NUTRITIONAL EVALUATION OF CYCAS SEED FLOUR (*Cycas circinalis* L.)

By

ANITHA. S.

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THESIS

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DECLARATION

I hereby declare that this thesis entitled, **"Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not been 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.

Vellanikkara **Anitha. S.**

Date:23.12.11

CERTIFICATE

Certified that the thesis entitled **"Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)"** is a record of research work done independently by **Miss. Anitha. S.** (2009-16-107) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikara
Date:23.12.11

Dr. V. Indira
(Major Advisor)
Professor and Head
Department of Home Science
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss. Anitha S. (2009-16-107)**, a candidate for the degree of **Master of Science in Home Science** with major field in **Food Science and Nutrition**, agree that this thesis entitled, **"Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)"** may be submitted by Miss. Anitha S. in partial fulfillment of the requirement for the degree.

Dr. V. Indira
(Chairperson)
Professor and Head
Department of Home Science
College of Horticulture
Vellanikkara

Dr. Suman K. T.
Assistant Professor
Department of Home Science
College of Horticulture
Vellanikkara
(Member)

Dr. Mini Raj N.
Professor
Department of Plantation Crops & Spices
College of Horticulture
Vellanikkara
(Member)

Dr. Beena C.
Associate Professor (Biochemistry)
AICRP on M & AP
College of Horticulture
Vellanikkara
(Member)

EXTERNAL EXAMINER: Dr. Karuna. M. S. Associate Professor and Head, Department of Home Science, Vimala College, Thrissur-9.
Email ID: dr.karunams@gmail.com

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ABBREVIATIONS

A.O.A.C.	- Association of Official Analytical Chemists
g	- Gram
mg	- Milligram
m	- Metre
ml	- Millilitre
cm	- Centimetre
^{o} C	- Degree centigrade
%	- Per cent
nm	- Nanometre
KJ	- Kilo Joules
$CuSO_4$	- Copper sulphate
HCl	- Hydrochloric acid
H_2SO_4	- Sulphuric acid
N	- Normal
NaOH	- Sodium hydroxide
OD	- Optical density
K_2SO_4	- Potassium sulphate
µl	- Micro litre
µg	- Micro gram
SDF	- Soluble Dietary Fibre
IDF	- Insoluble Dietary Fibre
TDF	- Total Dietary Fibre

INTRODUCTION

1. INTRODUCTION

Non Timber Forest Products (NTFP) represent important resources for hundreds of millions of people across the world (Iqbal, 1993 and Walter, 2001). *Cycas circinalis* L., a cycad endemic to South India is an important multi use NTFP for indigenous communities throughout India's Western Ghats (Myers *et al.*, 2000). It typically occurs in fairly dense, seasonally dry, scrubby woodlands in hilly areas. The pith and male cone of this species are collected for their medicinal values, the young leaves are used as food and medicine by indigenous and local communities and the matured leaves are sold in the floriculture industry (Varghese and Ticktin, 2006).

C. circinalis or *'eenth'* as it is locally called in Kerala is a small evergreen, palm like tree growing to 25 feet in height and found in deciduous forest up to 1200 m altitude (Saneesh, 2009). *Cycas circinalis,* belonging to the family Cycadaceae commonly called as queen sago palm, is one of the nine species of cycas growing in tropical or sub-tropical areas. The distribution of *Cycas circinalis* is restricted to India and tribal communities utilise the cycas seeds as their food.

Plants belonging to this family often have significant nutritional value in the form of edible starch, which can be extracted from roots, stem and seeds. They have medicinal, economic and nutritional importance in areas where they are indigenous. Cycas seeds are important as a source of cheap food in the form of sago. It is one of the few foods available during and following devastating typhoons and famines and is also a major energy food for many poor populations (Whiting, 1963).

Cycad stem, roots and leaf bases have been harvested for magical and medicinal uses also (Whiting, 1963; Jones, 1993; Osborne *et al.*, 1994; Norstog and Nichollas, 1997). As medicines, cycad products have been used in the form of

beverages and tea, as purgatives and as pain depressants (Harrison, 1966). Besides being used in traditional medicine, cycads are now also being used in proprietary drugs available in the market. In Kerala also, *Cycas circinalis* fruits are harvested and sold locally as medicine.

Thus, over the years, cycas seeds have found a high level of dependence by indigenous people and medicinal plant traders. Cycads are classified as cyanogenic plants, due to the presence of water soluble hepatotoxin and carcinogen namely cycasin. Various processing methods like soaking, steaming, repeated washing and brief leaching in water, prolonged leaching in water, ageing, boiling etc., have been employed to eliminate the toxic constituents in cycas seeds before preparing various dishes by the people who consume it.

Though, various studies with respect to morphology, ecology, ethnobiology, distribution and conservation of cycas were reported, authentic information are not available on the nutritional qualities of cycas seeds and the effect of processing on the various chemical constituents present in it. Hence, the present study was undertaken with the following objectives.

- To evaluate the chemical constituents of cycas seeds collected from forest and non forest regions.

- To study the effect of processing on the chemical constituents.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The studies relevant to the topic of research, "Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)" have been carried out in accordance with the objectives of the study. The literature pertaining to the study are elucidated under the following headings.

2.1. Importance of cycas
2.2. Quality characteristics of cycas
2.3. Processing of cycas seeds

2.1. Importance of cycas

The medicinal, economic and nutritional importance of cycas was indicated by Theiret (1958).

In Melville Island, the cycas were found to be one of the important plants selected for ceremonies (Whiting, 1963). In Guam, Australia, India, Indonesia, Africa, Java, Columbia, Mexico and Florida, the cycas have been used by people since prehistoric times and they have been traded for food (seeds and stems), starch (stems), ceremonies and decoration (leaves), basket work (leaves) and medicine or magic (stems, roots, barks) (Whiting, 1963; Harrison, 1966; Gilbert, 1984; Jones, 1993; Sacks, 1996; Norstog and Nichollas, 1997; Whitelock, 2002; Donaldson, 2003). The authors also indicated the use of cycas plants in Asia as ornamental plants.

Spencer (1990) indicated the exploitation of cycas stem starch for human consumption and as a commercial adhesive and laundry starch by the settlers of Western Australia.

According to Beck (1992) cycas provided a rich starch resource not only to meet the nutritional needs of aboriginal people, but also to meet social and ceremonial needs. The author also indicated the use of cycas as food, medicine as well as for ornamental purpose and for decoration.

Lal (2003) indicated the multipurpose use of different parts of cycas like the use of stem fibre to make cloth and rope, leaves for decoration and to make brooms, baskets and as a thatching material. The author also indicated the use of fleshy leaves as a vegetable and roots as a source of sago.

Cycas, in their natural habitat constituted an important component of the forest of the Western and Eastern Ghats and North Eastern states of India (Prathapan, 2006).

In Fiji, cycas fruits were reserved for chiefs (Degener, 1949). Theiret (1958) and Whiting (1963) indicated the use of starchy kernels of cycas in various traditional preparations.

Whiting (1963) indicated that cycas is one of the few foods available during drought and following devasting typhoons. In some countries eating cycas starch occurred mostly in times of war, drought or aftermath of typhoons (Whiting, 1963; Jones, 1993). The authors also indicated the use of cycas seeds as a food source in times of famines.

Whiting (1963) and Sacks (1996) reported cycas as an important item reserved for special occasions. Whiting *et al.* (1966) indicated the use of starchy portion of cycas seed, rhizome and stem as a source of food.

Cycas seed was reported as a major source of food for the indigenous residents of Guam and they used cycas flour to make tortillas (bread) and atole (beverage) (Spencer, 1990). The author also indicated the use of kernels of cycas to prepare soup. Jones (1993); Sacks (1996) and Whitelock (2002) also observed the use of seeds as a source of food in parts of Asia and Melanesia, where cycas are locally abundant.

Whitelock (2002) indicated the use of cycas as famine food since prehistoric times. The author also reported the use of cycas starch as a staple food in Mariana Island and as a food after baking by Australian aboriginals.

Cycas revoluta was reported as one of the cheapest and most available sources of food starch and was found to be a constituent of poor people's food especially in times of food scarcity (Lal, 2003). The author also observed that pregnant women used to demand sago palm seed flour preparation as a part of their pregnant cravings, particularly if they were in the habit of consuming sago during their childhood.

Varghese and Ticktin (2006) indicated the use of cycas for home consumption in Kerala as well as the use of *Cycas circinalis* L. by individual community in Niligri Biosphere Reserve (NBR) for food.

Traditionally, starch derived from the powdered nuts of cycas palm was found to be one of the primary sources of carbohydrate among Muduga and Kurumba tribal communities of Kerala (Tharakan, 2007). Binu (2010) reported the use of *Cycas circinalis* L. as food by tribals after frying. The author also reported the use of cycas flour in the preparation of steam cakes after preparing flour from seeds.

Indigenous cultures considered the medicinal values of cycas (Whiting, 1963). Cycas products were used as medicine in the form of beverages and tea as purgatives

and as pain depressants (Harrison, 1966). The author also indicated the use of sap of cycas plant for external application due to its astringent and mucilaginous properties. Whiting *et al*. (1966) reported the wound healing properties of fresh sap of cycas.

Spencer (1990) indicated the use of cycas seeds as a Chamorro medicine during World War II. For this, the freshly grated cycas seed kernel or its juice was applied to open wounds, leg ulcers, abscesses and boils and left in place as a poultice for several days. The author also indicated its use in treatment of skin lesions.

Lal (2003) indicated the use of crushed barks and seeds of cycas as a poultice for sores and wounds after mixing with coconut oil. Bissa *et al*. (2008) and Janick and Paull (2008) also reported the use of barks and seeds of *Cycas circinalis* as a poultice on sores and swelling after grinding with oil.

The use of sago palm flour as a cure for hemorrhoids (piles) and the decoction prepared by boiling young seeds of cycas as a purgative was indicated by Lal (2003). A new bioflavanoid was isolated from *Cycas beddomei* by Das *et al*. (2006).

Prathapan (2006) indicated the use of leaves, seeds and barks of cycas for medicinal purposes and reported the use of male cone of cycas in traditional medicine and also in proprietary drugs available in the market. Bissa *et al*. (2008) and Janick and Paull (2008) indicated the use of juice of tender leaves of cycas in the treatment of flatulence and vomiting. In traditional Chinese medicine, the seeds of *Cycas revoluta* were found to be used for gastrointestinal disturbances, musculoskeletal pain, cough and hypertension (Braceloux, 2008).

Beck (1992) indicated the use of cycas for ornamental and decorative purposes. The use of various species of cycas in the landscape gardening industry and nursery industry was indicated by Gorman *et al*. (2006) and Marler (2007). In Tamil

Nadu, the mature leaves were harvested for use in floriculture industry (Varghese and Ticktin, 2006). Janick and Paull (2008) indicated the use of different species of cycadaceae for landscape and as an indoor and outdoor plant and as bonsai.

2.2. Quality characteristics of cycas

In appearance, cycas are palm like with a cylindrical trunk, a swollen underground tuber like stem and a crown of very coarse stiff feathery leaves (Harrsion, 1966). Cycas are mostly terrestrial and arborescent with an unbranched aerial stem covered with persistent leaf bases or shrubby with a subterranean tuberous stem (Spencer, 1990).

Brenner *et al*. (2003) indicated that the cycads are the most primitive living plants with a fern or palm like appearance largely due to their pinnately compound leaves. Prathapan (2006) also indicated that most of the cycas are primitive seed plants characteristied by a large crown of compound leaves and a stout trunk.

The scientific name *circinalis* came from the Latin word for coiled and refers to the way the leaf unfolds as it grows (Whitelock, 2002).

Cycas circinalis L. is dioecious plant like shrub with aerial, cylindrical stem and persistant leaf-base (Jarvis *et al*., 1993).

According to Varghese and Ticktin (2006) *Cycas circinalis* is endemic to South India which grows upto 5 m height, with bipinnate leaves of 150-200 cm length and yellow seeds upto 4 cm long. *Cycas circinalis* is a perennial evergreen tree like herb with pinnate foliage and with pale reddish yellow seeds (Braceloux, 2008).

Cycas circinalis L. is regarded as an Indian endemic restricted to the Western Ghats and typically occurs in dense seasonally dry, scrubby woodlands in hilly areas (Janick and Paull, 2008). The authors also indicated that the stem of *Cycas circinalis* is seven meters tall and seeds are light yellow at maturity, 30- 39 mm long and 20-24 mm wide.

Saneesh (2009) reported that *Cycas circinalis* found in Kerala are small, evergreen, palm like tree growing to 25 feet in height and found in the deciduous forest and the ripened seeds are greenish yellow in colour.

Cycas revoluta, another species of cycas is a slow growing, evergreen, long lived, medium sized palm like plant with the stem consisting of an outer protective layer, the epidermis, large parenchymatous cortex and large pith containing thin walled cells densely filled with starchy sago grains, numerous mucilage canals and vascular bundles (Lal, 2003).

According to Braceloux (2008) *Cycas revoluta* Thumb is a slow growing fern like tree that reaches upto 3 m usually as a thick shaggy, solitary trunk topped by a terminal crown of stiff and shiny leaflets curved at margins with orange fruit.

Lindstrom and Hill (2007) reported that the seeds of *Cycas pectinata* had a light yellow sarcotesta and were found to be elongated with 30-39 mm length and 20-24 mm width. The authors also indicated that *Cycas arnhemica* is a slow growing, dioecious plant with a columnar growth form to atleast 5 m tall.

Cycas rumphii Miq. is bright green with glossy leaves and yellow to pale brown fusiform pollen cones (Braceloux, 2008).

The stem of *Cycas spherica* is upto 5 m tall, with light yellow coloured seeds of 25 mm in length (Janick and Paull, 2008).

Harvey (1945) observed that seeds of Australian cycas are made up of three components namely the fleshy outer layer (sarcotesta), strong adjacent layer within it (sclerotesta) and the female gametophyte and the embryo which together make up the starchy kernels. Lal (2003) also indicated that mature seeds of cycas could be differentiated into orange red coloured fleshy layer, stony middle layer and fleshy inner layer.

