree No.40	5.83 ^{ghij}	8.01 ^{abcde}
Tree No.129	4.81 ^j	3.91 ⁱ
Vengurla 2	5.75 ^{ghij}	6.90 ^{cde}
Vengurla 4	6.70 ^{efghi}	6.35 ^{odef}
VTH 30/4	6.06 ^{efghij}	6.63 ^{cde}
VTH 59/2	6.06 ^{efghij}	7.57 ^{abcde}
Mean ± S.E.	7.25±0.2	7.29±1.78

Values having different alphabets as superscripts are significantly different at 5% level

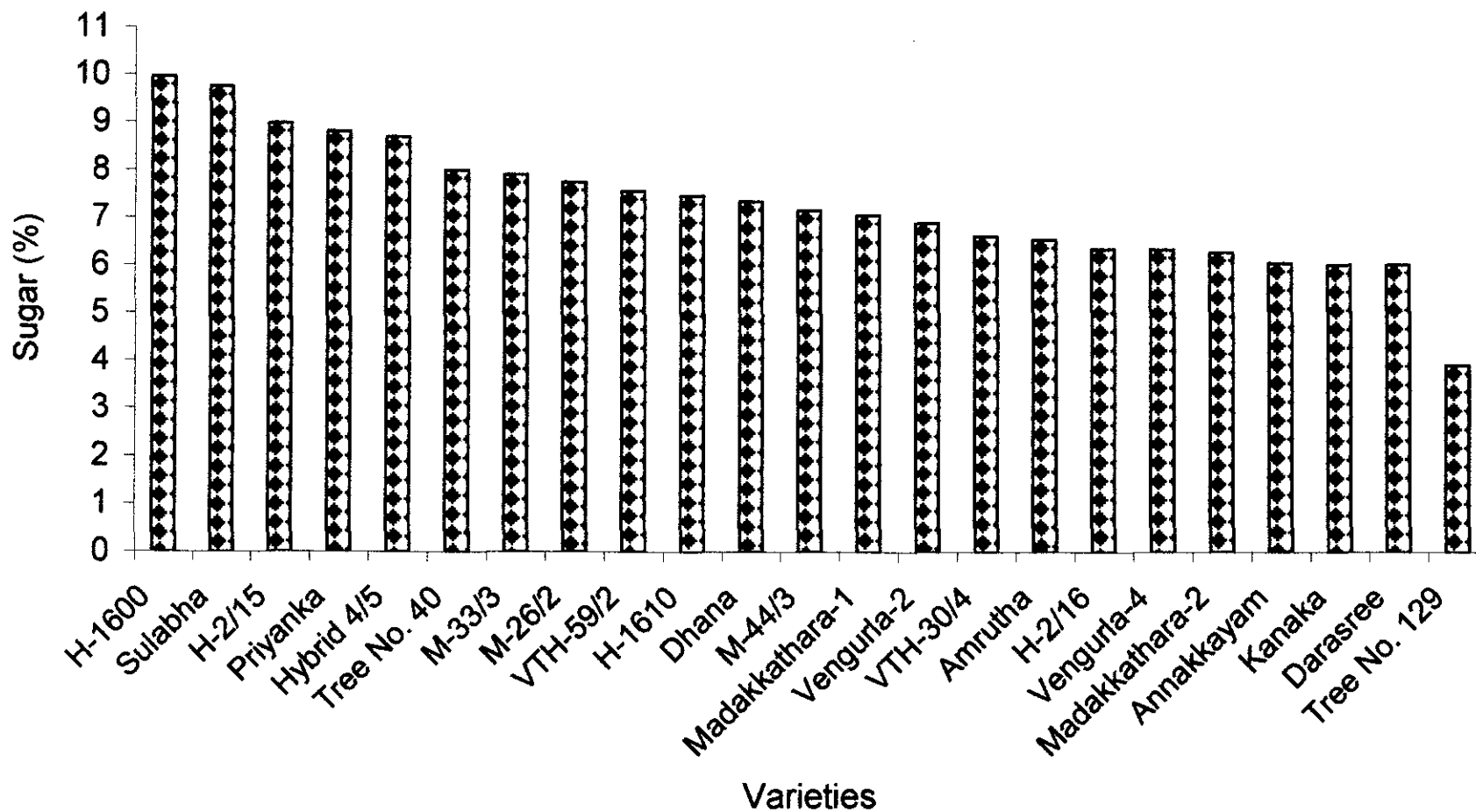


Fig. 9. Varietal variation in sugar content of cashew kernels

content were included in a separate group after processing indicating that these varieties are significantly different from all the other 22 varieties in sugar content after processing. The sugar content of kernels of different cashew varieties is shown in Fig.9.

4.2.6 Amino acid

The amino acid content of raw nut varied from 2.49 to 3.17 mg 100 g⁻¹ with a mean of about 2.83 mg. The highest and lowest values were observed in H-2/16 and H-2/15 respectively. The amino acid content after processing varied from 2.44 to 3.2 mg 100 g⁻¹. H-2/16 and Madakkathara-1 had the highest and lowest amino acid contents respectively. The mean amino acid content of kernels was found to be 2.82 mg (Table 8). Significant variation between varieties was observed with respect to amino acid content of raw nut (F value = 3.57) and kernels (F value = 5.88).

On the basis of amino acid content of the cashew varieties before processing they were grouped into 13 categories. The groups a, abcd and efg had three members each. All the other groups had one or two members.

On the basis of DMRT the cashew kernels after processing were differentiated into 9 groups. The group bcd had 6 members which are Madakkathara-2 (2.9 mg), Kanaka (2.88 mg), Tree No.40 (2.87 mg), VTH 30/4 (2.87 mg), Anakkayam (2.86 mg) and Vengurla 2 (2.85 mg). This indicated that these varieties are not significantly different from other varieties of the group in amino acid content but are significantly different from varieties included in other groups.

The amino acid content of cashew kernels is shown in Fig.10.

4.2.7 Fatty acid

The fatty acid content of cashew kernels varied from 1.91 to 3.08 per cent before processing and from 2.07 to 2.98 per cent after processing. Sulabha and

Table 8. Varietal variation in amino acid content (mg 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	2.67 ^{cdefg}	2.63 ^{def}
Anakkayam	2.94 ^{abcd}	2.86 ^{bcd}
Dhana	3.10 ^a	3.03 ^{abc}
Dharasree	2.66 ^{cdefg}	2.63 ^{def}
Kanaka	2.88 ^{abcdef}	2.88 ^{bcd}
Madakkathara-1	2.51 ^{fg}	2.44 ^f
Madakkathara-2	2.88 ^{abcdef}	2.90 ^{bcd}
Priyanka	2.97 ^{abcd}	2.96 ^{abcd}
Sulabha	2.57 ^{cfg}	2.55 ^{ef}
H-1600	2.64 ^{defg}	2.61 ^{def}
H-1610	3.07 ^{ab}	2.98 ^{abc}
H-2/15	2.49 ^g	2.47 ^f
H-2/16	3.17 ^a	3.20 ^a
Hybrid 4/5	2.96 ^{abcd}	2.93 ^{abc}
M-26/2	3.57 ^{cfg}	2.76 ^{cde}
M-33/3	3.02 ^{abc}	3.07 ^{ab}
M-44/3	3.11 ^a	3.09 ^{ab}
Tree No.40	2.91 ^{abcde}	2.87 ^{bcd}
Tree No.129	3.02 ^{ab}	2.99 ^{abc}
Vengurla 2	2.70 ^{bdefg}	2.85 ^{bcd}
Vengurla 4	2.79 ^{abcdefg}	2.80 ^{bcd}
VTH 30/4	2.89 ^{abcde}	2.87 ^{bcd}
VTH 59/2	2.55 ^{cfg}	2.53 ^{ef}
Mean ± S.E.	2.83±0.03	2.82±0.03

Values having different alphabets as superscripts are significantly different at 5% level

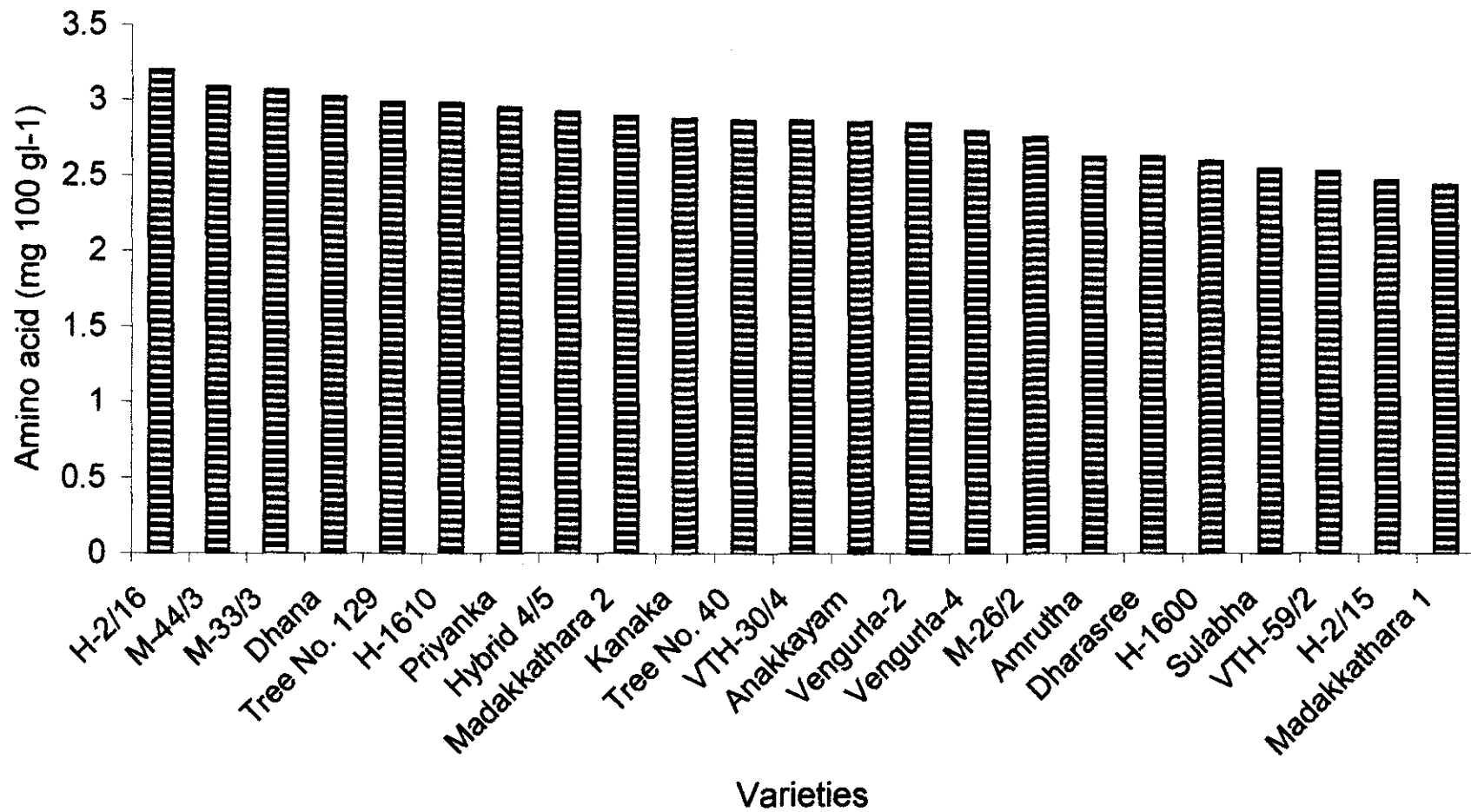


Fig. 10. Varietal variation in amino acid content of cashew kernels



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H-2/16 had the highest and lowest fatty acid content before and after processing. The mean fatty acid content of raw nuts and kernels was found to be 2.61 per cent and 2.65 per cent respectively (Table 9).

Analysis of variance indicated that there is significant variation between varieties of cashew nuts with respect to the fatty acid content (F value = 3.147) at one per cent level before processing. However, the difference in fatty acid content between varieties after processing was found to be insignificant (F value = 1.63).