According to Whiting (1963) cycas are dioecious with pollen bearing and seed bearing. The author also indicated that seeds of cycas have an outer fleshy layer and an inner stony portion, which were separated by a thin paper membrane. Reed and Solt (1986) indicated that the seed coats of some cycas are fleshy or scaly, often brightly coloured and bulk of the seed consisted of starchy endosperm containing the embryo. Spencer (1990) indicated that the mature cycas seeds are brightly coloured with a fleshy outer husk (scarcotesta) covering a thin stony shell than the starchy kernel.

Seeds of *Cycas circinalis* had a yellow, orange or brown fleshy outer sarcotesta and with or without spongy tissues beneath the inner woody sclerotesta (Jarvis *et al*., 1993).

Campbell *et al*. (1966) reported that cycas flour contains 2 per cent of nitrogen. Harris (1975) reported that *Cycas media* raw seeds contain 5.1 per cent of protein and raw seeds of *Cycas cairnsiana* had 5.8 per cent protein. James (1985) reported that the raw seeds of *Cycas media* had 4.1 per cent protein. Beck (1992) and Miller *et al.* (1993) also observed relatively high protein content of 5 per cent and 5.8 per cent respectively in raw cycas seeds.

Harris (1975) reported 845 KJ of energy in *Cycas media* raw seeds and 795 KJ in *Cycas cairnsiana*. However, James (1985) indicated that the raw seeds of *Cycas media* had only 537 KJ energy. Beck (1992) also indicated relatively high energy content in the range of 583-1306 KJ in raw cycas seeds. Miller *et al*. (1993) indicated an energy content of 338 KJ in cycas seeds.

Campbell *et al*. (1966) reported that cycas flour contains 0.8 per cent fat. However, Miller *et al*. (1993) observed only 0.4 per cent fat in cycas. The authors also indicated 28.1 per cent dietary fibre in cycas seeds.

Campbell *et al*. (1966) reported that cycas flour contains 2.6 per cent ash and Miller *et al*. (1993) observed 0.5 g ash, 21 mg calcium, 4.6 mg iron, 66 mg potassium, 5 mg of sodium and 1.2 mg zinc in 100 g of *Cycas armstrongii*.

The water soluble hepatotoxin and carcinogen, cycasin, found in the nuts and leaves of the gymnosperm *Cycas circinalis* L. and other cycas plants has been identified as β - D-glycosyloxyazomethane (Nishida *et al*., 1955 and Riggs, 1956).

A wide range of cycasin level emerged from the small volume of literature available on cycas, Matsumoto and Strong (1962) estimated 2.3 per cent cycasin in one batch of nuts of *Cycas circinalis* from Guam and in same batch, Mickelsen (1962) detected 4 per cent cycasin, while Kurland (1962) mentioned 3.6 per cent cycasin in Guam *Cycas circinalis*. Kurland (1962) and Janick and Paull (2008) indicated that *Cycas circinalis* had 0.42 per cent and 0.10 per cent of macrozamin and cycasin, *Cyacs revoluta* had 0.26 per cent and 0.28 per cent macrozamin and cycasin respectively.

Cycasin, is a Methylazoxymethanol β- glucoside (Kobayashi and Matsumoto, 1965). The authors also reported that cycas plants contained toxic azoxyglucoside with a common aglycone, Methylazoxymethanol. Harrison (1966) indicated that cycasin and the other Methylazoxymethanol are naturally occurring alkylating agents which were found in cycas plant. Azoxyglycoside, glycoside of Methylazoxymethanol (MAM) have been found only in Cycadales plants (Yagi and Tadera, 1987).

2.3. Processing of cycas seeds

In Northern Queensland and on Groote Eylandt (Levitt, 1981) fresh seeds were leached overnight in running water after cooking to remove toxic principle. After this, the seeds were dried and then made into flour. The authors also reported that in Groote Eylandt the seeds were flattened with a stone mortar, before leaching.

Prolonged leaching of the kernels of freshly picked seeds as well as dried seeds in running water for 3-7 days was probably the most common processing technique recorded which was used throughout the distribution area of Australian cycas (Tindale, 1925; Love, 1936; Thomson, 1949).

Seifter *et al*. (1950) reported soaking and leaching as an effective method to remove the toxic factor in cycas. The enzyme β glucosidase present in the nuts of *Cycas revoluta* and *Cycas circinalis* also destroy cycasin (Nishida *et al*., 1955; Matsumoto, 1962).

Soaking the seeds in water and changing the water once in four days upto three weeks was adopted by the natives in Guam, to eliminate the toxicity of cycas seeds (Whiting, 1963). Repeated washing and soaking the nuts for 8 days was

reported by Dastur (1964) which will probably liberate and activate the enzyme which destroys the cycasin.

Campbell *et al.* (1966) indicated that the toxicity of cycas could be decreased after soaking and incubation in water, heating and storage. The authors also indicated that toxic factor in unwashed cycas flour can be largely destroyed by moist or dry heat at 90°C. The authors also demonstrated that the toxicity of dried cycas powder can be decreased with ageing and with an increase in storage temperature.

Prolonged boiling was also suggested by Dastur and Palekar (1966) to destroy cycasin. The authors also suggested washing, boiling, fermentation and storage of cycas flour to remove substantial amount of cycasin.

Yang *et al.* (1966) suggested the local customs of preparing cycas flour by soaking, as an effective method to remove carcinogenic substance.

Prolonged soaking and storage of the fresh seeds in still water for 5 months will make the availability of cycas seeds in the off season (Meehan and Jone, 1977). Scarlett and White (1981) also observed that prolonged leaching or ageing of seeds particularly when leached into a loaf had good storage properties.

Spencer (1990) indicated slicing or crushing, soaking for days or weeks in fresh water and changing the water periodically as effective methods to remove poisonous principle in cycas. After processing, the seeds could be dried and ground into flour for various preparations.

The Queensland observation demonstrated that 3-4 days soaking in still water as an efficient method to remove toxins, but in Northern territory the time for still water leaching is given between 1-5 months (Beck, 1992). The author also indicated

that the soaked kernels could be eaten raw or individually roasted in ashes, but were more usually ground with water and made into large loaves which were baked in sand and ash. The entire kernels were also rolled in hot sand mixed with charcoal. This bag was dried in the sun for several days before being leached in running water. After four days, kernels were removed from water and pounded into a long cake before being roasted.

Three traditional methods like: brief leaching in water; prolonged leaching in water; and ageing were suggested by Beck (1992) to remove the toxins which were adopted by aboriginal people living at Donydji, Northeastern Arnhern land.

Yunupingu *et al*. (1995) reported that the aboriginal people in Eastern Arnhern land adopted drying, chipping and placing the chipped material in running water for 5 days and pounding to remove the toxins in cycas seeds. The detoxifying of cycas seeds involve repeated leaching in water of the gametophyte or pith fermentation (Hill and Osborne, 2001).

Roasting, boiling, shredding and soaking in water or sea water before drying and grinding into flour were adopted by indigenous people for generation. (Whitelock, 2002). Lal (2003) indicated that repeated washing of dried cycas seeds for atleast seven times after immersing in water for 3-6 hours as an effective way of removing toxins. Marler (2005) also indicated leaching in the water as an effective method to remove Methyl azoxyl- methanol (MAM) and β-Methyl-amino-alanine (BMAA).

Varghese and Ticktin (2006) reported various processing methods to remove the toxins in cycas seeds. Among the different methods, smoking the ripe fruits in bamboo mat, dehusking, drying and washing the fruit in running water, drying and leaving the outer shell of the fruit to rot in a dark corner and dehusking, boiling the

fruit four times and draining the water each time as well as steaming, boiling or fermentation were found to be effective in removing toxin.

Saneesh (2009) reported smoking the halved seeds and leaching several times in cold water adopted by Keralites to remove toxins. The author also indicated two ways of leaching the seeds. One is to keep seeds in a bamboo basket or a jute sack in running water. The other method is to boil seeds in water more than three times. After leaching, the seeds are left to dry and are then powdered to fine or coarse flour to make various delicacies. Keeping the seeds in boiling water for 30 minutes for three times was also found to be an effective method used to remove the toxin instead of drying.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The materials used and the methods followed in the present study entitled "Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)" are given under the following headings.

3.1. Collection of cycas seeds
3.2. Processing of cycas seeds and preparation of cycas seed flour
3.3. Analysis of chemical constituents of the cycas seed flour
3.4. Statistical analysis

3.1. Collection of cycas seeds

Fresh and matured cycas seeds were collected from forest and non forest areas of Thrissur district during the month of August, 2010. Forest samples were collected from the forest areas of Peechi and Thamaravellachal, and non forest samples were collected from Kandassamkadavu and Marottichal areas of Thrissur district. The cycas seeds collected from forest and non forest areas are depicted in Plate 1 and 2 respectively.

3.2. Processing of cycas seeds and preparation of cycas seed flour

The cycas seeds collected from different areas were split opened and the kernels were taken out and dried in sunlight for 8 to 10 days. After this, the dried cycas seeds collected from forest and non forest areas were pooled separately as forest and non forest samples. The dried cycas seeds collected from forest and non forest areas are shown in Plate 3 and 4 respectively.

Plate1. Cycas seeds collected from forest area

Plate 2. Cycas seeds collected from non forest area

Plate 3. Dried cycas seeds collected from forest area

Plate 4. Dried cycas seeds collected from non forest area

The dried cycas seeds collected from forest and non forest areas were processed separately using six different methods. The treatments used for processing are given in Table.1.

Table 1. Details of the processing treatments

Treatments	Details
T_0	Dried cycas seeds (control).
T_1	Soaked in cold water for 12 hours.
T_2	Soaked in cold water for 24 hours.
T_3	T_1 + Soaked in boiling water for 2 hours.
T_4	T_2 + Soaked in boiling water for 2 hours.
T_5	T_1 + Powdered and washed in water three times.
T_6	T_2 + Powdered and washed in water three times.

The processed (T_1 to T_4) and control seeds were washed separately and dried in sunlight for 30 minutes. Then, the dried cycas seeds were powdered in a mixie so as to get uniform flour. T_5 and T_6 were also prepared as in T_1 and T_2, and then powdered and washed in water three times. After draining the water, the flour was dried in sunlight for 30 minutes. Then, the flour prepared (T_0 to T_6) were dried in a cabinet drier at a temperature of 60 ± 5°C till the moisture content is reduced to 10 to 12 per cent. The flour obtained in each treatment was stored in sterilised glass bottles separately for further analysis.

3.3. Analysis of chemical constituents of the cycas seed flour

The cycas seed flour prepared before and after processing the cycas seeds collected from forest and non forest areas were evaluated for the following chemical constituents. Following analysis were carried out in triplicate samples.

3.3.1. Moisture

Moisture content of the cycas seed flour was estimated using standard method of A.O.A.C (1980).

To determine the moisture content, five grams of cycas seed flour was taken in a petri dish and dried in a hot air oven at 60 to 70°C and cooled in a desiccator and weighed. The process of heating and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.3.2. Protein

Protein content of cycas seed flour was estimated using standard method of A.O.A.C (1980).

Cycas flour (0.2g) was digested with 10 ml Conc. H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5g K_2SO_4 in a digestion flask until the colour of the sample was converted to green. After digestion, it was diluted with water and 25 ml of 40 per cent NaOH was pumped. The distillate was collected in 20 per cent boric acid containing mixed indicators and then titrated with 0.2 N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the crude protein content and expressed in percentage.

3.3.3. Starch

The starch content was estimated colorimetrically using anthrone reagent as suggested by Sadasivam and Manickam (1992).

The sample (0.5g) was extracted repeatedly with 80 per cent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml water and 6.5 ml 52 per cent perchloric acid were added and extracted at 0°C for 20 minutes. The sample was centrifuged and re extracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to 1 ml with water and 4 ml of anthrone reagent, heated for 8 minutes, cooled and read the OD at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph, glucose content of the sample was computed and multiplied by a factor 0.9 to arrive at the starch content and expressed in percentage.

3.3.4. Total carbohydrate

The total carbohydrate content was analysed colorimetrically using anthrone reagent as suggested by Sadasivam and Manickam (1992).

The powdered and dried sample was hydrolysed by keeping in a boiling water bath with 5 ml of 2.5 N HCl and then cooled to room temperature. The residue was then neutralised with solid sodium carbonate until the effervescence ceases and made up the volume to 100 ml with distilled water and centrifuged. Pipetted 0.5 ml of supernatant and made up to 1 ml with distilled water and added 4 ml anthrone reagent, heated for 8 minutes, cooled rapidly and the intensity of green to dark green colour was read at 630 nm.

A standard graph was prepared using standard glucose at serial dilutions. From the standard graph the amount of total carbohydrate present in the sample was estimated and expressed in percentage.

3.3.5. Crude fibre

The crude fibre content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978).

Two grams of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Repeated the filtration through a muslin cloth and the residue was washed with 1.25 per cent sulphuric acid, water and alcohol. The residue was transferred to a pre-weighed ashing dish, dried, cooled and weighed. The residue was then ignited in a muffle furnace at 600°C for 30 minutes, cooled in a desiccator and reweighed. The crude fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage.

3.3.6. Fat

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

Two grams of cycas seed flour was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for six hours without interruption by gentle heating in a soxhlet apparatus. Extraction flask was then cooled, and ether was removed by heating and weight was taken. The fat content was expressed in g per 100 g of the sample.

3.3.7. Calcium

The calcium content of cycas seed flour was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982).

One gram of the flour was predigested with 10 ml of 9:4 mixture of nitric acid and perchloric acid and made up to 100 ml and used directly in atomic absorption spectrophotometer and calcium content was expressed in mg per 100 g of sample.

3.3.8. Phosphorous

The phosphorous content was analysed colorimetrically as suggested by Jackson (1973), which gives yellow colour with nitric acid vandate molybdate reagent. To 5 ml of pre-digested aliquot, 5 ml of nitric acid vandate molybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes, the OD was read at 420 nm.

A standard graph was prepared using serial dilution of standard phosphorous solution. The phosphorous content of the sample was estimated from the standard graph and expressed in mg per 100 g of sample.

3.3.9. Sodium

The sodium content was estimated using flame photometer as suggested by Jackson (1973).

The diacid extract prepared was directly fed in the flame photometer and sodium content was expressed in mg per 100 g of sample.

3.3.10. Potassium

The potassium content was estimated using flame photometer as suggested by Jackson (1973).

The diacid extract prepared was read directly in flame photometer and potassium content was expressed in mg per 100 g of sample.

3.3.11. Iron

The iron content of cycas seed flour was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982).

The diacid solution was directly read in atomic absorption spectrophotometer and iron content was expressed in mg per 100 g of sample.

3.3.12. Zinc

The zinc content of cycas seed flour was estimated by atomic absorption spectrophotometric method using the diacid extract prepared from the sample (Perkin-Elmer, 1982).

The diacid solution was directly read in atomic absorption spectrophotometer to find out the zinc content and expressed in mg per 100 g of sample.

3.3.13. Crude alkaloid

The crude alkaloid content was estimated by spectrophotometric method suggested by Shamsa *et al.* (2008).

The sample was extracted with methanol for 24 hours continuously in extraction apparatus. The extract was filtered and methanol was evaporated on a

rotary evaporator under vaccum at a temperature of 45°C to dryness. A part of this residue was dissolved in 2 N HCl and then filtered. One ml of this solution was transferred to a separating funnel and washed with chloroform. The pH of this solution was adjusted to neutral with 0.1 N NaOH. Then, 5 ml of Bromocresol Green (BCG) solution and 5 ml of phosphate buffer were added to this solution. The mixture was shaken and the complex formed was extracted with 1, 2, 3 and 4 ml of chloroform by vigorous shaking. The extracts were collected in a 10 ml volumetric flask and diluted to volume with chloroform. The absorbance of the complex in chloroform was measured at 470 nm.

A standard curve was drawn using atropine standard solution. The absorbance of the complex in chloroform was measured at 470 nm against blank prepared but without atropine. The crude alkaloid content was expressed in mg $100g^{-1}$ of the sample.

3.3.14. Cycasin

The cycasin content of the cycas seeds was estimated by the method suggested by Yagi *et al.* (1983).

One gram of cycas seed flour was taken and extracted with 70 per cent ethanol. The extract was diluted four times with water and 10 µl of an aqueous solution of sulfosalicylic acid (250 mg/ml) was further added. After standing for 10 min at 0º C, the sample was passed through a membrane filter. A portion (10 to 30 µl) of the filtrate was applied to column for chromatography. The absorbance of the effluent was recorded at 215 nm. Methyl β-D glucopyranoside was used as the standard.

3.3.15. Hydrocyanic acid

The hydrocyanic acid content of the cycas seeds was estimated by the method suggested by Sadasivam and Manickam (1992).

One gram of sample was homogenised in 25 ml water with 3-4 drops of chloroform and the homogenate was placed in 500 ml conical flask. A filter paper cut in to strips of 10-12 cm long and 0.5 cm wide was saturated with alkaline picrate solution. The saturated filter paper was placed in the conical flask in hanging position with the help of the cork stopper and incubated at 20°C for 24 hours. Then, the filter paper was placed in a test tube containing 10 ml distilled water to elute the colour and absorbance was measured at 625 nm. Potassium cyanide was used as the standard.

3.4. Statistical analysis

Analysis of variance was performed in the data obtained using statistical package 'MSTAT' (Freed, 1986). The means were compared by using Duncan's Multiple Range Test (DMRT).

RESULTS

4. RESULTS

The results pertaining to the study entitled **"Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)"** are presented under the following headings.

4.1. Nutritive value of cycas seed flour
4.2. Effect of processing on the nutritive value of cycas seed flour
4.3. Antinutritional and toxic factors in cycas seed flour and the effect of processing on these factors

4.1. Nutritive value of cycas seed flour

The nutrients present in the flour of cycas seeds collected from forest and non forest areas were estimated with respect to moisture, protein, starch, total carbohydrate, crude fibre, fat, calcium, sodium, iron, zinc, phosphorous and potassium. The details on the nutritive value of the flour of cycas seeds collected from forest and non forest areas are given in Table 2.

The moisture content of the cycas flour prepared from the seeds collected from forest and non forest areas was found to be 10.74 g $100g^{-1}$.

The flour of cycas seeds collected from forest area had a protein content of 8.30 g $100g^{-1}$ while the samples collected from non forest area had a protein content of 8.50 g $100g^{-1}$.

The starch content of the flour of cycas seeds collected from forest and non forest areas were found to be 54.45 g and 51.90 g $100g^{-1}$ respectively.

The total carbohydrate content of the flour of cycas was found to be 74.33 g and 72.17 g $100g^{-1}$ in the samples collected from forest and non forest areas respectively.

Table 2. Nutritive value of the flour of cycas seeds collected from forest and non forest areas ($100g^{-1}$)

Constituents	Forest	Non forest
Moisture (g)	10.74	10.74
Protein (g)	8.30	8.50
Starch (g)	54.45	51.90
Total carbohydrate (g)	74.33	72.17
Crude fibre (g)	2.83	2.58
Fat (g)	4.42	4.70
Calcium (mg)	17.03	15.22
Phosphorous (mg)	0	0
Sodium (mg)	18.87	8.87
Potassium (mg)	494.30	276.43
Iron (mg)	1.89	1.79
Zinc (mg)	0.63	0.56

The crude fibre content of the flour of cycas seeds varied from 2.58 g to 2.83 g $100g^{-1}$ in the seeds collected from non forest and forest areas respectively.

The raw cycas seed flour had 4.42 g $100g^{-1}$ fat in samples collected from forest area and 4.70 g $100g^{-1}$in the seeds collected from non forest area.

The calcium content of the flour of cycas seeds collected from forest area was found to be 17.03 mg $100g^{-1}$, while in non forest samples the flour had a calcium content of 15.22 mg $100g^{-1}$.

Phosphorous content was not observed in the flour of cycas seeds collected from forest and non forest areas.

The flour of cycas seeds collected from forest and non forest areas had 18.87 mg and 8.87 mg $100g^{-1}$ of sodium.

The potassium content of the cycas flour was found to be 494.30 mg and 276.43 mg $100g^{-1}$ in the seeds collected from forest and non forest areas.

The iron content of cycas seed flour was found to be 1.89 mg and 1.79 mg $100g^{-1}$ in the samples collected from forest and non forest areas respectively

The zinc content of the flour of cycas seeds collected from forest and non forest areas was found to be 0.63 mg and 0.56 mg $100g^{-1}$ respectively.

4.2. Effect of processing on the nutritive value of cycas seed flour

4.2.1. Moisture

The moisture content of the cycas seed flour was assessed and measured in g per 100g. The moisture content of the flour of processed cycas seeds varied from 10.36 g (T_6) to 10.79 g (T_4) in samples collected from forest areas and 10.81 g (T_1) to 11.16 g (T_2) in samples collected from non forest areas.

The effect of processing on the moisture content of the flour of cycas seeds collected from forest and non forest areas are furnished in Table 3.

In the flour of processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the moisture content was found to be 10.77 g and 10.56 g respectively in forest samples. In non forest samples the moisture content was found to be 10.81 g and 11.16 g in the same treatments. Cycas seeds soaked in cold water for 12 hours (T_3) and 24 hours (T_4) and then soaked in boiling water for two hours, the moisture content was found to be 10.40 g and 10.79 g in forest samples and

Table 3. Effect of processing on the moisture content of cycas seed flour (g $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	10.74^{abcd}	10.74^{abcd}
T_1	10.77^{abcd}	10.81^{abcd}
T_2	10.56^{bcd}	11.16^{a}
T_3	10.40^{d}	11.08^{a}
T_4	10.79^{abcd}	10.86^{abc}
T_5	10.46^{cd}	10.93^{ab}
T_6	10.36^{d}	11.03^{a}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

11.08 g and 10.86 g in non forest samples. In T_5 and T_6 which were soaked in cold water for 12 hours and 24 hours and then powdered and washed in water three times,

the moisture content was found to be 10.46 g and 10.36 g in forest samples and 10.93 g and 11.03 g in non forest samples. The moisture content observed in T_1 and T_2; T_3 and T_4; T_5 and T_6 were found to be statistically insignificant in samples collected both from forest and non forest areas.

The effect of different processing methods on the moisture content of the flour of cycas seeds is shown in the Fig.1.

Among the different processing treatments employed, the moisture content was found to be high in T_4, and T_0 and T_1 were found to be on par with T_4 in forest samples and in non forest samples high moisture content was observed in T_2 and all the other treatments were on par with T_2. Significant variation in the moisture content of the processed cycas seed flour was observed between the samples collected from forest and non forest areas in the treatments T_2, T_3, T_5 and T_6.

4.2.2. Protein

The protein content is represented in g per 100g of cycas flour. The protein content of the flour of processed cycas seeds varied from 6.90 g to 7.90 g in samples collected from forest areas and 7.55 g to 8.17 g in samples collected from non forest areas.

The effect of processing on the protein content of the flour of cycas seeds collected from forest and non forest areas is furnished in Table 4 and Fig.2.

In the flour of processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the protein content was found to be 7.90 g and 7.27 g respectively in samples collected from forest areas and 8.17 g and 7.97 g in samples

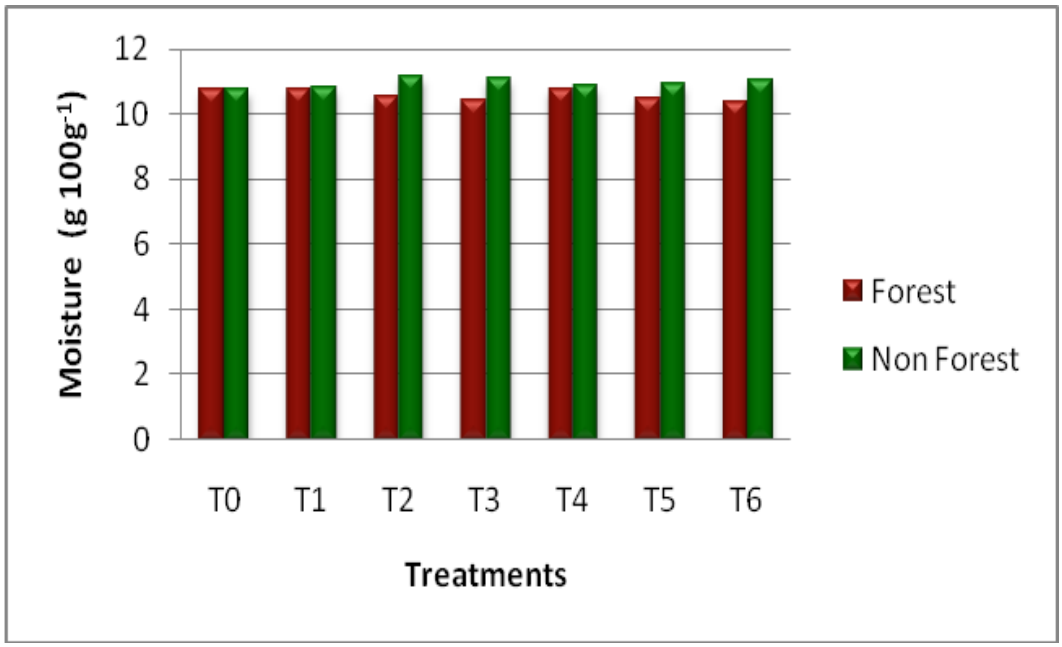

Fig.1. Effect of processing on the moisture content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

Table 4. Effect of processing on the protein content of cycas seed flour

(g $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	8.30^{ab}	8.50^{a}
T_1	7.90^{abcd}	8.17^{abc}
T_2	7.27^{cd}	7.97^{abc}
T_3	7.62^{abcd}	8.07^{abc}
T_4	7.23^{cd}	7.88^{abcd}
T_5	7.38^{bcd}	7.60^{abcd}
T_6	6.90^{d}	7.55^{abcd}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

collected from non forest areas. In the case of T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for two hours, the protein content was found to be 7.62 g and 7.23 g in seeds collected from forest area and 8.07 g and 7.88 g in seeds collected from non forest area. In the cycas seeds processed by soaking in cold water for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the protein content was found to be 7.38 g and 6.90 g in forest samples and 7.60 g and 7.55 g in non forest samples.

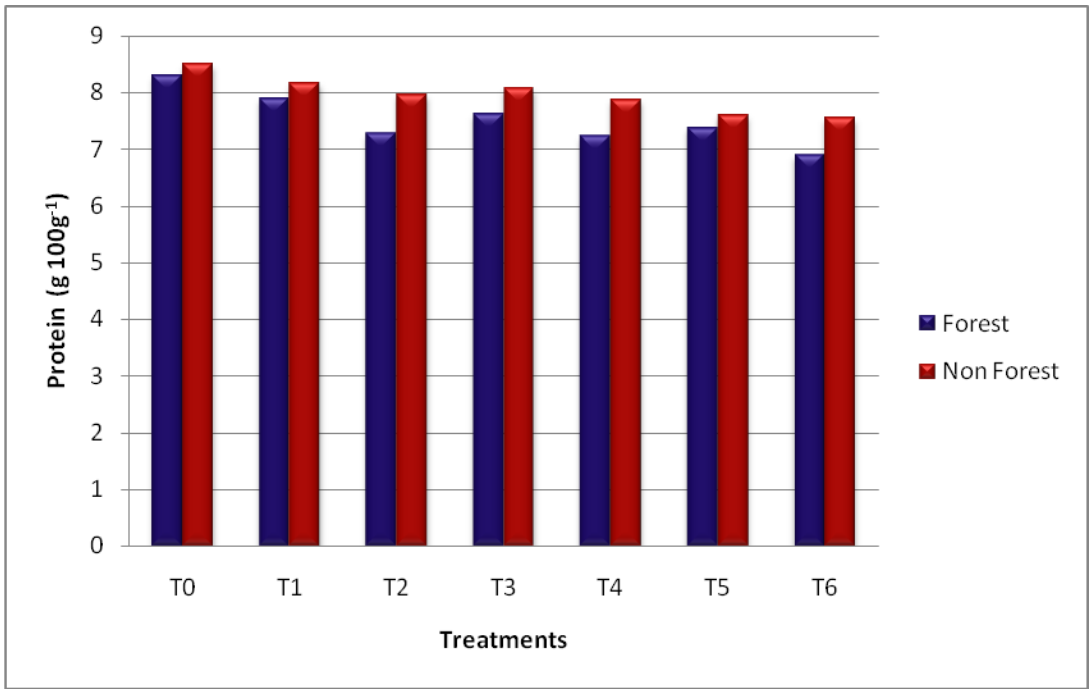

Fig.2. Effect of processing on the protein content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

The variation observed between the protein content of T_1 and T_2; T_3 and T_4; T_5 and T_6 was found to be statistically insignificant in samples collected both from forest and non forest areas.