On the basis of DMRT the different cashew nuts before processing were classified into 11 groups. The varieties like M-44/3 (2.88%), Vengurla-4 (2.85%), Hybrid 4/5 (2.84%), Priyanka (2.79%) and VTH 59/2 (2.72%) were included in the same group abcd. The class abcde also contained 5 members which are M-26/2 (2.69%), Kanaka (2.65%), H-2/15 (2.56%), M-33/3 (2.52%) and Madakkathara-1 (2.52%) indicating that the fatty acid content of these varieties are significantly not different from each other but different from other groups.

The cashew varieties were grouped into 3 classes statistically based on their fatty acid content after processing. The variety with the highest fatty acid content Sulabha was included along with other varieties namely Dharasree (2.97%), Vengurla-4 (2.94%), H-2/15 (2.93%), VTH-59/2 (2.86%), Priyanka (2.85%), Vengurla 2 (2.77%), Hybrid 4/5 (2.76%), Anakkayam (2.73%), H-1600 (2.70%) and Kanaka (2.69%) in a single group. The variety with lowest fatty acid content (H-2/16) was included in a separate group (b) as the sole member indicating that this variety differed significantly from all the other cashew varieties with respect to the fatty acid composition.

The fatty acid content of cashew kernels is shown in Fig.11.

4.2.8 Calcium

The calcium content of kernels ranged from 32.08 to 57.88 mg 100 g⁻¹. The highest and lowest values were observed in Madakkathara-2 and Vengurla-4

Table 9. Varietal variation in fatty acid (% oleic acid) content of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	2.34 ^{def}	2.37 ^{ab}
Anakkayam	2.45 ^{bcdel}	2.73 ^a
Dhana	2.33 ^{del}	2.50 ^{ab}
Dharasree	2.39 ^{def}	2.97 ^a
Kanaka	2.65 ^{abode}	2.69 ^a
Madakkathara-1	2.52 ^{abode}	2.54 ^{ab}
Madakkathara-2	2.13 ^{ef}	2.55 ^{ab}
Priyanka	2.79 ^{abcd}	2.85 ^a
Sulabha	3.08 ^a	2.98 ^a
H-1600	2.43 ^{bcdel}	2.70 ^a
H-1610	2.98 ^{abc}	2.65 ^{ab}
H-2/15	2.56 ^{abode}	2.93 ^a
H-2/16	1.91 ^f	2.07 ^b
Hybrid 4/5	2.84 ^{abcd}	2.76 ^a
M-26/2	2.69 ^{abode}	2.64 ^{ab}
M-33/3	2.52 ^{abode}	2.42 ^{ab}
M-44/3	2.88 ^{abcd}	2.37 ^{ab}
Tree No.40	3.00 ^{ab}	2.48 ^{ab}
Tree No.129	2.43 ^{cdel}	2.44 ^{ab}
Vengurla 2	2.99 ^{abc}	2.77 ^a
Vengurla 4	2.85 ^{abcd}	2.94 ^a
VTH 30/4	2.49 ^{bode}	2.66 ^{ab}
VTH 59/2	2.72 ^{abcd}	2.86 ^a
Mean ± S.E.	2.61±0.05	2.65±0.04

Values having different alphabets as superscripts are significantly different at 5% level

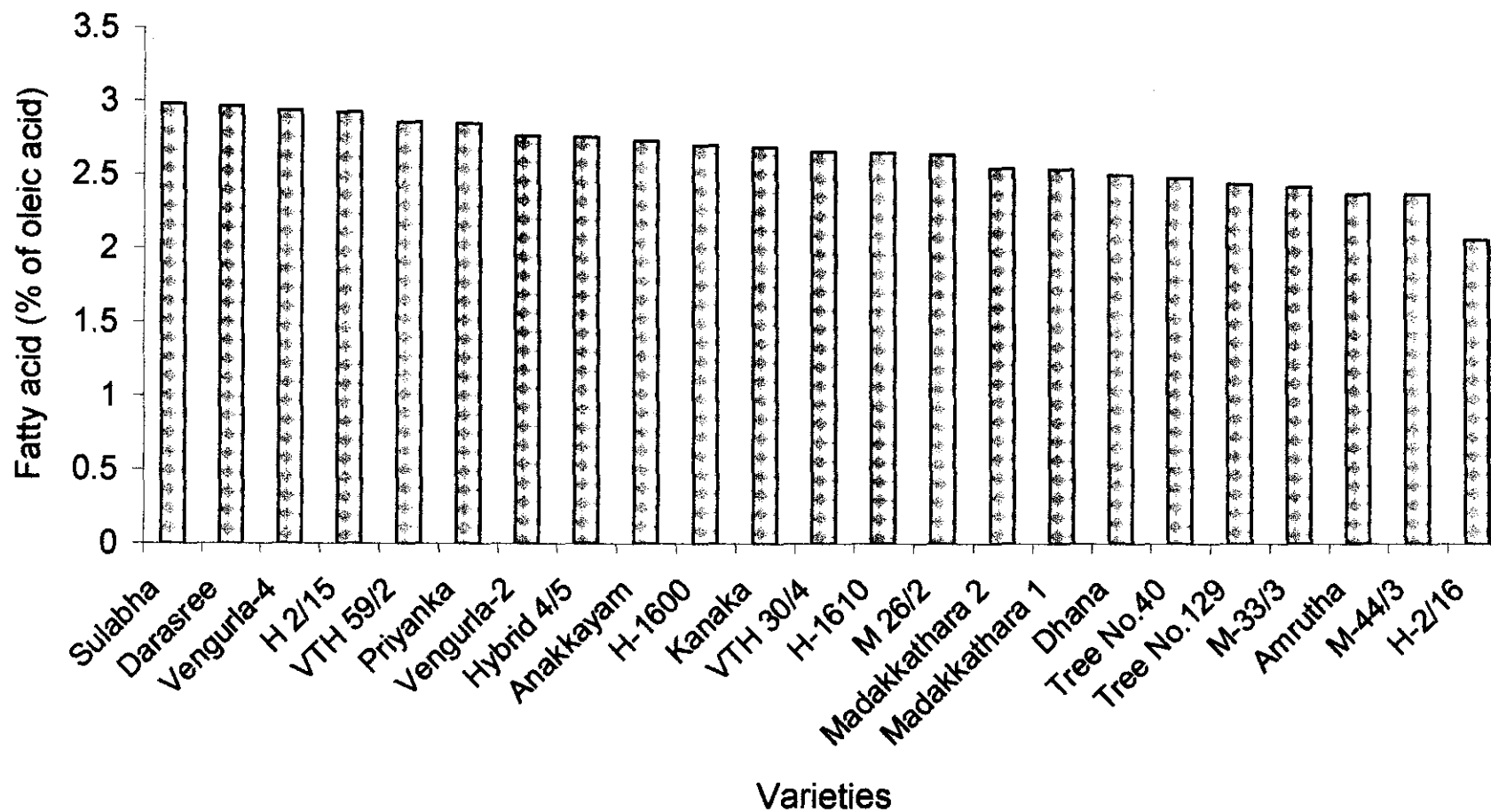


Fig. 11. Varietal variation in fatty acid content of cashew kernels

Table 10. Varietal variation in calcium content (mg 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	47.83 ^{cdef}	45.26 ^{efgh}
Anakkayam	41.95 ^{ghi}	57.83 ^{ab}
Dhana	54.08 ^{ab}	56.85 ^{abc}
Dharasree	52.33 ^{bc}	58.46 ^a
Kanaka	45.33 ^{efg}	39.20 ^{ghi}
Madakkathara-1	51.87 ^{bc}	51.67 ^{cde}
Madakkathara-2	57.88 ^a	56.96 ^{abc}
Priyanka	46.08 ^{defg}	54.32 ^{bcd}
Sulabha	47.58 ^{cdef}	50.73 ^{de}
H-1600	36.92 ^{ijk}	39.02 ^{ghi}
H-1610	36.42 ^k	42.89 ^{fgh}
H-2/15	51.97 ^{bc}	48.63 ^{def}
H-2/16	45.08 ^{efg}	49.72 ^{def}
Hybrid 4/5	40.83 ^{ghij}	52.28 ^{cde}
M-26/2	38.83 ^{hij}	44.70 ^{efgh}
M-33/3	42.67 ^{fgh}	42.89 ^{fgh}
M-44/3	45.00 ^{efg}	46.67 ^{defg}
Tree No.40	35.33 ^k	44.47 ^{efgh}
Tree No.129	49.92 ^{bode}	50.87 ^{de}
Vengurla 2	43.08 ^{fgh}	51.22 ^{de}
Vengurla 4	32.08 ^k	38.55 ^{hi}
VTH 30/4	51.00 ^{bcd}	34.40 ^f
VTH 59/2	41.08 ^{ghij}	50.00 ^{def}
Mean ± S.E.	44.92±0.85	48.7±0.98

Values having different alphabets as superscripts are significantly different at 5% level

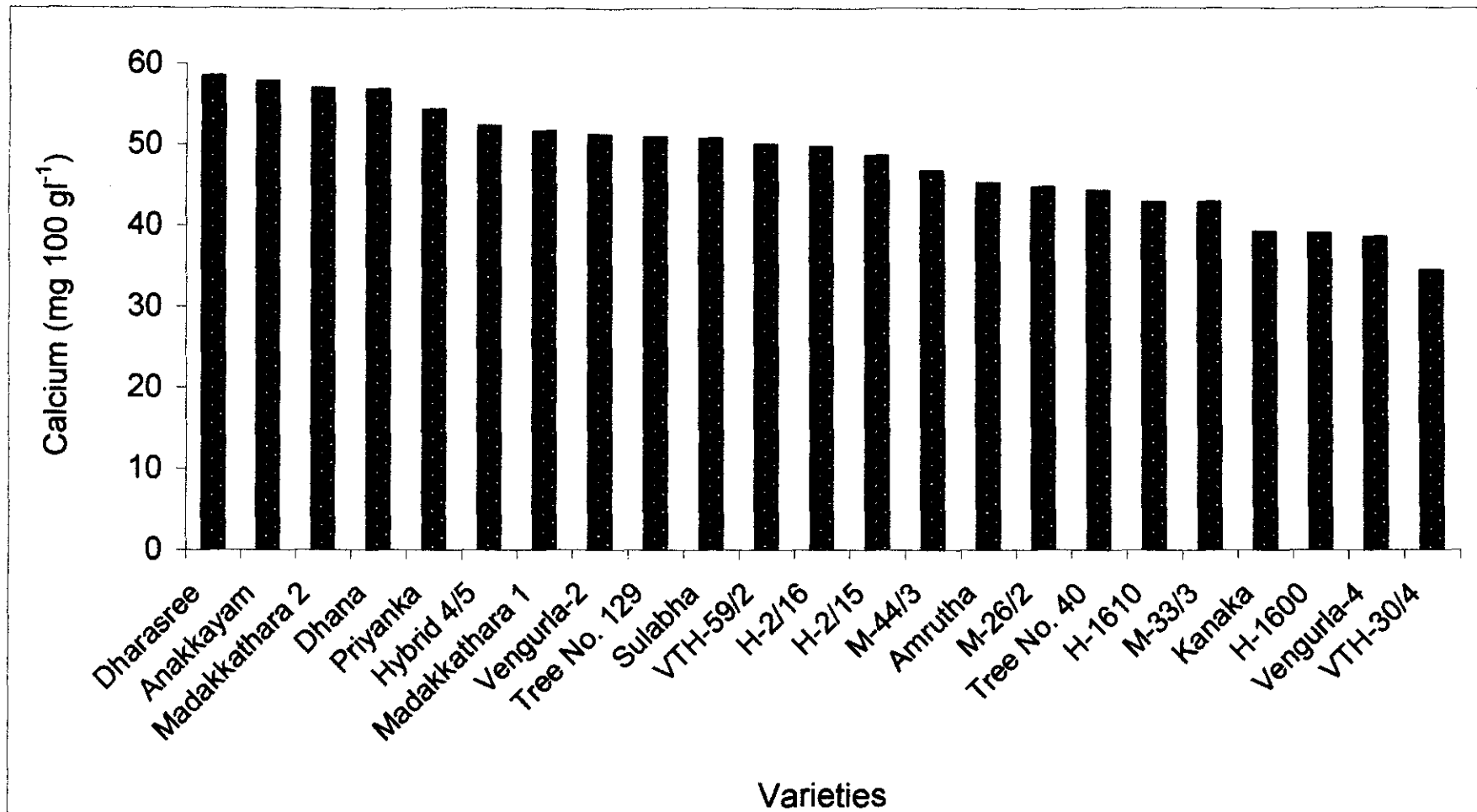


Fig. 12. Varietal variation in calcium content of cashew kernels

respectively. The calcium content after processing ranged from 34.4 to 58.46 mg 100 g⁻¹. The highest and lowest values were observed in Dharasree and VTH 30/4 respectively. The mean calcium content of raw nuts and kernels was found to be 44.92 mg and 48.7 mg respectively (Table 10).