Among the different processing treatments employed, the protein content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours (T_1) both in forest and non forest samples and T_0 and T_3 were found to be on par with T_1. In non forest samples also the highest protein content was noticed in T_1 and the variation observed in the protein content of the flour of cycas seeds prepared by other processing methods was found to be statistically insignificant. The variation noticed in the protein content of dried cycas seeds (control) as well as processed samples collected from forest and non forest areas were found to be statistically insignificant.

4.2.3. Starch

The starch content of cycas seed flour is measured in g per 100g of the flour. In the processed cycas seeds, the flour had a starch content in the range of 36.75 g to 52.50 g in seeds collected from forest area and 33.60 g to 51.30 g in seeds collected from non forest area.

The effect of processing on the starch content of the flour of cycas seeds collected from forest and non forest areas are furnished in Table 5.

In the flour of cycas seeds soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the starch content was found to be 52.50 g and 50.10 g, in samples collected from forest areas. In the case of non forest samples the starch content was found to be 51.30 g and 46.20 g in the same treatments. In treatments T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for

Table 5. Effect of processing on the starch content of cycas seed flour (g $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	54.45^{a}	51.90^{bc}
T_1	52.50^{b}	51.30^{c}
T_2	50.10^{d}	46.20^{ef}
T_3	46.95^{e}	41.40^{g}
T_4	45.30^{f}	40.05^{h}
T_5	40.95^{gh}	36.60^{i}
T_6	36.75^{i}	33.60^{j}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

two hours, the starch content was found to be 46.95 g and 45.30 g in the seeds collected from forest areas and 41.40 g and 40.05 g in seeds collected from non forest areas. In the flour of cycas seeds soaked in cold water for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the starch content varied from 40.95 g and 36.75 g in forest samples and from 36.60 g and 33.60 g in non forest samples. The variation observed between the starch content of T_1 and T_2; T_3 and T_4; T_5 and T_6 were found to be statistically significant in both forest and non forest samples. The starch content of the flour of cycas seeds processed by different methods varied significantly from the unprocessed cycas seeds collected both from forest and non forest areas except T_1 which was collected from non forest areas and processed by soaking the seeds in water for 12 hours.

The effect of different processing methods on the starch content of the flour of cycas seeds is shown in the Fig.3.

Among the different processing treatments employed, the starch content was found to be high in seeds soaked in cold water for 12 hours which were collected from forest as well as non forest areas. Significant variation was observed in the starch content of the flour of processed and unprocessed cycas seeds collected from forest and non forest areas.

4.2.4. Total carbohydrate

The total carbohydrate content of the flour of processed cycas seeds collected from forest and non forest areas are furnished in Table 6. The total carbohydrate content of each treatment is represented in g per 100g.

In the flour of processed cycas seeds, the total carbohydrate content varied from 49.50 g to 65.67 g in seeds collected from forest areas and 37.33 g to 62.17 g in seeds collected from non forest areas.

In the flour of processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the total carbohydrate content was found to be 65.67 g and 62.33 g respectively in the samples collected from forest areas and 62.17 g and 59.50 g in samples collected from non forest areas. In the case of T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for two hours, the total carbohydrate content was found to be 58.83 g and 55.33 g in the seeds collected from forest areas and 50.33 g and 45.17 g in seeds collected from non forest areas. In T_5 and T_6 which were soaked in cold water for 12 hours and 24 hours and then powdered and washed in water three times, the total carbohydrate

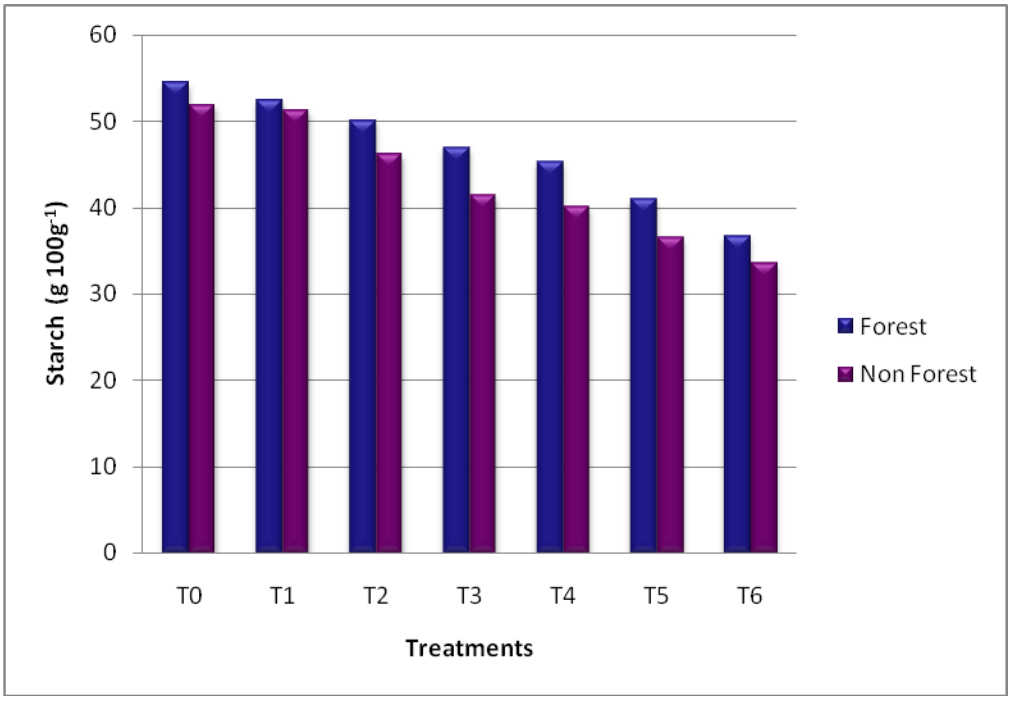

Fig.3. Effect of processing on the starch content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

Table 6. Effect of processing on the total carbohydrate content of cycas seed flour (g $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	74.33^a	72.17^a
T_1	65.67^b	62.17^c
T_2	62.33^c	59.50^d
T_3	58.83^d	50.33^f
T_4	55.33^e	45.17^g
T_5	51.83^f	41.00^h
T_6	49.50^f	37.33^i

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

content was found to be 51.83 g and 49.50 g in seeds collected from forest areas and 41.00 g and 37.33 g in the seeds collected from non forest areas. The variation observed in the total carbohydrate content of T_1 and T_2; T_3 and T_4; and T_5 and T_6 was also found to be statistically significant in the flour of cycas seeds collected both from forest and non forest areas except T_5 and T_6 in forest samples.

The effect of different processing methods on the total carbohydrate content of the flour of cycas seeds is shown in Fig.4.

Among the different processing treatments employed, the total carbohydrate content was found to be high in the flour of seeds soaked in cold water for 12 hours collected both from forest and non forest areas. The variation observed between the

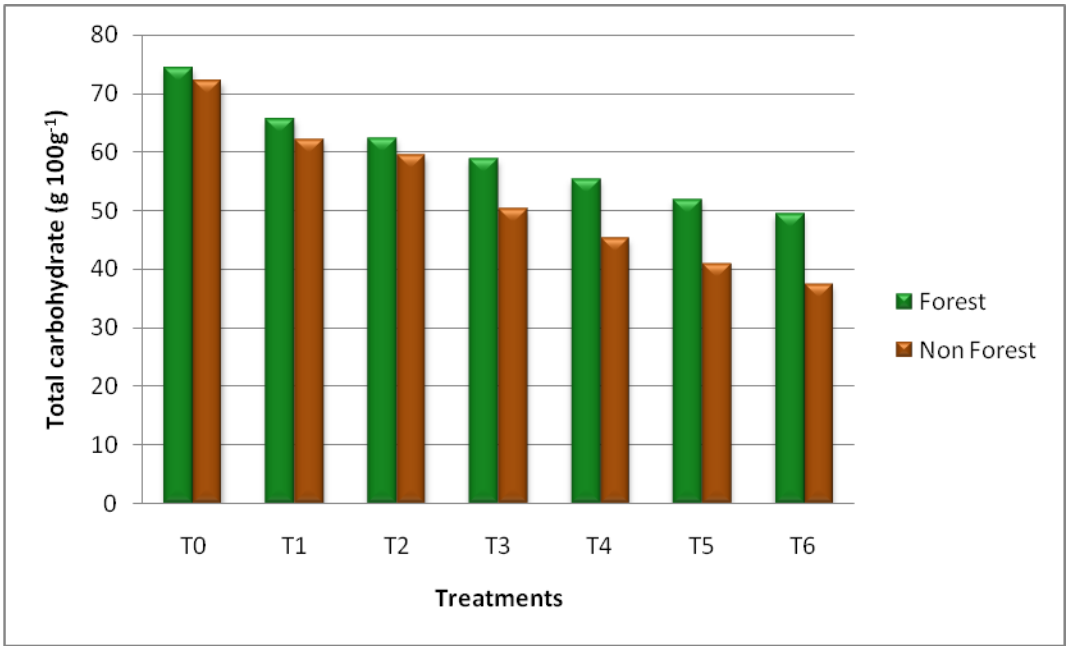

Fig.4. Effect of processing on the total carbohydrate content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

total carbohydrate content of the flour of unprocessed cycas seeds (T_0) collected from forest and non forest areas was found to be statistically insignificant. However, significant variation was noticed in the total carbohydrate content of the flour of processed cycas seeds (T_1 to T_6) collected both from forest and non forest areas.

4.2.5. Crude fibre

The effect of processing on the crude fibre content of the flour of cycas seeds collected from forest and non forest are furnished in Table 7. The crude fibre content of the cycas seed flour is represented in g per 100g.

The crude fibre content in the flour of processed cycas seeds varied from 1.50 g to 2.25 g in samples collected from forest and non forest areas.

In the processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the crude fibre content was found to be 2.25 g and 1.92 g in samples collected from forest areas and 2.25 g and 2.17 g in samples collected from non forest areas. In the case of T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for two hours, the crude fibre content was found to be 1.67 g and 1.50 g in seeds collected from forest areas and 1.83 g and 1.50 g in the seeds collected from non forest areas. Cycas seeds processed by soaking in cold water for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the crude fibre content was found to be 1.92 g and 1.67 g in forest samples and 2.08 g and 1.92 g in non forest samples. The variation observed between the crude fibre content of T_1 and T_2; T_3 and T_4; T_5 and T_6 were found to be statistically insignificant in both forest and non forest samples.

Table 7. Effect of processing on the crude fibre content of cycas seed flour (g $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	2.83^{a}	2.58^{ab}
T_1	2.25^{abc}	2.25^{abc}
T_2	1.92^{cd}	2.17^{bc}
T_3	1.67^{cd}	1.83^{cd}
T_4	1.50^{d}	1.50^{d}
T_5	1.92^{cd}	2.08^{bcd}
T_6	1.67^{cd}	1.92^{cd}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

The effect of different processing methods on the crude fibre content of the flour of cycas seeds is shown in the Fig.5.

Among the different processing treatments employed, the crude fibre content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours which were collected both from forest and non forest areas and was found to be on par with the flour of unprocessed dried cycas seeds (T_0). The crude fibre content of the flour of cycas seeds collected from forest and non forest areas was also found to be statistically insignificant both in processed and unprocessed samples.

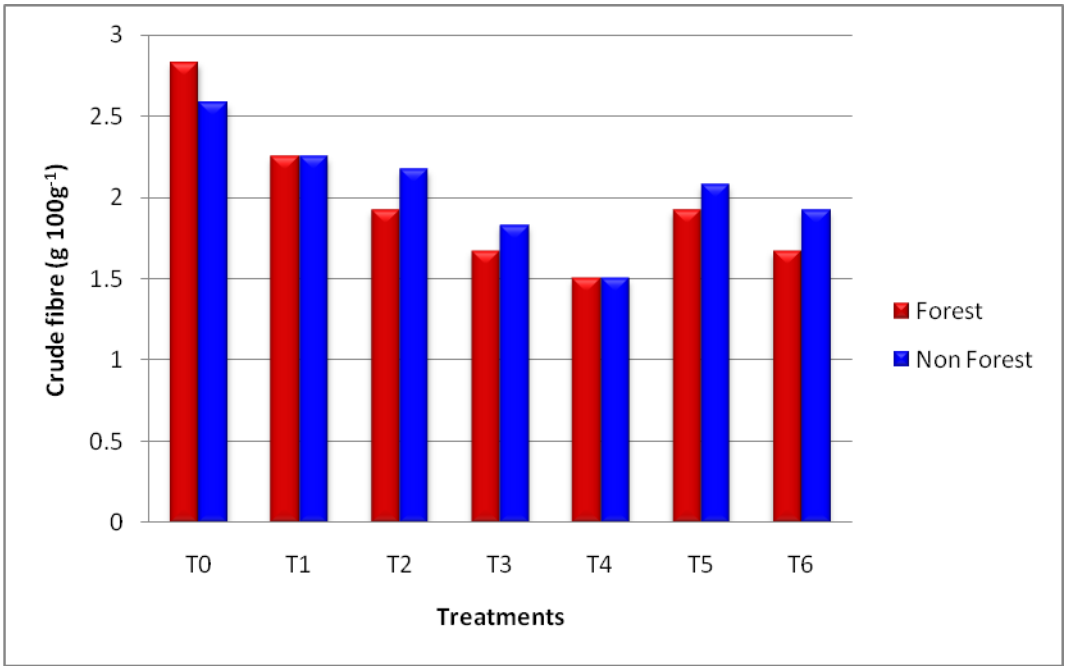

Fig.5. Effect of processing on the crude fibre content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

4.2.6. Fat

The effect of processing on the fat content of the flour of cycas seeds collected from forest and non forest areas are furnished in Table 8. The fat content is measured in g per 100g.