Analysis of variance indicated significant variation within varieties before (F value = 11.497) and after (F value = 15.302) processing.

DMRT differentiated cashew varieties into 15 groups with respect to their calcium content. Madakkathara-2 was included in a separate group (a) and it differed significantly from all other varieties. Dharasree (52.33 mg), H-2/15 (51.97 mg) and Madakkathara-1 (51.87 mg) were included in the same group bc. The class efg also had three members which were Kanaka (45.33 mg), H-2/16 (45.08 mg) and M-44/3 (45 mg).

On the basis of DMRT cashew varieties after processing were classified into 13 groups with respect to their calcium content. The groups de, efgh and def had three members each. Vengurla-2 (51.22 mg), Tree No.129 (50.87 mg) and Sulabha (50.73 mg) were included in the group dc. Amrutha (45.26 mg), M-26/2 (44.7 mg) and Tree No.40 (44.47 mg) were included in the group efgh. The group def include varieties like VTH 59/2 (50 mg), H-2/16 (49.72 mg) and H-2/15 (48.63 mg). The varieties namely Madakkathara-2 and Dharasree with the highest calcium content before and after processing respectively were included as a single member in their respective groups and this indicated that the calcium content of these two varieties were significantly different from all the other varieties both before and after processing.

The calcium content of kernels of different cashew varieties is given in Fig.12.

4.2.9 Iron

The iron content of raw nuts varied from 3.3 to 5 mg 100 g⁻¹ with a mean content of 4.07 mg (Table 11). The highest and lowest values were observed in Madakkathara-1 and Vengurla-2 respectively.

The iron content of varieties of cashew kernels after processing varied from 3.42 to 4.97 mg 100 g⁻¹ with a mean content of 4.15 mg (Table 11). Highest and lowest values were observed in Sulabha and Vengurla-4 respectively.

Analysis of variance indicated that there is significant variation within varieties before (F value = 9.355) and after (F value = 6.19) processing.

Statistically the varieties were classified into 12 classes based on their iron content before processing. Most of the varieties were included in the group defg. Varieties such as M-26/2 (4.1 mg), M-44/3 (4 mg), Amrutha (3.96 mg), Vengurla-4 (3.93 mg), H-1610 (3.90 mg), H-1600 (3.93 mg) and Anakkayam (3.92 mg) were included in the same group (defg). The group a included the best three varieties namely Madakkathara-1, Madakkathara-2 and Dhana with respect to iron content. The groups efg and efgh contain three and two varieties respectively. The varieties included in the same category had no significant difference between the varieties of the same class but they were significantly different from the varieties of other classes.

On the basis of DMRT, varieties of cashew kernels were divided into 11 classes based on their iron content. Kanaka and Sulabha were categorised as the best varieties with respect to iron content and were included in category a. The groups defgh and abcd had 4 members each. The group cdefg had three members and all others have one or two varieties in each category.

The iron content of cashew kernels is shown in Fig.13.

Table 11. Varietal variation in iron content (mg 100 g⁻¹) of raw nuts and kernels

Varieties	Raw nuts	Kernels
Amrutha	3.96 ^{defg}	3.86 ^{defgh}
Anakkayam	3.92 ^{defg}	4.03 ^{cdetg}
Dhana	4.83 ^a	4.76 ^{ab}
Dharasree	3.82 ^{efg}	4.20 ^{bodef}
Kanaka	3.82 ^{efg}	4.96 ^a
Madakkathara-1	5.00 ^a	4.42 ^{abcd}
Madakkathara-2	4.86 ^a	4.36 ^{bcd}
Priyanka	4.36 ^{bcd}	4.09 ^{cdetg}
Sulabha	4.78 ^{ab}	4.97 ^a
H-1600	3.93 ^{defg}	4.50 ^{abc}
H-1610	3.90 ^{defg}	4.40 ^{abcd}
H-2/15	4.06 ^{def}	4.20 ^{bodef}
H-2/16	3.76 ^{efgh}	3.92 ^{defgh}
Hybrid 4/5	3.56 ^{lgh}	3.56 ^{gh}
M-26/2	4.10 ^{defg}	4.44 ^{abcd}
M-33/3	3.80 ^{efg}	4.07 ^{cdetg}
M-44/3	4.00 ^{defg}	4.43 ^{abcd}
Tree No.40	4.53 ^{abc}	3.83 ^{defgh}
Tree No.129	3.52 ^{gh}	3.50 ^{gh}
Vengurla 2	3.30 ^h	3.73 ^{lgh}
Vengurla 4	3.93 ^{defg}	3.42 ^h
VTH 30/4	4.13 ^{cde}	3.76 ^{lgh}
VTH 59/2	3.70 ^{efgh}	3.83 ^{defgh}
Mean ± S.E.	4.07±0.06	4.15±0.06

Values having different alphabets as superscripts are significantly different at 5% level

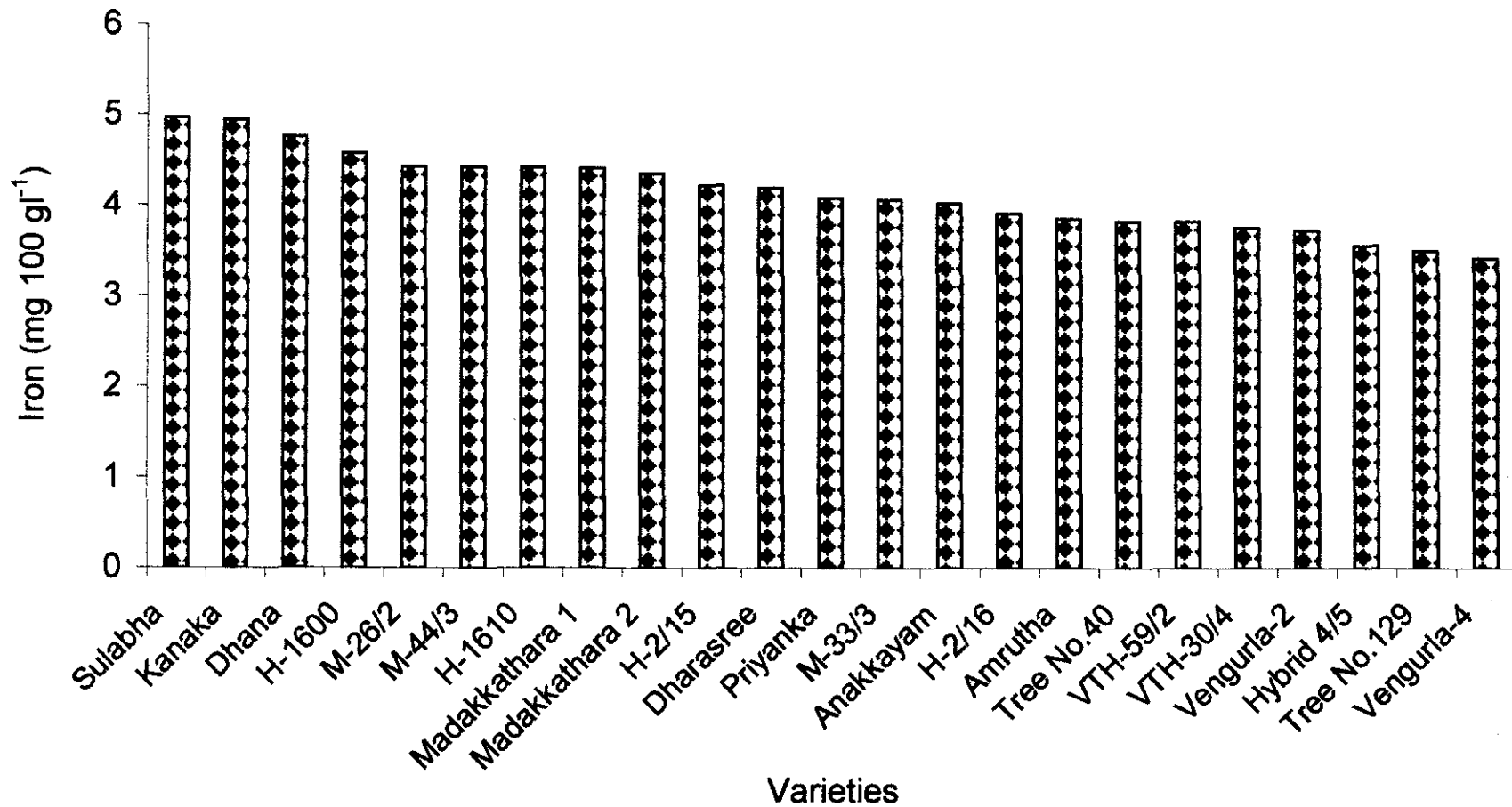


Fig. 13. Varietal variation in iron content of cashew kernels

4.2.10 Phosphorus

The phosphorus content varied from 411.8 mg in H-2/15 to 460.9 mg 100 g⁻¹ in Tree No.40 before processing. The phosphorus content of cashew kernels after processing varied from 408.4 mg to 460 mg 100 g⁻¹. The mean phosphorus content of raw nuts and kernels was found to be 433.04 and 431.73 respectively (Table 12). The highest and lowest values were observed in Tree No.40 and Anakkayam respectively.

Analysis of variance indicated that there is no significant variation between varieties with respect to their phosphorus content both before (F value = 1.581) and after (F value = 1.645) processing.

DMRT classified varieties into 5 groups on the basis of phosphorus content. The group abc harboured the highest number (16) of varieties followed by the group c with 4 members namely Vengurla-4 (413.7 mg), M-26/2 (412.5 mg), Anakkayam (412.2 mg) and H-2/15 (411.8 mg). The 16 varieties included in group abc differed significantly from the other 4 groups in phosphorus content before processing.

After processing also the cashew varieties were categorised into 4 groups with group abc having the highest number of varieties (15) followed by group bc with 6 varieties. Tree No.40 and Anakkayam were given under separate groups a and c respectively.

The phosphorus content of cashew kernels of different varieties is shown in Fig.14.

4.3 Processing characters of cashew kernels

The processing characters like kernel weight, shelling percentage, percentage yield of whole kernels and kernel count of the selected samples were evaluated and the results are given in Table 13.