In the processed cycas seed flour, the fat content varied from 3.00 g to 3.83 g in samples collected from forest areas and 2.67 g to 4.33 g in samples collected from non forest areas.

Table 8. Effect of processing on the fat content of cycas seed flour ($g\ 100g^{-1}$)

Treatments	Forest	Non Forest
T_0	4.42^{ab}	4.70^{a}
T_1	3.83^{bcde}	4.33^{abc}
T_2	3.75^{bcdef}	4.00^{abcd}
T_3	3.25^{defg}	3.83^{bcde}
T_4	3.17^{efg}	3.58^{cdef}
T_5	3.08^{efg}	2.75^{g}
T_6	3.00^{fg}	2.67^{g}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 - T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

In the flour of processed cycas seeds which was soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the fat content was found to be 3.83 g and 3.75 g

respectively in samples collected from forest areas. In the case of non forest samples the fat content was found to be 4.33 g and 4.00 g in the same treatments. In the cycas seeds soaked in cold water for 12 hours (T_3) and 24 hours (T_4) and then soaked in boiling water for two hours, the fat content was found to be 3.25 g and 3.17 g in forest samples and 3.83 g and 3.58 g in non forest samples. In the flour of cycas seeds which were soaked in cold water for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the fat content was found to be 3.08 g and 3.00 g in forest samples and 2.75 g and 2.67 g in samples collected from non forest areas. The variation observed in the fat content of T_1 and T_2; T_3 and T_4; T_5 and T_6 were found to be statistically insignificant in the cycas seeds collected both from forest and non forest areas.

The effect of different processing methods on the fat content of the flour of cycas seeds is shown in the Fig.6.

Among the different processing treatments employed, the fat content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours (T_1) both in forest and non forest samples and T_0 was found to be on par with T_1. The variation observed between the fat content of the flour of cycas seeds collected from forest and non forest areas was found to be statistically insignificant.

4.2.7. Calcium

The effect of processing on the calcium content of the flour of cycas seeds collected from forest and non forest areas are furnished in Table 9. The calcium content was measured in mg per100g.

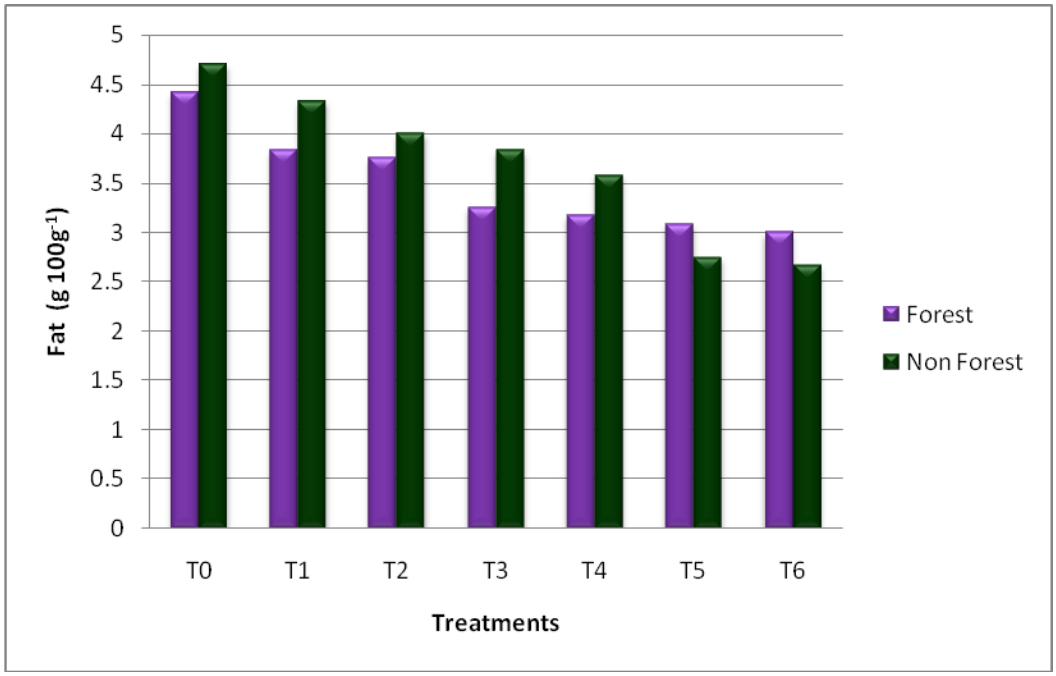

Fig.6. Effect of processing on the fat content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

The calcium content of the flour of processed cycas seeds varied from 9.00 mg to 14.10 mg in seeds collected from forest areas and 7.53 mg to 12.12 mg in seeds collected from non forest areas.

Table 9. Effect of processing on the calcium content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	17.03^{a}	15.22^{b}
T_1	14.10^{c}	12.12^{d}
T_2	12.07^{d}	10.20^{fg}
T_3	11.30^{de}	9.93^{fgh}
T_4	10.52^{ef}	9.30^{gh}
T_5	9.78^{fgh}	8.23^{ij}
T_6	9.00^{hi}	7.53^{j}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).
T_1 - Soaked in cold water for 12 hours.
T_2 - Soaked in cold water for 24 hours.
T_3 - T_1 + Soaked in boiling water for 2 hours.
T_4 -T_2 + Soaked in boiling water for 2 hours.
T_5 - T_1 + Powdered and washed in water three times.
T_6 - T_2 + Powdered and washed in water three times

In the flour of processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the calcium content was found to be 14.10 mg and 12.07 mg respectively in samples collected from forest areas and 12.12 mg and 10.20 mg in samples collected from non forest areas. In the case of T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for two hours, the calcium content was found to be 11.03 mg and 10.52 mg in seeds collected from forest areas and 9.93 mg and 9.30 mg in seeds collected from non forest areas. In the flour of cycas seeds soaked in cold water for 12 hours (T_5) and 24

hours (T_6) and then powdered and washed in water three times, the calcium content was found to be 9.78 mg and 9.00 mg in forest samples and 8.23 mg and 7.53 mg in non forest samples. The decrease observed in the calcium content of cycas seeds during processing over the raw seeds was found to be statistically significant both in forest and non forest samples

The effect of different processing methods on the calcium content of the flour of cycas seeds is shown in the Fig.7.

Among the different processing treatments employed, the calcium content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours in both forest and non forest samples. The variation observed in the calcium content of the processed and the unprocessed cycas seeds between the forest and non forest samples were found to be statistically significant.

4.2.8. Sodium

The sodium content of the flour of cycas seeds collected from forest and non forest areas as well as the effect of processing on the sodium content are furnished in Table 10. The sodium content is represented in mg per 100g.

In the flour of processed cycas seeds, the sodium content varied from 7.73 mg to 18.87 mg in samples collected from forest areas and 6.40 mg to 8.00 mg in samples collected from non forest areas.

In the processed cycas seed flour, which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the sodium content was found to be 18.87 mg and 16.60 mg respectively in samples collected from forest areas and 8.00 mg and 7.10 mg in samples collected from non forest areas. In the case of T_3 and T_4 which were soaked

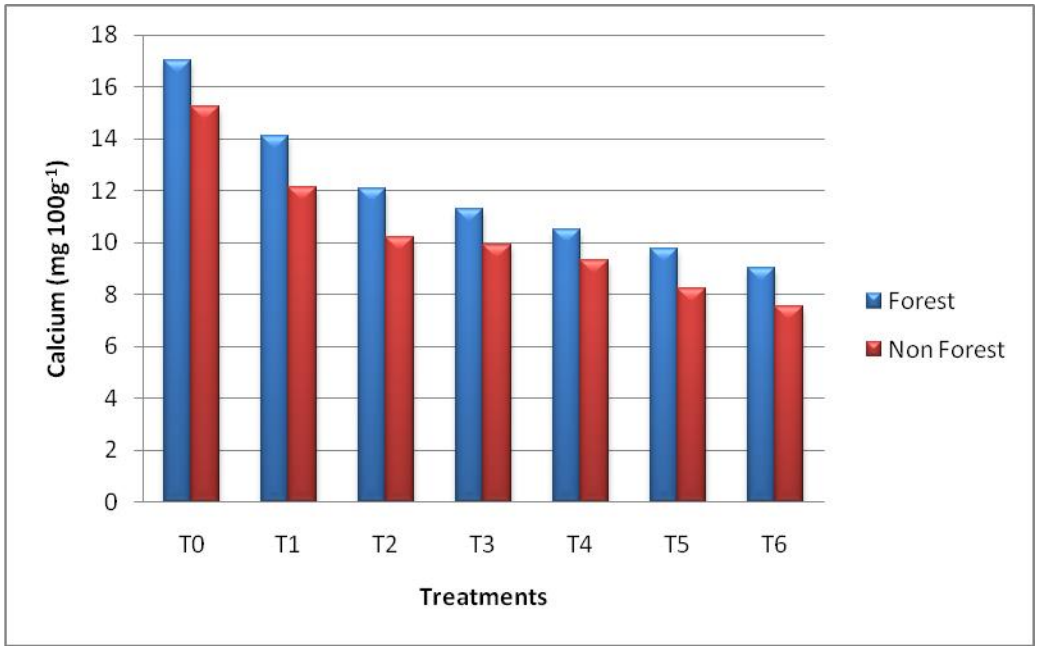

Fig.7. Effect of processing on the calcium content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

in cold water for 12 and 24 hours and then soaked in boiling water for two hours, the sodium content was found to be 13.30 mg and 7.73 mg in seeds collected from forest

Table 10. Effect of processing on the sodium content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	18.87^{a}	8.87^{cd}
T_1	18.87^{a}	8.00^{cd}
T_2	16.60^{a}	7.10^{cd}
T_3	13.30^{b}	8.00^{cd}
T_4	7.73^{cd}	6.63^{d}
T_5	10.40^{bc}	7.30^{cd}
T_6	8.63^{cd}	6.40^{d}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

areas and 8.00 mg and 6.63 mg in seeds collected from non forest areas. In the flour of cycas seeds which were soaked in cold water for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the sodium content was found to be 10.40 mg and 8.63 mg in forest samples and 7.30 mg and 6.40 mg in non forest samples. The variation observed between T_1 and T_2 and T_5 and T_6 were found to be statistically insignificant in cycas seeds collected both from forest and non forest areas. However, significant variation was noticed in the sodium content of T_3 and T_4 collected from forest areas.

The effect of processing on the sodium content of the flour of cycas seeds is shown in the Fig.8.

Among the different processing treatments employed, the sodium content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours (T_1), and T_0 and T_2 were found to be on par with T_1 collected from forest areas. In non forest samples also highest sodium was present in T_1 and T_0, T_2, T_3, T_4, T_5 and T_6 were found to be on par. Significant variation between the sodium content of the flour of cycas seeds collected from forest and non forest areas were observed in unprocessed cycas seeds (T_0) as well as in T_1, T_2 and T_3. In all others the variation was found to be statistically insignificant.

4.2.9. Potassium

The effect of processing cycas seeds on the potassium content are furnished in Table 11. The potassium content of the samples are represented in mg per 100g.

In the processed cycas seeds, the potassium content varied from 0.44 mg to 154.40 mg in samples collected from forest areas and 3.53 mg to 105.53 mg in samples collected from non forest areas.

In the cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the potassium content was found to be 154.40 mg and 76.63 mg respectively in forest samples and 105.53 mg and 74.40 mg in non forest samples. Cycas seeds which were soaked in cold water for 12 hours (T_3) and 24 hours (T_4) and then soaked in boiling water for two hours, the potassium content was found to be 98.83 mg and 79.53 mg in seeds collected from forest areas and 71.10 mg and 17.77 mg in seeds collected from non forest areas. In T_5 and T_6 which were soaked in cold water for 12 hours and 24 hours and then powdered and washed in water three times,

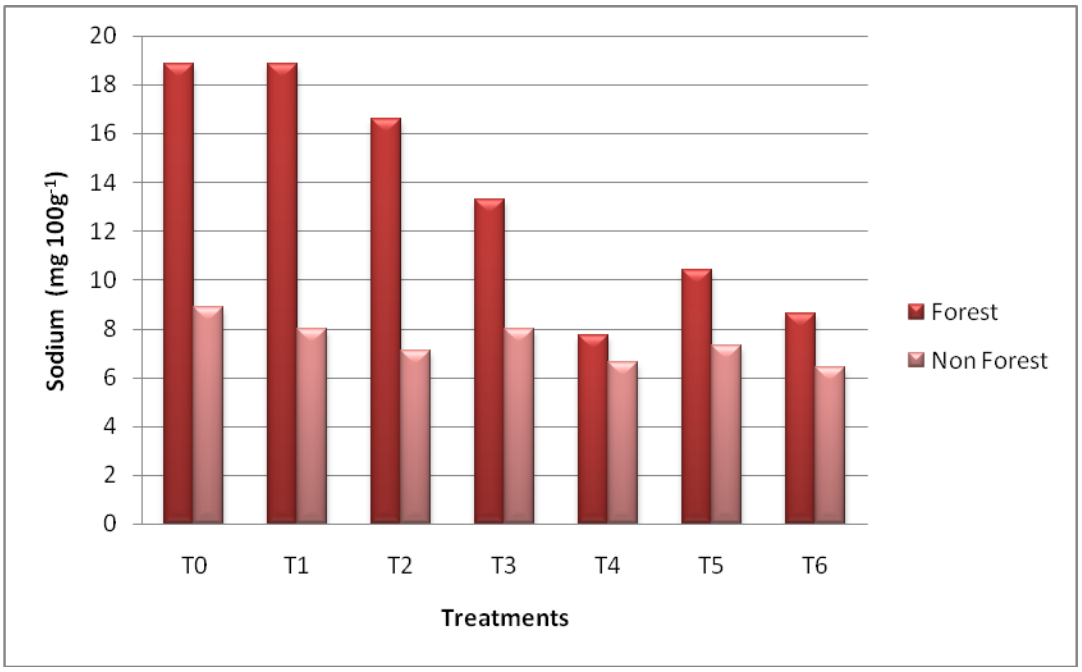

Fig.8. Effect of processing on the sodium content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

the potassium content was found to be 8.87 mg and 0.44 mg in forest samples and 6.40 mg and 3.53 mg in non forest samples.

Table 11. Effect of processing on the potassium content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	494.30^a	276.43^b
T_1	154.40^c	105.53^d
T_2	76.63^d	74.40^d
T_3	98.83^d	71.10^d
T_4	79.53^d	17.77^e
T_5	8.87^e	6.40^e
T_6	0.44^e	3.53^e

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

The potassium content varied significantly in the processed cycas seeds soaked for 12 and 24 hours which were collected from forest areas, whereas the variation observed was found to be statistically insignificant in T_3 and T_4; as well as in T_5 and T_6. In non forest samples, the potassium content varied significantly in T_3 and T_4 which were processed by soaking in boiled water for two hours after soaking in cold water for 12 and 24 hours respectively.

The effect of different processing methods on the potassium content of the flour of cycas seeds are shown in the Fig.9.

Among the different processing treatments employed, the potassium content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours, which were collected both from forest and non forest areas. The variation between potassium content of cycas seeds collected from forest and non forest areas were found to be statistically significant only in treatments T_0, T_1, and T_4.

4.2.10. Iron

The iron content of the flour of cycas seeds collected from forest and non forest areas as well as the effect of processing on the iron content are furnished in Table 12.The iron content of the flour of cycas seed flour is represented in mg per 100g.

The iron content of the flour of processed cycas seeds collected from forest and non forest areas were found to be in the range of 1.31 mg and 1.82 mg in samples collected from forest areas and 1.22 mg and 1.66 mg in samples collected from non forest areas.

In the processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2), the iron content was found to be 1.82 mg and 1.73 mg respectively in samples collected from forest areas. In the case of non forest samples, the iron content was found to be 1.66 mg and 1.57 mg in the same treatments. In the case of T_3 and T_4 which were soaked in cold water for 12 hours and 24 hours and then soaked in boiling water for two hours, the iron content was found to be 1.62 mg and 1.56 mg in seeds collected from forest areas and 1.43 mg and 1.39 mg in seeds collected from non forest areas. In the cycas seeds processed by soaking in cold water

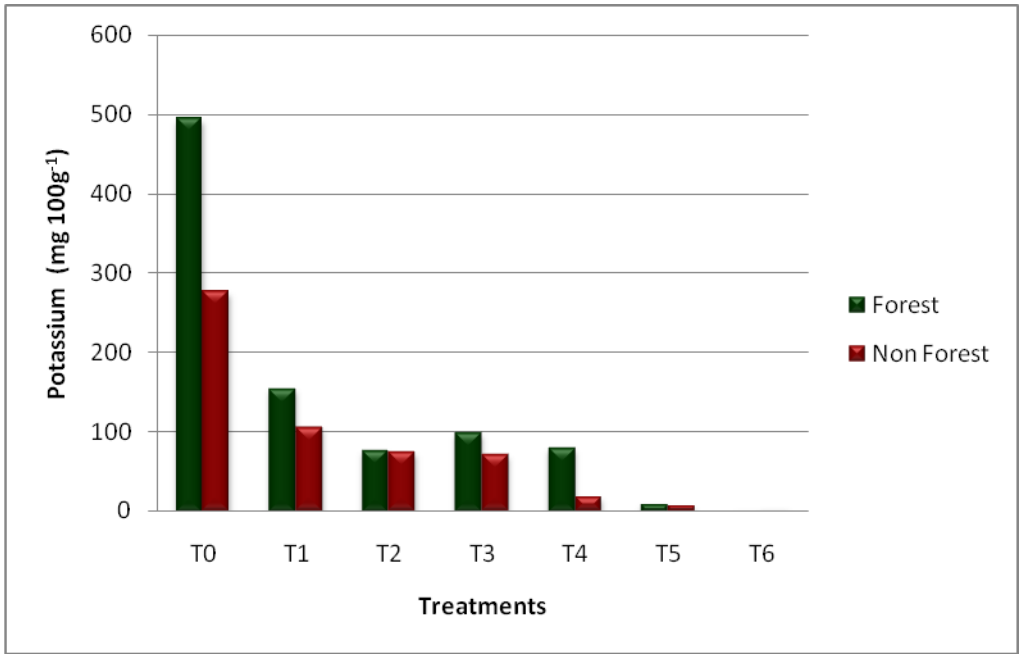

Fig.9. Effect of processing on the potassium content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

Table 12. Effect of processing on the iron content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	1.89	1.79
T_1	1.82	1.66
T_2	1.73	1.57
T_3	1.62	1.43
T_4	1.56	1.39
T_5	1.39	1.31
T_6	1.31	1.22

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 -T_1 + Powdered and washed in water three times.

T_6-T_2 + Powdered and washed in water three times.

for 12 hours (T_5) and 24 hours (T_6) and then powdered and washed in water three times, the iron content was found to be 1.39 mg and 1.31 mg in forest samples and 1.31 mg and 1.22 mg in non forest samples.

The effect of different processing methods on the iron content of the flour of cycas seeds is shown in the Fig.10. Among the different processing treatments employed the iron content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours which were collected both from forest and non forest areas.

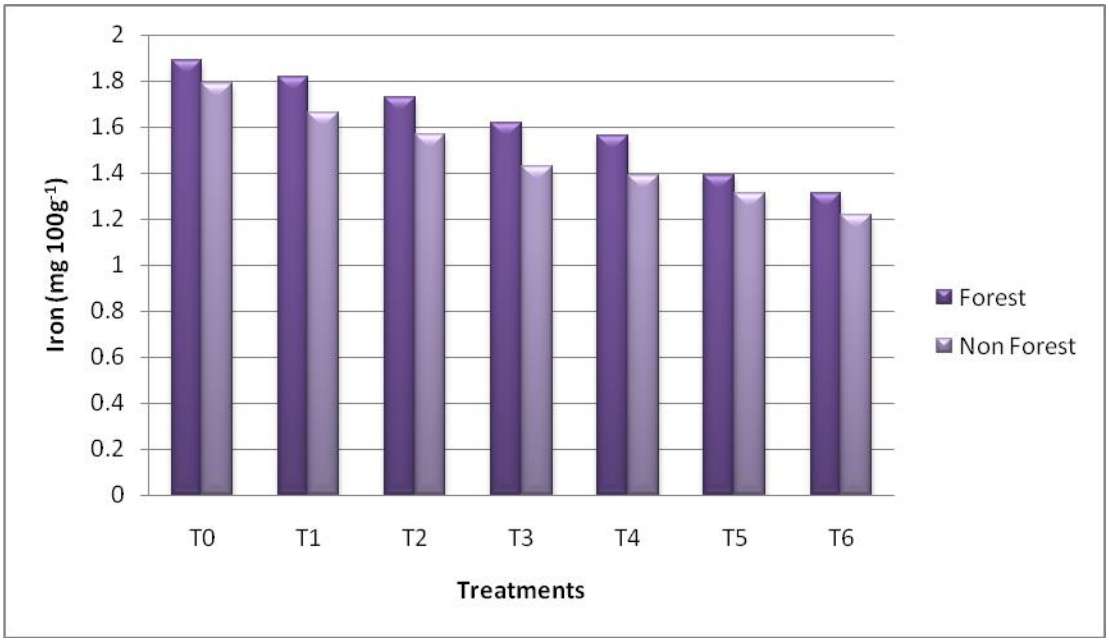

Fig.10. Effect of processing on the iron content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

4.2.11. Zinc

The zinc content of cycas seed flour was assessed and is represented in mg per 100g. The zinc content of the flour of cycas seeds collected from forest and non forest areas as well as the effect of processing on the zinc content are furnished in Table 13.

The zinc content of the flour of processed cycas seeds collected from forest and non forest areas varied from 0.23 mg to 0.54 mg in samples collected from forest areas and 0.23 mg to 0.50 mg in samples collected from non forest areas.

Table 13. Effect of processing on the zinc content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	0.63	0.56
T_1	0.54	0.50
T_2	0.46	0.47
T_3	0.41	0.38
T_4	0.37	0.33
T_5	0.31	0.28
T_6	0.23	0.23

T_0 - Dried cycas seeds (control).
T_1 - Soaked in cold water for 12 hours.
T_2 - Soaked in cold water for 24 hours.
T_3 - T_1 + Soaked in boiling water for 2 hours.
T_4 - T_2 + Soaked in boiling water for 2 hours.
T_5 - T_1 + Powdered and washed in water three times.
T_6 - T_2 + Powdered and washed in water three times.

In the processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2) the zinc content were found to be 0.54 mg and 0.46 mg respectively in samples collected from forest areas. In the case of non forest samples

the zinc content was found to be 0.50 mg and 0.47 mg in the same treatments. In the flour of cycas seeds soaked in cold water for 12 hours (T_3) and 24 hours (T_4) and then soaked in boiling water for two hours, the zinc content was found to be 0.41 mg and 0.37 mg in seeds collected from forest areas and 0.38 mg and 0.33 mg in seeds collected from non forest areas. In T_5 and T_6 which were soaked in cold water for 12 hours and 24 hours and then powdered and washed in water three times, the zinc content was found to be 0.31 mg and 0.23 mg in forest samples and 0.28 mg and 0.23 mg in non forest samples.

The effect of different processing methods on the zinc content of the flour of cycas seeds is illustrated in the Fig.11. Among the different processing treatments employed the zinc content was found to be high in the flour of cycas seeds soaked in cold water for 12 hours which were collected both from forest and non forest areas.

4.3. Antinutritional and toxic factors in cycas seed flour and the effect of processing on these factors

4.3.1. Crude alkaloids

The crude alkaloid content of the flour of cycas seeds collected from forest and non forest areas as well as the effect of processing on the crude alkaloid content of the cycas seed flour are furnished in Table 14. The crude alkaloid content of cycas seeds are represented in mg $100g^{-1}$ of flour. The crude alkaloid content of the flour of cycas seeds collected from forest and non forest areas were found to be 1.56 mg and 1.69 mg respectively.

The variation observed in the crude alkaloid content of forest and non forest samples was found to be statistically significant. In the processed cycas seeds, the flour had crude alkaloid content in the range of 0.54 mg to 1.46 mg in samples

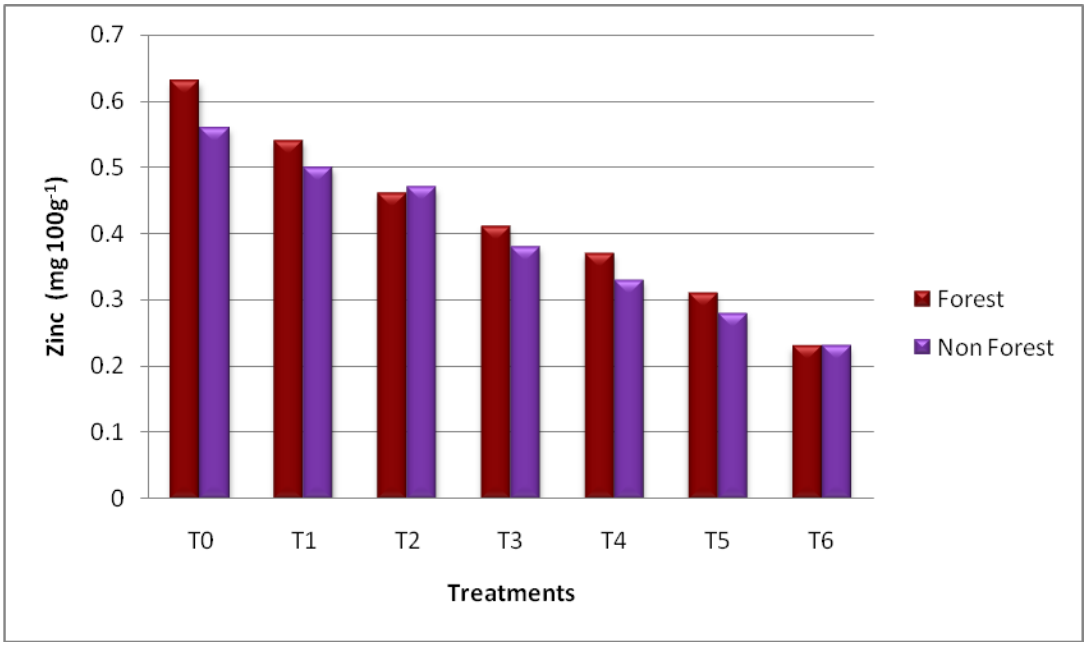

Fig.11. Effect of processing on the zinc content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

collected from forest areas and 0.66 mg to 1.40 mg in samples collected from non forest areas.