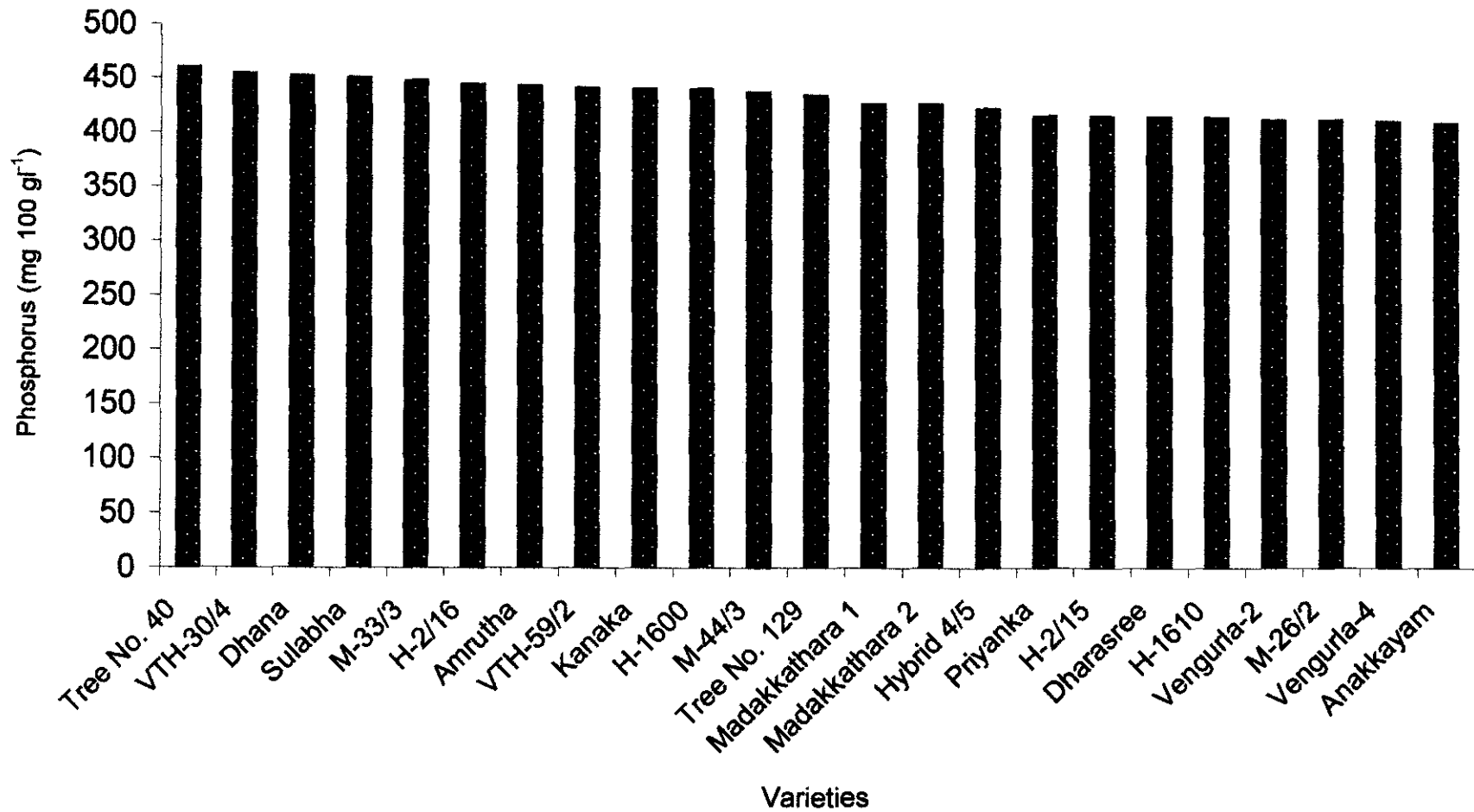


Fig. 14. Varietal variation in phosphorus content of cashew kernels

4.3.1 Kernel weight

The kernel weight after processing ranged from 1.21 g in M-33/3 to 2.46 g in Priyanka with a mean weight of 1.76 (Table 13).

Analysis of variance indicated that there is significant variation between the varieties with respect to their kernel weight (F value = 278.7) at one per cent level.

Statistically the different cashew varieties were differentiated into 14 classes based on their kernel weight after processing. The classes j and i had four members each. The group a had only one member namely Prinyanka (2.46 g) which was found to be significantly different from all other varieties with respect to kernel weight. H-1610 (2.10 g), H-2/15 (2.07 g) and VTH-59/2 (2.06 g) were included in the same group c.

The kernel weight of different cashew varieties is shown in Fig.15.

4.3.2 Shelling percentage

The shelling percentage of kernels varied from 19.17 to 32.37 per cent with a mean value of 24.45 (Table 13). The highest and lowest values were observed in Madakkathara-1 and VTH-30/4 respectively.

Analysis of variance indicated significant difference between cashew varieties with respect to their shelling percentage (F value = 11.352) at one per cent level.

On the basis of Duncan's Multiple Range Test the different varieties were divided into 11 classes. The groups bc, defg and gh had four members each. Madakkathara-1 was found to be the best variety and included as a single member of the group which was found to be significantly different from all other varieties

Table 13. Varietal variation in processing characters of cashew kernels

Varieties	Kernel weight (g)	Shelling percentage	Percentage yield of whole kernels	Kernel count
Amrutha	1.63 ^l	27.53 ^{bc}	90.00 ^{cd}	277 ^{ef}
Anakkayam	1.63 ^l	27.73 ^{bc}	73.00 ^h	276 ^f
Dhana	1.86 ^d	23.53 ^{defg}	95.30 ^{ab}	244 ^j
Dharasree	1.52 ^j	28.00 ^b	74.30 ^h	298 ^c
Kanaka	1.51 ^j	26.10 ^{bode}	79.33 ^g	300 ^c
Madakkathara-1	2.27 ^b	32.37 ^a	90.67 ^{cd}	194 ^l
Madakkathara-2	1.70 ^h	22.16 ^{fgh}	96.33 ^a	266 ^g
Priyanka	2.46 ^a	24.67 ^{odef}	89.00 ^{ode}	184 ^m
Sulabha	1.51 ^j	26.97 ^{bc}	79.00 ^g	302 ^c
H-1600	1.77 th	24.86 ^{odef}	86.67 ^{def}	255 ^h
H-1610	2.10 ^c	23.50 ^{defg}	86.67 ^{def}	216 ^k
H-2/15	2.07 ^c	21.30 ^{gh}	90.00 ^{cd}	219 ^k
H-2/16	1.87 ^d	23.70 ^{defg}	88.00 ^{ode}	242 ^j
Hybrid 4/5	1.83 ^{de}	26.53 ^{bod}	85.33 ^{ef}	247 ^{ij}
M-26/2	1.80 ^{ef}	21.27 ^{gh}	87.00 ^{de}	261 ^{hi}
M-33/3	1.21 ^l	21.25 ^{gh}	90.00 ^{cd}	372 ^a
M-44/3	1.41 ^k	26.5 ^{bod}	92.00 ^{bc}	321 ^b
Tree No.40	1.58 ^l	27.15 ^{bc}	87.30 ^{de}	287 ^d
Tree No.129	1.51 ^j	19.93 ^h	90.00 ^{cd}	299 ^e
Vengurla 2	1.59 ^l	23.33 ^{efg}	90.33 ^{cd}	284 ^{de}
Vengurla 4	1.82 ^{def}	21.36 ^{gh}	88.00 ^{ode}	249 ^{hij}
VTH 30/4	1.72 ^{gh}	19.17 ^h	85.33 ^{ef}	263 ^g
VTH 59/2	2.06 ^c	23.5 ^{defg}	83.00 ^f	219 ^k
Mean ± S.E.	1.76±0.03	24.45±0.41	86.81±0.72	263±5

Values having different alphabets as superscripts are significantly different at 5% level

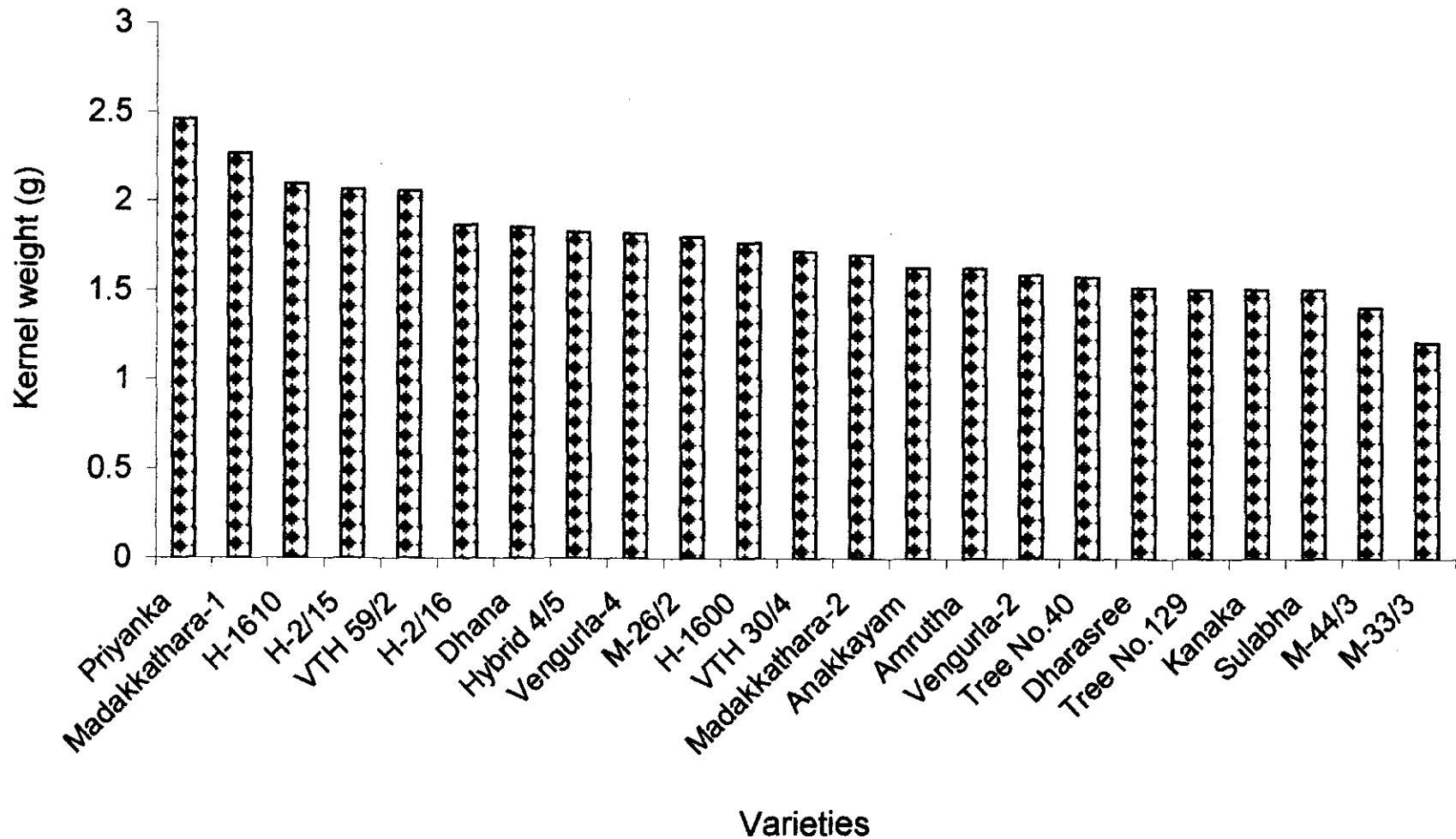


Fig. 15. Varietal variation in kernel weight

with respect to shelling percentage. Hybrid 4/5 (26.53%) and M-44/3 (26.5%) were included in the same group bcd. H-1600 (24.86%) and Priyanka (24.67%) were also included in the same group cdef.

The shelling percentage of varieties of cashew kernels is given in Fig.16.

4.3.3 Percentage yield of whole kernels

The percentage yield of whole kernels varied from 73 to 96.33. The mean percentage yield was 86.81. The highest yield of cashew kernels after processing was noticed in Madakkathara-2 and the lowest in Anakkayam (Table 13).

Analysis of variance indicated significant difference between the varieties with respect to their percentage yield of whole kernels (F value = 23.5) at one per cent level.

Statistically the cashew nuts were divided into eleven classes. The class cd had the maximum number (6) of varieties namely Madakkathara-1, Amrutha, H-2/15, Tree No.129, M-33/3 and Vengurla-2. The groups de, def, ef, g and h contained two members each. Priyanka (89%), Vengurla-4 (88%) and H-2/16 (88%) were included in the same group cde which showed that the yield of cashew kernels in these three varieties after processing were similar and they differed significantly from the varieties included in other groups.