In the flour of processed cycas seeds which were soaked in cold water for 12 hours (T_1) and 24 hours (T_2) the crude alkaloid content was found to be 1.46 mg and 1.24 mg in samples collected from forest areas. In the case of T_3 and T_4 which were soaked in cold water for 12 and 24 hours respectively and then soaked in boiling water for two hours, the crude alkaloid content was found to be 1.00 mg and 0.87 mg in seeds collected from forest areas and 1.13 mg and 1.02 mg in seeds collected from non forest areas. In the cycas seeds processed by soaking in cold water for 12 hours

Table 14. Effect of processing on the crude alkaloid content of cycas seed flour (mg $100g^{-1}$)

Treatments	Forest	Non Forest
T_0	1.56^{a}	1.60^{b}
T_1	1.46^{ab}	1.40^{d}
T_2	1.24^{c}	1.20^{d}
T_3	1.00^{de}	1.13^{d}
T_4	0.87^{ef}	1.02^{e}
T_5	0.71^{fg}	0.80^{e}
T_6	0.54^{h}	0.66^{e}

Values with the same superscript do not differ significantly

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 -T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times

(T_5) and 24 hours (T_6) and then powdered and washed in water three times, the crude alkaloid content was found to be 0.71 mg and 0.54 mg in forest samples and 0.80 mg and 0.66 mg in non forest samples.

The effect of different processing methods on the crude alkaloid content of the flour of cycas seeds is shown in Fig.12.

Significant variation was found in the alkaloid content between T_1 and T_2; T_5 and T_6 in forest samples while in non forest samples significant variation in the alkaloid content was observed between T_3 and T_4. The variation observed in the alkaloid content of T_0, T_1, T_2, T_5 and T_6 between forest and non forest samples was found to be statistically significant.

4.3.2. Cycasin

Cycasin content in the cycas flour was determined by following the procedure as detailed in 3.3.14. The cycasin content could not be estimated using Methyl β- D glucopyranoside as standard.

4.3.3. Hydrocyanic acid

Hydrocyanic acid was not present in the processed and unprocessed flour of cycas seeds collected from forest and non forest areas.

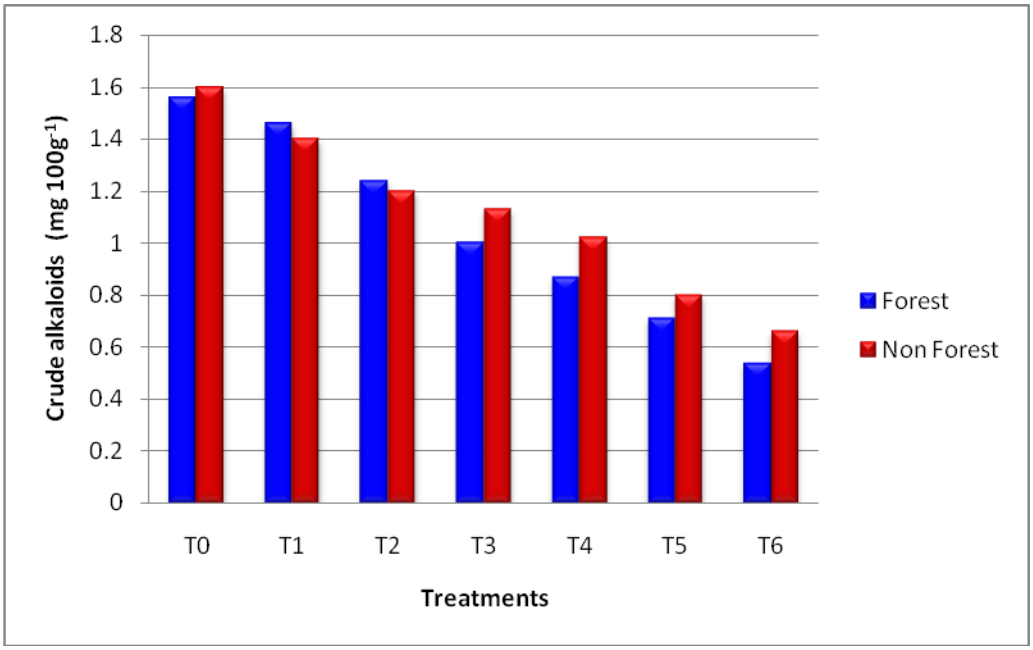

Fig.12. Effect of processing on the crude alkaloid content of cycas seed flour

T_0 - Dried cycas seeds (control).

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

$T_3 – T_1$ + Soaked in boiling water for 2 hours.

$T_4 – T_2$ + Soaked in boiling water for 2 hours.

$T_5 – T_1$ + Powdered and washed in water three times.

$T_6 – T_2$ + Powdered and washed in water three times.

DISCUSSION

5. DISCUSSION

The discussion pertaining to the study entitiled, "Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)" is presented in this section under the following headings.

5.1 Chemical constituents in cycas seed flour and the effect of processing on the chemical constituents

5.2. Selection of the most desirable processing method.

5.1 Chemical constituents in cycas seed flour and the effect of processing on the chemical constituents

The moisture content of the flour prepared from cycas seeds collected from forest and non forest areas were found to be uniform (10.74 g $100g^{-1}$). Studies conducted by Blessing and Gregory (2010) also indicated almost similar moisture content of 10.25 g $100g^{-1}$ in raw mung bean flour. However, Bhatty *et al.* (2000) and Mubarak (2005) reported a lower moisture content of 8.25 g $100g^{-1}$ in raw pulses. Sat and Keles (2002) also observed a lower moisture content of 9.61 g $100g^{-1}$ in the dry bean variety of *P. vulgaris*.

The moisture content of cycas flour prepared after processing the seeds collected from forest areas varied from 10.36 g in T_6 to 10.79 g $100g^{-1}$ in T_4. Thus, only a slight increase of 0.28 to 0.47 per cent in the moisture content over the raw seeds was seen in the processed cycas seeds collected from forest areas (Table 15). In the case of non forest samples the moisture content varied from 10.81 g (T_1) to 11.16 g $100g^{-1}$ (T_2). Here also, only a slight increase in the moisture content from 0.65 to 3.91 per cent was noticed in the flour prepared after processing (Table15). Thus, the moisture content of the flour prepared from unprocessed cycas seeds as well as processed cycas seeds were found to be almost same. Statistically also, the moisture content of all treatments were found to be on par with raw seeds. In the present study, the flour of processed and unprocessed cycas seeds were prepared by drying the flour so as to attain a uniform moisture

content in the range of 10 to 12 per cent. This might be the reason for not observing any significant variation in the moisture content of raw cycas seed flour and those prepared by different processing methods. However, in certain processing treatments, a decrease of 1.68 to 3.54 per cent moisture was observed as in the case of T_2, T_3, T_5 and T_6 in samples collected from forest areas. Studies conducted by Bau *et al*. (1997) and Mubarak (2005) indicated a slight increase in the moisture content of soybean flour and mung bean flour due to processing. The authors attributed this increase in the moisture content due to hydration of seeds during soaking. Various studies conducted by Chakraborty (1993); Bhagya *et al*. (2007); Ghavidel and Prakash (2007); Khattak *et al.* (2007) and Kakati *et al.* (2010) also reported an increase in the moisture content of pulses during soaking. As reported by the above authors, a slight increase in the moisture content of the cycas flour was noticed in almost all the processed samples when compared to the raw seeds except in T_2, T_3, T_5 and T_6 of forest samples. The decrease observed in the moisture content of T_2, T_3, T_5 and T_6 might be due to the prolonged time taken while drying the flour. Blesssing and Gregory (2010) also indicated a drastic and significant decrease in the moisture content of mung bean due to toasting.

The flour of cycas seeds collected from forest and non forest areas had a protein content of 8.30 and 8.50 g $100g^{-1}$ respectively. Though, slightly higher protein content was noticed in the cycas seeds collected from non forest areas, the variation was found to be statistically insignificant. The protein content of the flour of cycas seeds (*Cycas circinalis*) in the present study was found to be higher than the protein content of 5.8 and 5.1 g $100g^{-1}$ observed by Harris (1975) in the raw seeds of *Cycas cairnsiana* and *Cycas media* respectively. Beck (1992) and Miller *et al.* (1993) also observed relatively low protein content of 5 g and 5.8 g $100g^{-1}$ respectively in raw cycas seeds. This variation might be due to the difference in the cultivars selected for the study and the variation in the environmental factors, soil nutrition, nutrient uptake and efficiency of plants to accumulate nutrients from soil as reported by Gupta (1983); Singh (1985); Brennan (2006) and Ragab *et al*. (2010). Cemeroglu and Acar (1986) also

indicated variations in nutrients due to factors like ecological aspects, soil qualities, cultivation techniques, maturity levels and storage conditions.

When the cycas seeds were processed by different methods, the protein content decreased up to 6.90 g $100g^{-1}$ in forest samples and 7.55 g $100g^{-1}$ in non forest samples. A decrease of 4.82 to 16.87 per cent protein over the raw seeds was noticed in forest samples and 3.88 to 11.18 per cent in non forest samples (Table 16). In the case of forest samples a significant decrease in the protein content of cycas seeds was noticed in all the three treatments (T_2, T_4 and T_6) in which the seeds were soaked for 24 hours. The loss might be due to the leaching of nitrogenous substances in the water used for soaking. As the duration of soaking increased more nitrogenous substances might have leached out and decreased the protein content. In the case of non forest samples also the same trend of decrease in protein content was noticed in the same treatments of T_2, T_4 and T_6 which were soaked for 24 hours. This trend of decrease is similar to the observation made by Obasi and Wogu (2008) in yellow maize, Mubarak (2005) in mung bean seeds and Udensi *et al.* (2010) in *Mucuna flagellipes* during soaking. Studies conducted by Adeparusi (2001); Saxena *et al.* (2003); Ijeh *et al.* (2010) and Jimoh *et al.* (2011) also indicated a decrease in the protein content of lima bean, chickpea, *Treculia africana* and sesame seed meal during processing. Nwaoguikpe *et al.* (2011) indicated a decrease of 21.47 per cent in the protein content of velvet bean during soaking and attributed the decrease due to solublisation of nitrogenous substances. Sharma and Kapoor (1997); Ukachukwu and Obioha (2000); Saxena *et al.* (2003); Obasi and Wogu (2008); Kakati *et al.* (2010) and Udensi *et al.* (2010) also indicated a decrease in the protein content during soaking due to the progressive solublisation and leaching out of the nitrogenous substances and water soluble proteins into soaked water. Contrary to the present finding, studies conducted by Lemessa (2004) in harikot beans and Blessing and Gregory (2010) in mung bean flour indicated an increase in the protein content during processing due to the release of soluble nitrogen fraction concentrated in the endosperm and germ of the bean rather than the seed coat.

Table 15. Percentage change in the moisture content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	0.28	0.65
T_2	-1.68	3.91
T_3	-3.17	3.17
T_4	0.47	1.12
T_5	-2.61	1.77
T_6	-3.54	2.70

Table 16. Percentage decrease in the protein content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	4.82	3.88
T_2	12.41	6.24
T_3	8.19	5.06
T_4	12.89	7.29
T_5	11.08	10.59
T_6	16.87	11.18

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

Ragab *et al.* (2010) also observed an increase in the crude protein content of whole seeds of *Cajanus cajan* and *Lablab purpureus* during soaking. However, the authors observed a decrease in the protein content in the raw decorticated seeds of *Cajanus cajan* and *Vigna unguiculata* seeds after soaking.

Among the different processing methods employed maximum decrease was noticed in T_6, in which cycas seeds were powdered and washed in water three times after soaking the seeds in cold water for 24 hours. Different studies conducted by Kylen and McCready (1975) and Fagbemi (2007) indicated loss of protein in soybean and mung bean flour as well as pumpkin seed flour due to leaching in boiling water. Blessing and Gregory (2010) also observed significant decrease in protein content of mung bean flour seeds with an increase in the time of soaking due to leaching out of nutrients in soaked water. The decrease observed in the protein content of the flour of processed cycas seeds might be attributed due to leaching during processing. In the present study also, variation in soaking time influenced the amount of leaching out of nitrogenous substances and thus increased the amount of protein lost from the seeds.

In the case of starch, it was seen that, cycas seeds collected from forest regions had significantly higher starch content of 54.45 g $100g^{-1}$, when compared to the starch content of 51.90 g $100g^{-1}$ in non forest samples. This variation might be due to the variation in the environmental factors, soil nutrition and efficiency of plants to accumulate nutrients from soil as reported by Gupta (1983); Singh (1985); Cemeroglu and Acar (1986); Brennan (2006) and Ragab *et al.* (2010).

When the cycas seeds were processed by different treatments, starch content decreased significantly in each and every processing treatment both in forest and non forest samples. It was also seen that with the increase in the time and temperature of soaking, as well as with the increase in the number of washings in water a proportionate and significant decrease in starch content occurred in the seeds collected both from forest and non forest areas. The decrease is mainly due to the leaching of starch during the processing of seeds. Studies

conducted by Joot *et al*. (1986) and Valverde *et al.* (1998) also indicated a reduction in starch content of pulses during processing. The authors indicated an increased loss of starch with an increase in the duration of soaking. Sinha *et al.* (2002) reported a gradual decrease in the starch content of cowpea during soaking which increased with an increase in soaking period. In the present study also, an increased loss of starch was noticed with an increase in the time of soaking. The loss of starch was found to be high, when the cycas seeds were soaked in boiling water when compared to cold water. When the cycas seed flour was washed in water three times after soaking for 12 and 24 hours in cold water the loss of starch further increased up to 33 per cent in forest sample and 35 per cent in non forest sample (Table 17). This loss could be due to the washing away or leaching out of the soluble starch content from the cycas seed flour into the water medium as suggested by Sinha *et al.* (2002). The decrease in the starch content during processing might be due to the action of hydrolytic enzymes present in the seeds which hydrolyses starch into lower molecular weight carbohydrates like maltose, glucose and dextrins as reported by Mubarak (2005). Kakati *et al*. (2010) reported a decrease in the starch content of green gram and black gram during soaking. The decrease in the starch content of processed samples is in accordance with the results revealed by Joot *et al*. (1986) and Rehman *et al*. (2001).