The percentage yield of whole kernels of cashew varieties is shown in Fig.17.

4.3.4 Kernel count

The kernel count of cashew varieties varied from 184 to 372 with a mean kernel count of 263 (Table 13). The highest and lowest values were observed in M-33/3 and Priyanka respectively.

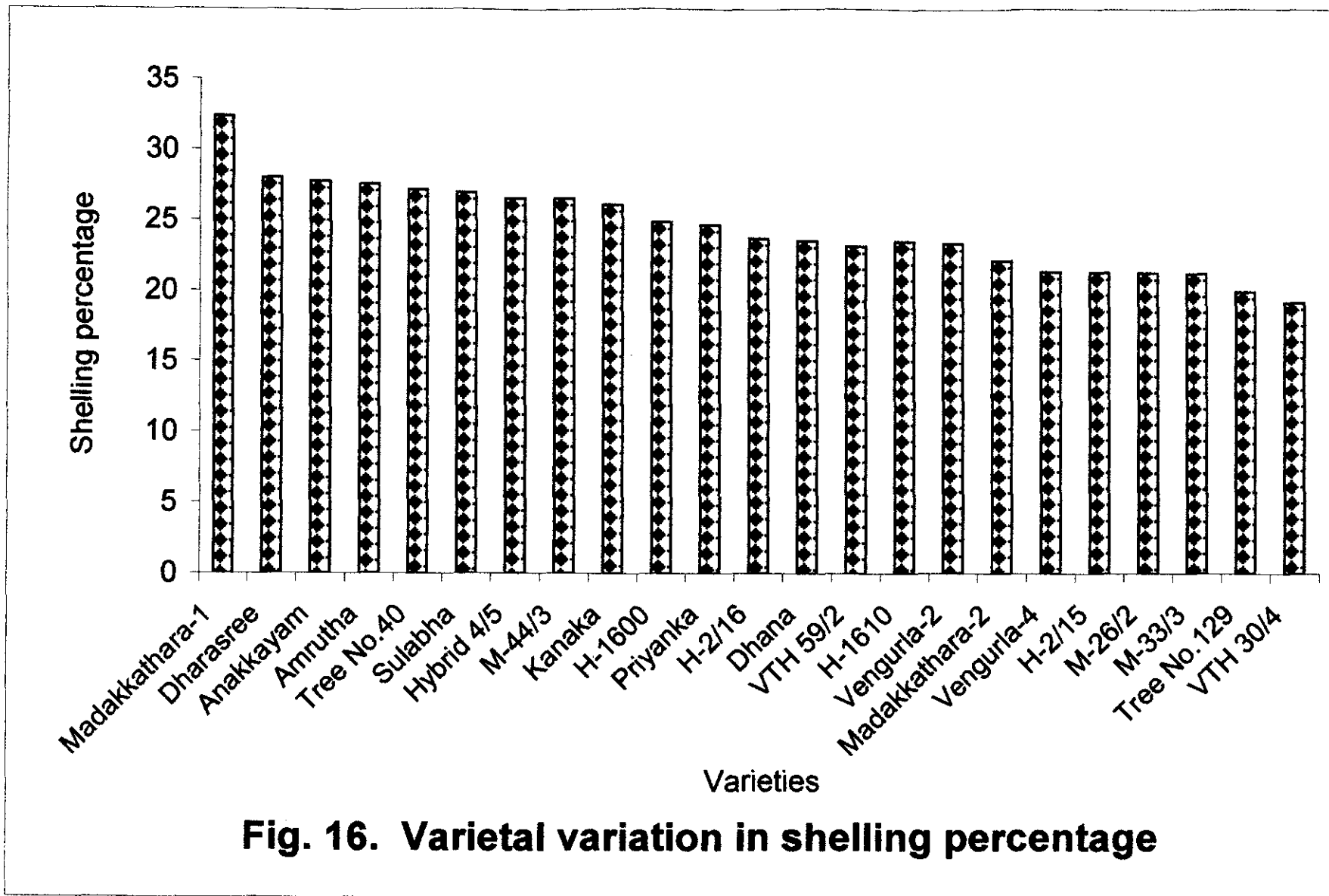


Fig. 16. Varietal variation in shelling percentage

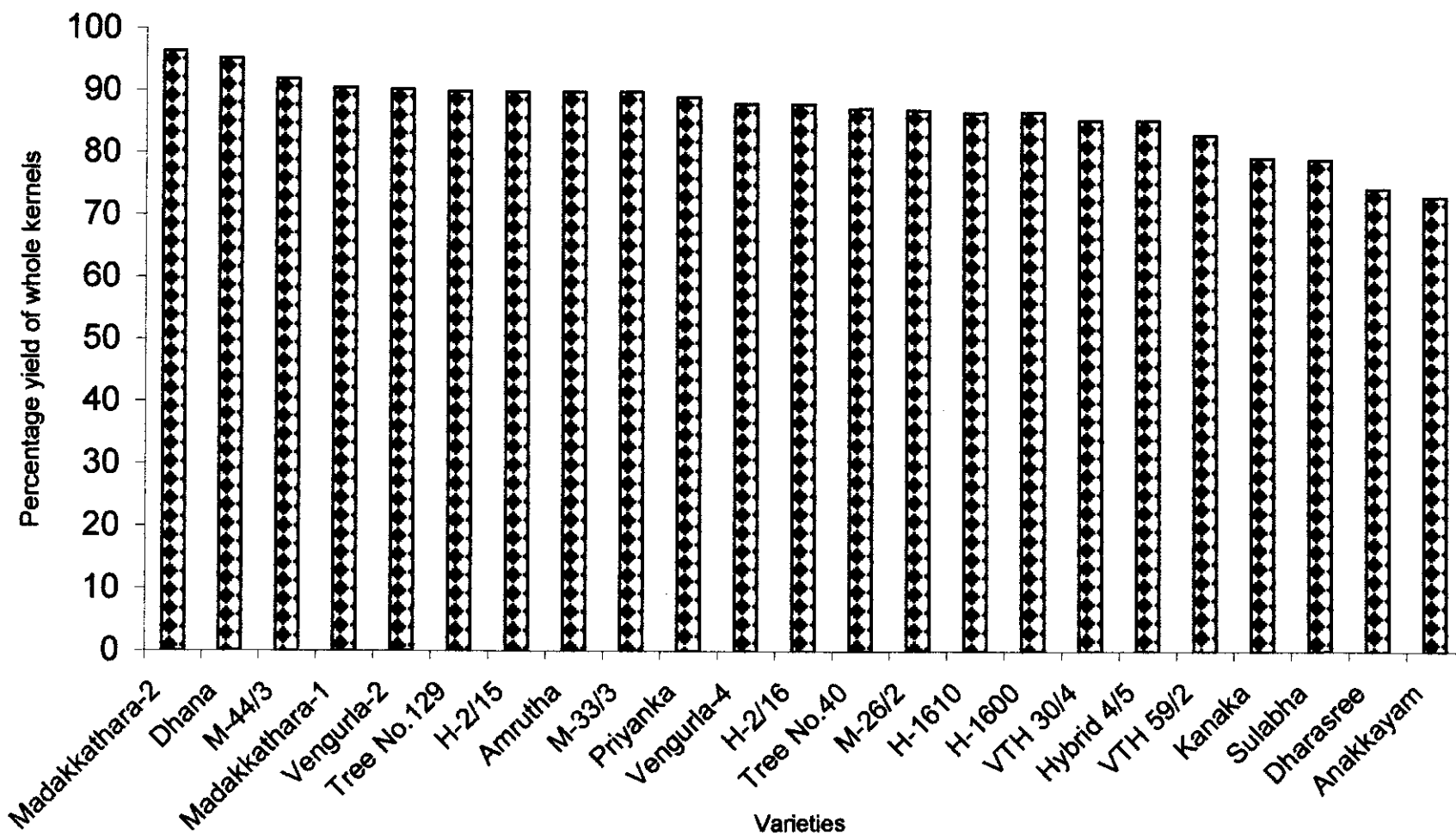


Fig. 17. Varietal variation in percentage yield of whole kernels

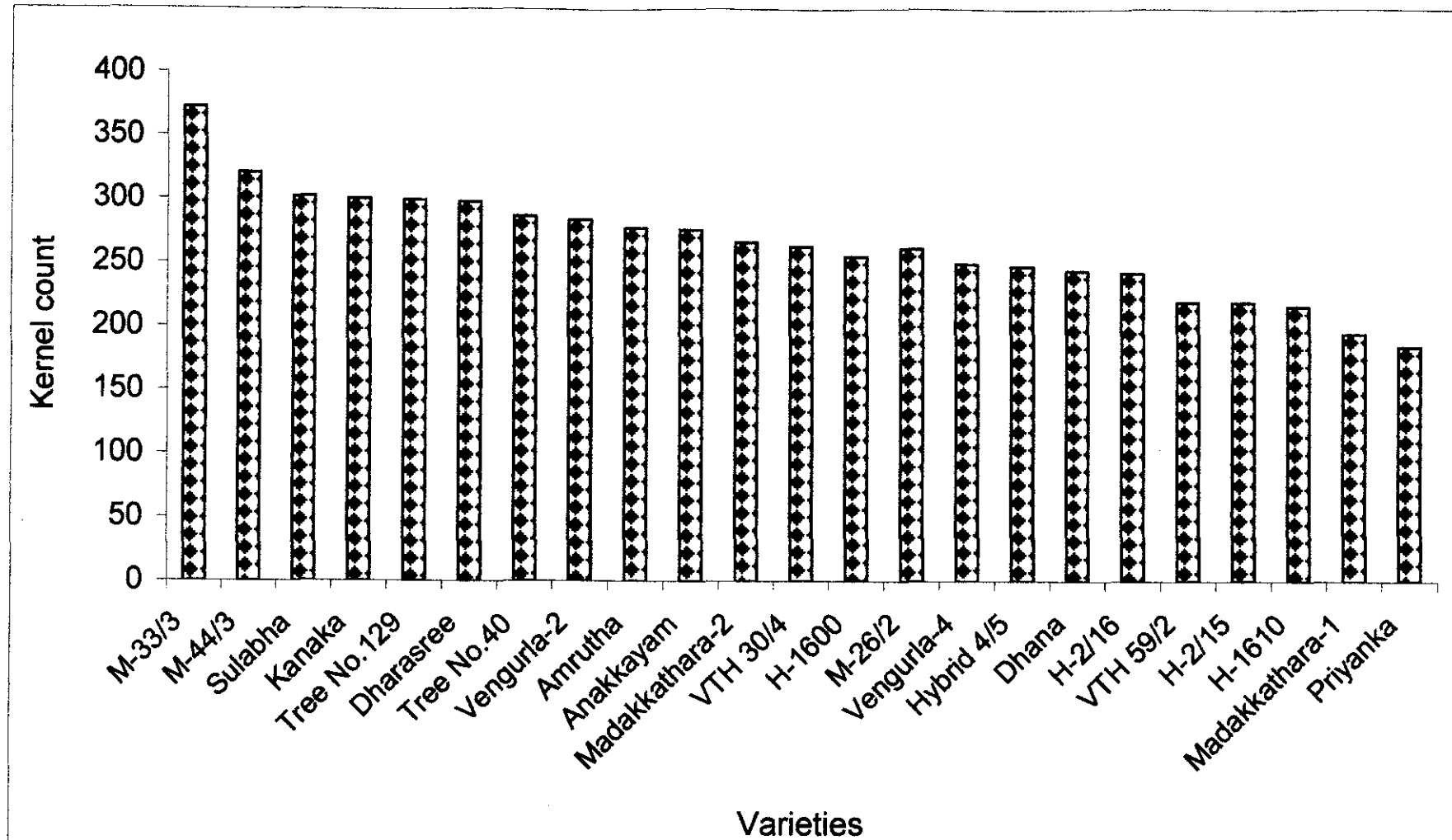


Fig. 18. Varietal variation in kernel count

Analysis of variance indicated significant variation between the varieties with respect to their kernel count (F value = 346.31) at one per cent level.

According to DMRT, the different cashew varieties were divided into sixteen classes with respect to their kernel count. The class c had four members which are Sulabha (302), Kanaka (300), Tree No.129 (299) and Dharasree (298). The group k had three members which are VTH-59/2 (219), H-2/15 (219) and H-1610 (216). All other groups had two or less than two members.

The kernel count of different varieties is shown in Fig.18.

4.4 Comparison of nutrients of raw nuts and kernels

Nutritional composition of raw nuts and kernels were compared using paired 't' test (Table 14). The difference was found to be not significant in all nutrients except in the case of calcium. Calcium content was found to be increased during processing.

4.5 Cluster analysis of cashew nuts

Hierarchical Euclidean Cluster Analysis was carried out to find out the homogeneous groups of cashew nuts.

Based on the physical characters cashew nuts were grouped into three clusters as shown below (Fig.19).

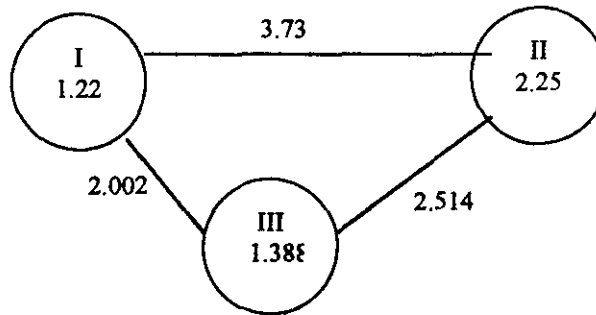
Table 14. Comparison of nutrients of raw nuts and kernels

Parameter	Mean value		t value	Significance
	Raw nut	Kernel		
Moisture (g 100 g ⁻¹)	7.04	7.14	-0.485	NS
Protein (g 100 g ⁻¹)	21.26	21.1	-1.15	NS
Fat (g 100 g ⁻¹)	43.75	44.13	-1.450	NS
Carbohydrate (g 100 g ⁻¹)	20.62	20.45	0.639	NS
Sugar (g 100 g ⁻¹)	7.25	7.29	-0.186	NS
Amino acid (mg 100 g ⁻¹)	2.83	2.82	0.470	NS
Fatty acid (% oleic acid)	2.61	2.65	-0.689	NS
Calcium (mg 100 g ⁻¹)	44.92	48.7	1.89	S
Iron (mg 100 g ⁻¹)	4.07	4.15	-1.261	NS
Phosphorus (mg 100 g ⁻¹)	433.04	431.73	0.884	NS

NS : Not Significant

S : Significant

Fig. 19. Cluster analysis of cashew nuts based on physical characters



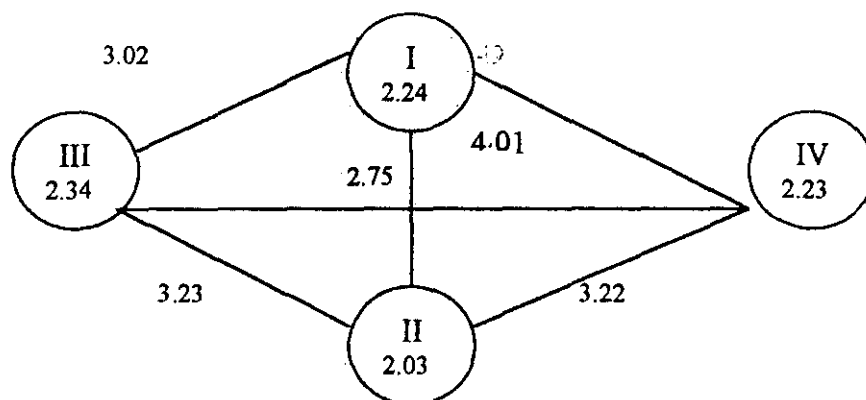
- Cluster I - Anakkayam, Madakkathara-2, Sulabha, Dharasree, Priyanka, Tree No.40, VTH 30/4, VTH 59/2, M-33/3, M-44/3, H-2/16
- Cluster II - Kanaka, Dhana, H-1600, H-2/15, Hybrid 4/5
- Cluster III - Amrutha, Madakkathara-1, H-1610, Tree No.129, Vengurla-4, Vengurla-2, M-26/2

The members of cluster I were high in length breadth and thickness. Among the members of cluster I length of nut varied from 2.96 - 4.5 cm with a mean length of 3.77 cm. Cluster mean for breadth was 2.55 cm which varied from 2.14 - 2.96 cm among the members. Thickness of nut varied from 17.51 - 21.65 mm with a cluster mean of 19.63 mm.

Cluster II members were found to be high in nut weight. Cluster mean for nut weight was 7.75g which varied from 4.24 to 11.4 g among the members.

Based on the nutritional composition cashew kernels were grouped into four clusters (Fig. 20).

Fig. 20. Cluster analysis of cashew kernels based on nutritional characters



Cluster - I Dhana, Amrutha, H-2/16, Tree No:129, Tree No:40, M-44/3, M-26/2

Cluster - II Dharasree, H-1600, M-33/3

Cluster - III Anakkayam, Madakkathara - 1, Sulabha, H-2/15, VTH 30/4, VTH 59/2, Hybrid 4/5

Cluster - IV Madakkathara - 2, Kanaka, Priyanka, H-1610, Vengurla - 2, Vengurla - 4.

The members of cluster I were high aminoacid and phosphorus. The cluster mean for aminoacid was 2.93 mg. Within the cluster aminoacid content varied from 2.63 to 3.2 mg. Cluster mean for phosphorus was 440.74 mg which varied from 411.6 to 460 mg $100g^{-1}$ among the cluster members.

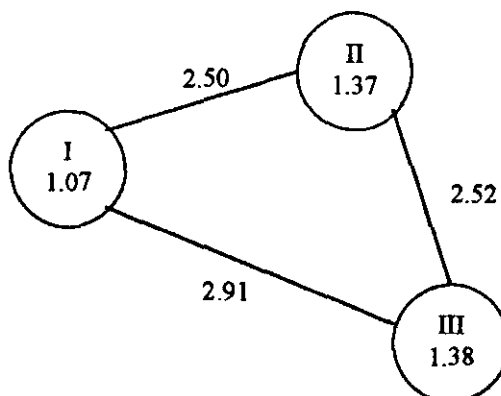
The members of cluster II were high in fat, iron and sugars. Cluster mean for sugar in cluster II was 7.96 per cent with a variation of 6.03 to 9.96 per cent among the cluster members. The fat content of members of cluster II was in between 43.83 per cent and 47.17 per cent with a cluster mean of 45.52 per cent. Cluster mean for iron content 4.26 mg which varied from 4.07 to 4.5 mg.

Moisture, protein, carbohydrate and fatty acid were found to be highest in cluster III. Carbohydrate content varied from 17.18 per cent to 23.26 per cent among the members with a cluster mean of 20.59 per cent. Cluster mean for protein was 21.36 per cent which varied from 20.49 to 21.96 per cent within the

cluster members. The lowest and highest values for fatty acid were 2.54 and 2.98 per cent respectively with a cluster mean of 2.79 per cent. Moisture was found to be high in cluster III with a variation of 8.03 per cent to 6.76 per cent. Cluster mean for moisture was 7.5 per cent.

Based on the processing characters cashew kernels were grouped into 3 clusters (Fig.21).

Fig. 21. Cluster analysis of cashew kernels based on processing characters



Cluster I - Dhana, Amrutha, Sulabha, H-2/16, Tree No.40, VTH-30/4, M-26/2

Cluster II - Anakkayam, Madakkathara-1, Kanaka, Priyanka, Dharasree, H-1600, H-2/15, Tree No.129, Hybrid 4/5, M-33/3, M-44/3

Cluster III - Madakkathara-2, H-1610, VTH 30/4, Vengurla-2, Vengurla-4

The members of cluster II were high in shelling percentage of kernels. Shelling percentage of kernels varied from 19.93 to 32.37 among the cluster members with a cluster mean of 25.39.

Cluster III members were found to be high in percentage yield of whole kernels, kernel weight and low in kernel count. Cluster mean for percentage yield was 89.33 with a variation of 85.33 to 96.33 among the members. Kernel weight of members of cluster III varied from 1.59 g to 2.19 g with a mean weight of 1.79. Cluster mean for kernel count was 263 which varied from 216 to 284 among the members.

Discussion

DISCUSSION

The study on “Quality evaluation of kernels of different cashew varieties” was attempted to assess the nutritional composition of cashew kernels before and after processing and physical and processing characters of cashew nuts.

The kernels of selected cashew varieties were analysed for different nutrients such as moisture, protein, fat, carbohydrate, sugar, fatty acid, free amino acid, calcium, iron and phosphorus. The physical characters like weight, length, breadth, thickness and processing characters like kernel weight, percentage yield of whole kernels, shelling percentage and kernel count of the varieties were evaluated. The results of the study are discussed under the following heads.

- 5.1 Physical characters of cashew nuts
- 5.2 Nutritional composition of cashew kernels before and after processing
- 5.3 Processing characters of cashew kernels
- 5.4 Cluster analysis of cashew varieties

5.1 Physical characters of cashew nuts

The weight of nuts varied from 4.24 g to 11.4 g. H-1600 has got the highest value and it differed significantly from other varieties with respect to weight. Hybrid 4/5 was the smallest among the varieties. Priyanka stands second among varieties which had a nut weight of 10.8g. The values were similar to the reported values of Nandini and James (1985), Nalini and Santhakumari (1991) Swamy and Mohan (1991), Manoj *et al.* (1994) and Salam (1998). K.A.U (1995) observed a nut weight of 10.8g per nut which was similar to the present values.

Among the cashew nut varieties, M-33/3 has got the highest value for length. Tree No.40 has got the lowest value.

The length of cashew nuts varied from 2.96 cm to 4.5 cm. There is significant variation between varieties with respect to length. Vengurla-2, Kanaka, Madakkathara-1 and Amrutha had similar nut length. The length of varieties such as Tree No.129 and M-26/2, Anakkayam and Madakkathara-2 and M-44/3 and Sulabha were found to be almost similar. Veeraraghavan *et al.* (1991) reported a nut length of 2.98 cm and 3.12 cm for Madakkathara-1 and Madakkathara-2 respectively. This is lower than the values observed in the present study.

The breadth of cashew nuts varied from 2.14 cm to 3.04 cm. Priyanka has got the highest and VTH 59/2 has got the lowest. There is significant variation between varieties with respect to breadth. The breadth was found to be similar among varieties such as Dhana, M-26/2 and H-1600 and Vengurla-2, Anakkayam and Amrutha. Nalini *et al.* (1994a) reported a slightly lower value for breadth of nuts.

The varieties H-2/15 and Hybrid 4/5 has got the highest and lowest values for thickness respectively.

The values varied from 17.19 to 22.01 mm. H-2/15 differed significantly from others except H-2/16, VTH 59/2 and M-44/3. The breadth of varieties such as Kanaka, Madakkathara-2, M-26/2, H-1610, and Madakkathara-1 were found to be almost similar.

5.2 Nutritional composition of kernels before and after processing

The moisture content of cashew nuts ranged from 4.9 per cent to 7.9 per cent before processing and from 4.78 to 8.03 per cent after processing. The moisture content of cashew nuts before processing was found to be in accordance with the values reported by Gopalan *et al.* (1989), Saleem *et al.* (1991), Minifie (1997), Melo *et al.* (1998) and Jisha *et al.* (1999). Lal (1997) reported a little lower moisture content for cashew nuts which was about 2.94 per cent. According to

Shivasankar *et al.* (1998) raw cashew nut contained about 17-20 percent of moisture which is greater than the values obtained from the findings.

Cashew nuts of different varieties differed significantly in moisture content before and after processing but the variation between two stages of processing was found to be insignificant. The moisture content of H-2/15, Tree No:40, Anakkayam, Vengurla 2, Vengurla-4, Hybrid 4/5 and Dharasree were found to be almost similar before processing. M-26/2 differed significantly from all other varieties with respect to moisture content after processing. The moisture content of VTH 59/2, H-1600 and Madakkathara-1 were found to be similar after processing. H 2/15 and Vengurla-4, Hybrid 4/5 and M-33/3; had almost similar moisture content after processing. There is no significant difference in the moisture content between Madakkathara-1, Madakkathara-2, Sulabha and Dharasree before and after processing.

H-2/16, which had a protein content of 22.31 per cent was found to be the best among 23 cashew varieties with respect to their protein content before processing. This variety differed significantly from all other varieties in its protein content. The protein content of cashew nuts ranged from 19.69 per cent to 22.31 before processing. These values are in accordance with the values reported by Mohapatra *et al.* (1972), Gopalan *et al.* (1989), Mahendru (1990 a), Soman (1990), Manoj *et al.* (1994) Kumar (1998) and Srilakshmi (1999). The values were found to be slightly greater than the values reported by Panda and Pal (1993) and slightly lower than the values of Nagaraja and Nampoothiri (1986) and Aravindakshnan *et al.* (1986). This may be due to the varietal difference.

There is significant variation between varieties both before and after processing with respect to protein content. Mohapatra *et al.* (1972), Nagaraja and Nampoothiri (1986), Aravindakshan *et al.* (1986), also reported variation between cashew varieties based on their protein content.

The protein content of Tree No:129 Dhana, VTH 30/4, and Anakkayam were found to be almost similar before processing. Cashew varieties such as VTH 59/2 and H-1610; Amrutha and H-2/15 as well as Vengurla 3 and Sulabha had almost similar protein content and they differed from all other varieties. The protein content of Madakkathara-2, Hybrid 4/5, M-33/3 and Kanaka was found to be significantly different from each other and from all other varieties. After processing, the protein content of cashew nuts ranged from 19.32 per cent to 22.11 per cent. H-2/16 with the highest protein content after processing differed significantly from all the other varieties except M-33/3. Tree No.129, Madakkathara-1, Hybrid 4/5, VTH 59/2 and Amrutha had almost similar protein contents before and after processing.

The fat content of cashew nuts ranged from 40.27 per cent to 46.77 per cent before processing and from 40.23 per cent to 47.17 per cent after processing. The values obtained are in accordance with that reported by Murthy and Yadav (1972), Joseph (1978), Gopalan *et al.* (1989), Mahendru (1990a), Soman (1990), Kumar (1998), Narayanan (1998) and Jisha *et al.* (1999). However Arogba (1999) reported a slightly greater value (51%) than those obtained in the present findings. This difference may be accounted for the difference in the varieties.

Dharasree was found to be the best with respect to fat content before processing and had the fat content similar to H-1600. They differed significantly from other varieties in their fat content. The fat content of M-26/2, H-2/15, Kanaka and M-44/3, before processing were found to be similar and different from the values of other varieties.

There is significant variation between varieties in their fat content after processing also. The variety with highest fat content after processing namely H-1600 was grouped as a single entity and differed significantly from all other varieties with respect to fat content. While analyzing nuts after processing it was found that VTH 30/4, M-26/2, VTH 59/2, H-1610, M-33/3 and Dhana had similar

fat content and differed significantly from all other varieties. The variety Anakkayam had a fat content of 40.23 per cent which was the lowest and it differed significantly from all other varieties.

The fat content of M-26/2, M-44/3 Vengurla 3, Madakkathara-1, Tree No.40, Vengurla 2, Anakkayam, H-1610 and Tree No:129 were found to be almost similar before and after processing.

The carbohydrate content of 23 varieties varied from 17.69 to 24.02 per cent before processing and from 17.18 to 23.26 per cent after processing. The values are in accordance with that reported by Mahendru (1990a), Soman (1990) and Narayanan (1998). Among the varieties Anakkayam with a carbohydrate content of 24.02 per cent and 23.26 per cent was found to be the best with respect to carbohydrate content before and after processing and it differed significantly from all other varieties. The variety Madakkathara-1 had the lowest carbohydrate content before and after processing. H-1610 and Priyanka; VTH 30/4 and Tree No:129; Madakkathara-2 and Vengurla 2; VTH 59/2 and Dharasree, H-2/16 and Kanaka; M-33/3 and Amrutha were similar in their carbohydrate content before processing.

After processing, the carbohydrate content of M-26/2, H-2/16, Hybrid 4/5, Amrutha, VTH 30/4 and H-1600 were found to be almost similar. The varieties such as Madakkathara-2 H-2/15, M-33/3, M-44/3, VTH 59/2, and H-1610 also contained similar amounts of carbohydrates. Madakkathara-1, Priyanka, Dharasree, H-2/15, Tree No:129, Tree No:40, and M-26/2 contained almost similar amounts of carbohydrates before and after processing.

Wide variation in sugar content was observed in cashew varieties before and after processing. It varied from 4.81 to 10.15 per cent before processing and from 3.91 to 9.96 per cent after processing. These observations were found to be almost similar to the values reported by Murthy and Yadav (1972) Nagaraja and

Nampoothiri (1986) and Melo *et al.* (1998). In contrast to the findings of the study Mahendru (1990b) and Narayanan (1998) reported less than 1 per cent of soluble sugars in cashew nuts. Sulabha was found to be the best variety with the highest sugar content before processing and it differed significantly from all other varieties.

VTH 30/4, VTH 59/2 and Tree No.40 contained almost similar amounts of sugar before processing Tree No.129 had the lowest sugar content before and after processing and they differed significantly from all other varieties during both stages of processing. The highest sugar content was observed in H-1600 with a significant difference from other varieties. Varieties such as H-1610, M-33/3, M-44/3, Vengurla-4, Kanaka, Amrutha and VTH 30/4 had almost similar sugar content before and after processing.

The variation in sugar content observed in various cashew nuts may be due to the varietal differences and differences in the growing conditions as reported by FAO (1997).

In the amino acid content H-2/16 got the highest value and H-2/15 got the least value before processing.

The amino acid content of cashew nuts observed in the present study is in accordance with that reported by (Soman 1990) but lower than that reported by Nagaraja and Nampoothiri (1986) on dry weight basis.

There is significant variation between varieties with respect to amino acid content before and after processing. FAO (1997) reported that growing conditions and variety of cashew influences the composition of kernels.

H-2/16 with the highest content of amino acid differed significantly from other varieties except M-44/3 and Dhana before processing. After processing also H-2/16 was the best with higher concentration of amino acid. Though

significant variation was observed in cashew varieties both before and after processing, the variation between the two stages of processing was found to be insignificant.

The fatty acid content of cashew kernels ranged from 1.91 to 3.08 per cent before processing and from 2.07 to 2.98 per cent after processing. The values were similar to those reported by Lercker and Pallotta (1985). Shivasankar *et al.* (1998) reported that cashew kernels contained 0.9 to 1.5 per cent of free fatty acids which was lower than the values obtained in the present study.

Sulabha had the highest amount of fatty acids and this variety differed from all others with respect to fatty acid content. There was significant variation between varieties before processing. After processing the fatty acid content of Sulabha, Dharasree, Vengurla-4, H-2/15, VTH 59/2, Priyanka, Vengurla 2, Hybrid 4/5, Anakayam, H-1600 and Kanaka were found to be almost similar. Though, an increase in fatty acid content of cashew kernels was observed after processing the increase was found to be statistically insignificant.

The calcium content of cashew nuts ranged from 32.08 mg to 57.88 mg before processing and from 34.4 mg to 58.46 mg 100 g⁻¹ after processing. Madakkathara-2 had the highest calcium content before processing while Dharasree had the highest calcium content after processing. The values obtained in the present study are in accordance with the values reported by Gopalan *et al.* (1989), Mahendru (1990a), Balasubramanian (1998), CEPC (1998a & c) and Kumar (1998).

Madakkathara-2 was found to be the best before processing with respect to calcium content and it significantly differed from all the other varieties. Dharasree, Madakkathara-1 and H-2/15 can be considered as one group based on their calcium content before processing.

After processing also there was significant variation between varieties with respect to calcium content. The variety Dharasree had got the highest calcium content. VTH 30/4 had the lowest calcium content and it differed significantly from all others. A significant increase in the calcium content was noticed in the cashew kernels.

Madakkathara-1 and Sulabha were found to be the best with highest iron content while Vengurla-2 and Vengurla-4 had the lowest iron content before and after processing respectively. The iron content of cashew kernels varied from 3.3 to 5 mg before processing and from 3.42 to 4.97 mg after processing. The values are in accordance with that reported by Swaminathan (1989), Gopalan *et al.*, (1989) Mahendru (1990a) CEPC (1998a), Kumar (1998), Narayanan (1998) and Vijayapushpam and Kumari (1998).

There is significant variation between varieties with respect to iron content both before and after processing. Madakkathara-1 which has got the highest value varied significantly from all others except Madakkathara-2 and Dhana. Priyanka, VTH 30/4, Tree No.40, Sulabha, Hybrid 4/5 and Tree No.129 were grouped as a single member in their respective groups and thus differed significantly among themselves. H-2/16, Amrutha, Tree No.40, and VTH-59/2 contained almost similar amounts of iron after processing. There is no significant variation in the iron content between the two processing stages while significant variation in iron content of cashew varieties was observed before and after processing.

The phosphorus content are in accordance with those reported by Gopalan *et al.* (1989) Mahendru (1990a), CEPC (1998a) and Kumar (1998). Anon (1985) reported a lower value of 370 mg for phosphorus in 100 g of cashew kernel. According to Soman (1990) cashew nut contained about 510 mg of phosphorus

which is slightly greater than the values obtained in the study. This may be due to the variation in growing conditions as suggested by FAO (1997).

The phosphorus content of cashew nuts varied from 411.8 mg to 460.9 mg before processing and from 408.4 mg to 460 mg after processing. Tree No.40 was found to be the best in phosphorus content before and after processing. There is no significant difference between varieties with respect to phosphorus content both before and after processing as well as between the two processing stages. Tree No.40 with highest phosphorus content differed significantly from all others before and after processing. H-2/15 with the lowest phosphorus content before processing differed significantly from all others except Vengurla 3, M-26/2, and Anakkayam.

5.3 Processing characters of cashew kernels

Kernel weight of varieties varied from 1.21 to 2.46 g. The highest weight was observed in Priyanka which differed significantly from all other varieties. Madakkathara-1 stands second among the varieties on the basis of kernel weight. The kernel weight was found to be similar in varieties such as H-1610, H-2/15 and VTH 59/2. M-33/3 was found to be the smallest which differed significantly from all other varieties selected for the study.

Aravindakshan *et al.* (1986) observed a kernel weight varying from 1.41 to 2 g in cashew varieties. George *et al.* (1991) Salam *et al.* (1991) and Manoj *et al.* (1994) reported that kernel weight varied from 1.42 to 3.08 g which is almost similar to the values obtained in the present study. Pushpalatha (2000) reported a kernel weight of 1.13 to 2.93 g in cashew varieties selected from Cashew Research Station, Madakkathara.

Highest and lowest values of shelling percentage was observed in Madakkathara-1 (32.37%) and VTH 30/4 (19.17%) respectively. There is significant difference between varieties with respect to shelling percentage. This

may be due to varietal differences as reported by Nandini and James (1985). Devi (1989) also observed maximum variability for nut weight and shelling percentage. Swamy *et al.* (1990) and Manoj *et al.* (1994) reported that shelling percentage of cashew kernels varies from 22 to 37.55 which is almost similar to the values observed in the present study. However, Salam (1998) observed a higher shelling percentage of 28 to 37 per cent for cashew varieties selected from CRS, Madakkathara. This higher per cent may be due to difference in watering of plants or growing conditions as suggested by Ghosh (1995).

As observed in the present study Ghosh and Chatterjee (1987) reported higher variability of 18 to per cent 34.7 per cent in shelling percentage of cashew kernels.

Nalini *et al.* (1998) indicated a shelling percentage of 30.5 for cashew variety Dharasree which is almost similar to the values observed in the present study.

Anakkayam, Amrutha, Tree No:40 and Sulabha were found to be similar with respect to shelling percentage. There is no significant difference in shelling percentage of varieties such as H-2/16, Dhana, VTH – 59/2 and H-1610 as well as Vengurla-4, H-2/15, M-26/2 and M-33/3.

The percentage yield of whole kernels varied with variety and it ranged from 73 per cent for Anakkayam – 96.33 per cent for Madakkathara-2. The percentage of white wholes were found to be above 90 for varieties like Madakkathara-2, Dhana, M-44/3, Madakkathara-1 and Vengurla-2. Salam (1998) reported a percentage yield of whole kernels of 86.3 for the variety Vengurla-4 which was found to be almost similar to the values observed in the present study.

Processing of cashew results in kernels of different grades like wholes splits, bits etc. In the present study the kernel count of cashew nuts varied from 184 for Priyanka to 372 for M-33/3. Kernel count differed significantly with

variety. VTH 59/2, H-2/15 and H-1610 had similar kernel count. Sulabha, Tree No:129, Dharasree and Kanaka also contained small kernels of almost similar size.

5.4 Cluster analysis of cashew nuts

Based on the physical characters cashew nuts were grouped into three clusters. Anakkayam, Madakkathara-2, Priyanka, Sulabha, Dharasree, H-2/16, Tree No.40, VTH-30/4, VTH-59/2, M-33/3 and M-44/3 were included in cluster I. Cluster II contained Kanaka, Dhana, H-1600, H-2/15 and Hybrid 4/5. Madakkathara-1, Amrutha, H-1610, Tree No.129, Vengurla-2, Vengurla-4 and M-26/2 constituted cluster III.

The cluster means of cluster I for length breadth and thickness were 3.77 cm, 2.55 cm and 19.63 cm.

In cluster II cluster mean for weight was 7.75 g.

Length, breadth and thickness were found to be highest in cluster I. Among the members of cluster I Priyanka was found to be the best with respect to physical characters.

Considering the inter cluster distance it can be seen that the members of cluster I and cluster II differ very much (Fig. 19).

When the intra cluster distance was considered, more variation was observed among the members of cluster III. Members of cluster I inhibited the least intracluster distance showing similarity in chemical composition.

Based on the nutritional composition cashew kernels were grouped into four clusters. Dhana, Amrutha, H-2/16, Tree No.129, Tree No.40, M-44/3 and M-26/2 were included in cluster I. Dharasree H-1600 and M-33/3 constituted cluster II. Cluster III contain Anakkayam, Madakkathara-1, Sulabha, H-2/15,

VTH-30/4, VTH-59/2 and Hybrid 4/5. Madakkathara-2, Kanaka, Priyanka, H-1610, Vengurla-2 and Vengurla-4 included in cluster IV.

The cluster means of cluster I for amino acid and phosphorus were 2.93 mg and 440.74 mg respectively.

In cluster II the cluster mean for fat, iron and sugar were 45.52 per cent, 4.26 mg and 7.96 g respectively.

In cluster III cluster mean for moisture, protein, carbohydrate, fatty acid and calcium were 7.5 per cent, 21.36 per cent, 20.59 per cent, 2.79 per cent and 48.5 mg respectively.

Cluster III was found to be the best with respect to nutritional characters. Among the members of cluster III Sulabha, was found to be the best variety with higher content of carbohydrate, calcium, sugar and fatty acid.

The inter cluster distance was more between cluster II and cluster IV showing difference in composition of members of two clusters (Fig. 20).

When the intracluster distance was considered, more variation was observed among the members of cluster III. Members of cluster II namely Dharasree, H-1600 and M-33/3 exhibited the least intra cluster distance showing similarity in chemical composition, physical and processing characters.

Based on the processing characters kernels were grouped into III clusters. Dhana, Amrutha, Sulabha, H-2/16, Tree, No.40, VTH 30/4 and M-26/2 were included cluster I. Cluster II contained Anakkayam, Madakkathara-1, Kanaka, Priyanka, Dharasree, H-1600, H-2/15, Tree, No.129, Hybrid 4/5, M-33/3 and M-44/3 and Madakkathara-2, H-1610, VTH-30/4, Vengurla-2 and Vengurla-4 constituted cluster III.

The mean of cluster II for shelling percentage and kernel count were 25.39 and 269 respectively.

In cluster III cluster mean for kernel weight and percentage yield of whole kernels were 1.79 g and 89.33 respectively.

Based on the processing characters such as kernel weight, percentage yield of whole kernels shelling percentage and kernel count Madakkathara-1 was found to be the best variety.

Priyanka with best physical characters and with nutritional composition almost similar to Sulabha and processing characters similar to Madakkathara-1 can be considered as the best variety with respect to all characters.

Summary

SUMMARY

The study on "Quality evaluation of kernels of different cashew varieties" was made to evaluate the physical characters, processing characters and nutritional composition before and after processing of twenty three cashew varieties available and maintained at Cashew Research Station, Madakkathara. The varieties analysed were Amrutha, Anakkayam, Dhana, Dharasree, Kanaka, Madakkathara-1, Madakkathara-2, Priyanka, Sulabha, H-1600, H-1610, H-2/15, H-2/16, Hybrid 4/5, M-26/2, M-33/3, M-44/3, Tree No.40, Tree No.129, Vengurla-2, Vengurla-4, VTH-30/4 and VTH-59/2.

The selected cashew nut varieties were evaluated for physical characters such as nut weight, length, breadth and thickness.

Processing characters of cashew nuts such as kernel weight, shelling percentage, percentage yield of whole kernels and kernel count were evaluated.

The nutrients such as moisture, protein, fat, carbohydrate, sugar, amino acid, fatty acid, calcium, iron and phosphorus were evaluated before and after processing.

The study revealed that nut weight of cashew nuts varied from 4.24 g to 11.4 g. The highest was observed in H-1600. The mean length and breadth of varieties varied from 2.96 cm to 4.5 cm and 2.14 to 3.04 cm respectively.

The thickness of the varieties was found to be varied from 17.19 mm to 22.01 mm.

Statistical analysis revealed that there is significant variation between varieties with respect to all physical characters.

Nutrient analysis of varieties was done in both processed and non-processed nuts. The mean moisture content varied from 4.9 to 7.9 per cent before processing and from 4.78 to 8.03 per cent after processing. Protein content also showed a wide variation of 19.69 to 22.31 per cent before processing and 19.32 to 22.11 per cent after processing among different varieties. Fat content varied from 40.27 to 46.77 per cent before processing and from 40.23 to 47.17 per cent after processing. The mean carbohydrate content ranged from 17.69 to 24.02 per cent and 17.18 to 23.26 per cent before and after processing respectively.

The mean sugar content also showed a variation between varieties. The sugar content ranged between 4.81 to 10.15 per cent before processing and from 3.91 to 9.96 per cent after processing.

The mean fatty acid content varied from 1.91 to 3.08 per cent before processing and from 2.07 to 2.98 per cent after processing.

Cashew nuts contained appreciable amounts of minerals such as calcium, iron and phosphorus. Calcium content varied from 32.08 to 57.88 mg and 34.4 to 58.46 mg 100 g⁻¹ before and after processing respectively.

The mean iron content varied from 3.3 to 5 mg before processing and from 3.42 to 4.97 mg 100 g⁻¹ after processing. Madakkathara-1 and Sulabha had the highest values before and after processing respectively. The mean phosphorus content varied from 411.8 mg to 460.96 mg before processing and 408.4 to 460 mg after processing.

The statistical analysis indicated significant variation between varieties both before and after processing except in the case of phosphorus. The difference in nutrient content in two processing stages was found to be insignificant for all varieties of cashew nuts except for calcium.

After processing of cashew nuts characters such as kernel weight, shelling percentage, percentage yield of whole kernels and kernel count were evaluated.

The kernel weight varied from 1.21 g in Priyanka to 2.46 g in M-33/3. Shelling percentage also showed a variation from 19.17 to 32.37. The mean percentage yield of whole kernels varied from 73 to 96.33. Priyanka had the lowest number of kernels (184) while M-33/3 contained about 372 kernels.

Statistical analysis indicated significant variation between varieties with respect to processing characters.

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***Originals not seen**

QUALITY EVALUATION OF KERNELS OF DIFFERENT CASHEW VARIETIES

**By
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ABSTRACT OF THE THESIS
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ABSTRACT

The study on "Quality evaluation of kernels of different cashew varieties" was conducted to evaluate the physical characters, nutritional composition and processing characters of twenty three cashew varieties available and maintained at Cashew Research Station, Madakkathara.

The physical characters evaluated were weight, length, breadth and thickness. The highest weight, length, breadth and thickness were observed in H-1600, M-33/3, Priyanka and H 2/15 respectively.

The nutrients analysed were moisture, protein, fat, carbohydrate, sugar, amino acid, fatty acid, calcium, iron and phosphorus. They were estimated before and after processing. The sugar content before processing, fatty acid content before and after processing and iron content after processing were highest in Sulabha whereas H-1600 had the highest mean value for sugar and fat contents after processing. The highest protein and amino acid contents before and after processing was observed in H-2/16. Dharasree had the highest mean value for fat content before processing and calcium after processing. Highest calcium content before and after processing was found to be in Madakkathara-2 and Dharasree respectively. Carbohydrate content was found to be highest in Anakayam and lowest in Madakkathara-1 before and after processing. Phosphorus and iron contents before processing was found to be highest in Tree No. 40 and Madakkathara-1 respectively. There was significant variation **between varieties** with respect to all nutrients except phosphorus. The difference in nutrients before and after processing was not significant except in the case of calcium.

After processing cashew nuts were analysed for characters such as kernel weight, shelling percentage, percentage yield of whole kernels and kernel count. Madakkathara-1 and Madakkathara-2 had got the highest values for shelling percentage and percentage yield of whole kernels. Highest kernel weight was

observed in Priyanka. The difference in processing characters of different varieties was found to be significant statistically.

Based on the physical characters cashewnuts were divided into three clusters. Cluster I had eleven members which were Anakkayam, Madakkathara-2, Priyanka, Sulabha, Dharasree, H-2/16, Tree No.40, VTH 30/4, VTH 59/2. M-33/3, M-44/3. Cluster II contained Kanaka, Dhana, H-1600, H-2/15 and Hybrid 4/5. Madakkathara-1, Amrutha, H-1610, Tree No.129, Vengurla-2, Vengurla-4 and M-26/2 constituted cluster III. Priyanka was found to be the best variety with respect to physical characters.

Based on the nutritional composition cashew kernels were divided into four clusters. Cluster I had seven members which were Amrutha, Dhana, H-2/16, Tree No.129, Tree No.40, M-44/3 and M-26/2. Dharasree H-1600 and M-33/3 were included in cluster II. Cluster III contained Anakkayam, Madakkathara-1, Sulabha, H-2/15, VTH-30/4, VTH-59/2 and Hybrid-4/5. Madakkathara-2, Kanaka, Priyanka, H-1610, Vengurla-2 and Vengurla-4 constituted cluster IV. Based on the nutritional characters Sulabha was found to be the best variety.

Based on the processing characters cashew nuts were grouped into III clusters. Cluster I contained 7 varieties namely Dhana, Amrutha, Sulabha, H-2/16, Tree No.40, VTH 30/4 and M-26/2. Anakkayam, Madakkathara-1, Kanaka, Priyanka, Dharasree, H-1600, H-2/15, Tree NO.129, Hybrid 4/5, M-33/3 and M-44/3 constituted cluster II and Madakkathara-2, H-1610, VTH-30/4, Vengurla-2 and Vengurla-4 constituted cluster III. Among the varieties Madakkathara-1 was found to be the best with respect to processing characters.

Priyanka with best physical characters and with nutritional composition almost similar to Sulabha and processing characters similar to Madakkathara-1 can be considered as the best variety with respect to all characters.