The total carbohydrate content of the flour of cycas seeds collected from forest and non forest areas was found to be 74.33 g and 72.17 g $100g^{-1}$. Campbell *et al.* (1966) also reported 74 g $100g^{-1}$ carbohydrate in cycas flour. The variation observed in the total carbohydrate content of cycas seeds collected from two areas was statistically insignificant.

During processing, a significant decrease in the total carbohydrate content was also observed in which the content decreased up to 49.50 g 100 g^{-1} in forest samples and 37.33 g $100g^{-1}$ in non forest samples. As the time of soaking increased, the loss of carbohydrate from the cycas seeds also increased. Thus, about 11.65 to 33.41 per cent loss of carbohydrates occurred in forest samples and 13.86 to 48.27 per cent (Table 18) loss occurred in non forest samples.

Table 17. Percentage decrease in the starch content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	3.58	1.16
T_2	7.99	10.98
T_3	13.77	20.23
T_4	16.80	22.83
T_5	24.79	29.48
T_6	32.51	35.26

Table 18. Percentage decrease in the total carbohydrate content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	11.65	13.86
T_2	16.14	17.56
T_3	20.85	30.26
T_4	25.56	37.41
T_5	30.27	43.19
T_6	33.41	48.27

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

This observation is in line with the findings of Valverde *et al.* (1992) and Rehman *et al.* (2001) in which the authors indicated significant decrease in carbohydrate content in pulses with an increase in the duration and temperature of soaked water. The decrease observed in the carbohydrate content of cycas seeds processed by different treatments (T_1 to T_6) when compared to raw cycas seed was found to be statistically significant in the seeds collected both from forest and non forest areas. Maximum reduction of total carbohydrate was observed in the samples washed in water three times after soaking for 24 hours both in samples collected from forest areas (33.41%) and non forest areas (48.27%). This reduction might be due to the leaching of soluble carbohydrates in the water used for processing. Kataria *et al.* (1990) and Sat and Keles (2002) also observed significant reduction in reducing sugars, stachyose and raffinose in pulses and *P. vulgaris* during processing. However, contrary to the present study, Mubarak (2005) and Udensi *et al.* (2010) indicated an increase in the total carbohydrate content in mung bean seeds and *Mucuna flagellipes* seeds during soaking and attributed this increase due to breakdown of complex carbohydrate during processing which were otherwise bound in the raw sample.

The crude fibre content of cycas seed flour was found to be 2.83 and 2.58 g $100g^{-1}$ in forest and non forest samples respectively, and the variation was found to be statistically insignificant. However, Miller *et al.* (1993) indicated a very high fibre content of 28.1 g $100g^{-1}$ in *Cycas armstrongii*.

During processing, the crude fibre content of cycas seeds collected from forest and non forest areas decreased significantly in all treatments except T_1 in which the seeds were soaked in cold water for 12 hours. A decrease of 20.49 to 46.99 per cent was noticed in forest samples and 12.79 to 41.86 per cent in non forest samples during processing when compared to raw seeds (Table 19). Among the different treatments, maximum decrease was recorded in T_4 which was soaked in cold water for 24 hours and then in boiling water for two hours both in forest and non forest samples. This loss of crude fibre during processing might be due to the structural changes occurring in the non starchy polysaccharides which form

the main constituent of the dietary fibre. Hady *et al.* (1998) also indicated a reduction in fibre content of sorghum seeds during processing. Udensi *et al.* (2010) indicated a decrease in crude fibre content of *Mucuna flagellipes* flour during soaking and boiling with a maximum decrease in samples soaked for 24 hours followed by boiling. The finding of the present study was found to be in line with the observations made by Ukachukwu and Obioha (2000) in *Mucuna cochinchinensis,* Mubarak (2005) in mung bean seed, Ijeh *et al*. (2010) in *Treculia africana* and Kakati *et al*. (2010) in green gram and black gram. Similar results were also reported by Rajaram and Janardhan (1990) in *Vigna* spp. and Bhagya *et al.* (2007) in wild legumes in which the authors indicated a decrease in crude fibre content during processing. But, Ragab *et al.* (2010) indicated an increase in the crude fibre content of *Cajanus cajan, Lablab purpureus* and *Vigna unguiculata* during soaking. However, Valverde *et al.* (1992) did not observe any change in the crude fibre content of lentils during processing. Azizah and Zainan (1997) though indicated a high fibre content in the range of 22.3 to 25.9 g $100g^{-1}$ in legumes and 1.1 to 15.8 g $100g^{-1}$ in cereals, reported different effects on SDF, IDF and TDF due to different processing treatments. During processing, the percentage loss of crude fibre was found to be more in forest samples when compared to non forest samples. This might be due to the variation in the soluble fibre content of the cycas seeds collected from two areas.

The fat content of the flour of raw cycas seeds was found to be 4.42 g and 4.70 g $100g^{-1}$ in the samples collected from forest and non forest areas respectively and the variation was found to be statistically insignificant. The fat content observed in the flour of cycas seeds was found to be higher than the reported value of 0.8 g $100g^{-1}$ in *Cycas circinalis* by Campbell *et al.* (1966). Miller *et al.* (1993) indicated still lower fat content of 0.4 g $100g^{-1}$ in *Cycas armstrongii.* This difference might be due to the variation in the species selected for the study.

A gradual decrease in the fat content of the flour of cycas seeds collected from forest and non forest areas was observed during processing with an increase in the time of soaking and increase in the temperature of soaked water. In the processed samples the fat content varied from 3.00 g to 3.83 g $100g^{-1}$ in forest samples and 2.67 g to 4.33 g $100g^{-1}$ in non forest samples. Thus, a loss of 13.35 to 32 per cent fat in forest sample and 7.87 to 43.19 per cent in non forest sample occurred during processing (Table 20). The decrease in fat content during processing might be due to the mobilisation of fat during processing and due to hydrolysis of fat into simple fatty acids during processing. Kakati *et al.* (2010) also indicated a decrease in the fat content of green gram and black gram during soaking. Palminano and Juliano (1972) and Mohan *et al.* (2010) observed a decrease in the fat content of rice during processing due to hydrolysis of fatty acids. Hady *et al.* (1998) reported a slight decrease in the range of 2.51 to 2.99 per cent fat in sorghum during processing. The authors indicated that the decrease occurred due to the biochemical and physiological changes taking place during processing since such changes require energy and a part of the fat present might have been utilised for energy purpose and consequently decreased the fat content. Mubarak (2005) indicated a decrease in the fat content of mung bean seeds due to the diffusion into the water. The decrease in fat content in soaked samples as \compared to untreated seeds can be corroborated with the findings of other studies conducted by Ramakrishna *et al.* (2006) and Osman (2007). However, Akpapunam and Achinewhu (1985) indicated moderate increase in fat due to soaking and attributed this increase due to the dissociation of the lipid compounds. However, Ragab *et al.* (2010) indicated no serious changes in the fat content of legumes due to soaking and other processing methods.

The flour of cycas seeds collected from forest areas had significantly high calcium content than those collected from non forest areas. The calcium content of flour of cycas seeds collected from forest and non forest areas were found to be 17.03 mg and 15.22 mg $100g^{-1}$ respectively. This variation might be due to the

Table 19. Percentage decrease in the crude fibre content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	20.49	12.79
T_2	32.15	15.90
T_3	40.99	29.07
T_4	46.99	41.86
T_5	32.16	19.38
T_6	40.99	25.58

Table 20. Percentage decrease in the fat content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	13.35	7.87
T_2	15.16	14.89
T_3	26.47	18.51
T_4	28.28	23.83
T_5	30.32	41.49
T_6	32.13	43.19

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

variation in the environmental factors, soil nutrition, nutrient uptake and efficiency of plants to accumulate nutrients from soil as reported by Gupta (1983); Singh (1985); Cemeroglu and Acar (1986); Brennan (2006) and Ragab *et al.* (2010). Miller *et al.* (1993) indicated almost similar calcium content of 21 mg $100g^{-1}$ in *Cycas armstrongii*, an indigenous food consumed in Australia.

When the cycas seeds were processed by different methods, the calcium content decreased significantly and the content varied from 9.00 mg to 14.10 mg $100g^{-1}$ in forest samples and 7.53 mg to 12.12 mg $100g^{-1}$ in non forest samples. Thus, a decrease of 17 to 47 per cent calcium was noticed in samples collected from forest areas and a loss of 20 to 51 per cent was noticed in non forest samples (Table 21). Maximum decrease was observed in T_6 which was processed by soaking the seeds in cold water for 24 hours and the flour prepared from the soaked samples was washed three times in cold water both in forest and non forest samples. Minimum decrease was noticed in the seeds soaked for 12 hours in cold water. More than 25 per cent calcium was lost even in T_2 in which the seeds were soaked for 24 hours in cold water. Thus, with an increase in the time of soaking and temperature of soaked water as well as with an increase in number of washings the calcium content decreased gradually. The loss of calcium during processing could be attributed due to the draining or leaching out of calcium along with the water used for processing as suggested by Rincon *et al.* (1993) and Ragab *et al.* (2010). When the cycas seeds were soaked in cold water for 12 and 24 hours there was slight decrease in calcium content which might be due to the leaching out of soluble content. Akintunde (2008) also indicated loss of large amount of calcium due to leaching in soaked water even at ambient conditions. In the case of T_3 and T_4 which were processed by soaking in cold water for 12 and 24 hours and then soaking in boiling water for two hours, about 34 to 38 per cent calcium was lost. When the flour was washed in water three times after soaking the seeds in cold water for 12 and 24 hours (T_5 and T_6) the loss of calcium content further increased from 43 to 47 per cent in forest sample and 46 to 51 per cent in non forest samples. Here also, more calcium must be drained off in the water used

for washing and decreased the calcium content. Valverde *et al.* (1998) also indicated a loss of calcium during processing in faba bean.

Wide variation in the sodium content was noticed in the flour of cycas seeds collected from forest and non forest areas. The sodium content was found to be significantly high in the samples collected from forest areas (18.87 mg $100g^{-1}$) when compared to those collected from non forest areas (8.87 mg $100g^{-1}$). Miller *et al.* (1993) reported a very low sodium content of 5 mg $100g^{-1}$ in *Cycas armstrongii* an indigenous food of Australia.

In the processed samples, the sodium content decreased gradually in all treatments except in the samples soaked for 12 hours in cold water (forest sample) in which sodium was not lost during soaking. Maximum loss of sodium was observed in T_4 which was soaked in cold water for 24 hours and boiling water for two hours, in the seeds collected from forest areas. In the case of non forest samples, maximum loss of sodium was noticed in T_6 in which the cycas flour prepared after soaking the seed in water for 24 hours was washed in water three times. The decrease observed in the sodium content of the flour of cycas seeds soaked for 12 and 24 hours (T_1 and T_2) was found to be statistically insignificant when compared to T_0 both in forest and non forest samples. In T_3, T_4, T_5 and T_6 the decrease in the sodium content of the flour of cycas seeds was found to be statistically significant only in forest samples while in non forest samples it was found to be on par with the raw seeds. The percentage decrease in the sodium content from that of control is given in Table 22. Udensi *et al.* (2010) also indicated a decrease in the sodium content of *Mucuna flagellipes* due to soaking and boiling. With an increase in the time of soaking and temperature of soaked water the leaching of sodium from the seeds increased. In the present study also maximum loss of sodium was observed when the seeds were soaked in boiling water for two hours along with 24 hours of soaking in cold water. The loss of sodium during processing might be due to the leaching of the minerals in the water used for processing. Mubarak (2005) and Ragab *et al.* (2010) also indicated a decrease in the sodium content of legume seeds during processing due to the

Table 21. Percentage decrease in the calcium content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	17.20	20.37
T_2	28.95	32.98
T_3	33.65	34.76
T_4	38.23	36.89
T_5	42.57	45.93
T_6	47.15	50.53

Table 22. Percentage decrease in the sodium content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	0	9.81
T_2	12.03	19.95
T_3	29.52	9.81
T_4	59.04	25.25
T_5	44.89	17.70
T_6	54.27	27.85

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

draining of sodium in the water. Mathew (2010) indicated a significant decrease in the sodium content of bamboo shoots during processing due to the leaching of sodium in water.

The potassium content of cycas seed flour collected from forest and non forest areas were found to be 494.30 mg and 276.43 mg $100g^{-1}$ respectively. The potassium content of the flour of cycas seeds collected from non forest areas was found to be significantly lower than those collected from forest areas. Contrary to the present finding Miller *et al.* (1993) reported a very low potassium content of 66 mg $100g^{-1}$ in *Cycas armstrongii*. The significant variation observed in the potassium content of cycas seeds collected from forest and non forest areas might be due to the variation in the environmental factors, soil nutrition, nutrient uptake and efficiency of plants to accumulate minerals from soil as reported by Gupta (1983); Singh (1985); Cemeroglu and Acar (1986); Brennan (2006) and Ragab *et al.* (2010). The lower potassium content observed in *Cycas armstrongii* by Miller *et al.* (1993) might be due to the variation in the species selected for the study. A very high potassium content in the range of 320 to 500 mg $100g^{-1}$ as in the present study was reported in *Telfaira occidentalis, Cissus vogelii* and *Mucuna sloanei* the edible plant seeds of Nigeria by Ude *et al.* (2002).

A drastic and significant reduction in the potassium content of the flour of cycas seeds was also noticed during processing both in forest and non forest samples. Here also, as in the case of sodium, as the time of soaking and temperature of water used for soaking increased the loss of potassium also increased. This might be due to leaching out of potassium in the water used for processing as reported by Rincon *et al.* (1993) and Mubarak (2005). Upto 99.9 per cent potassium was lost in T_6 which was processed by soaking the seeds in water for 24 hours and then washing the prepared flour in water for three times (Table 23). Maximum reduction was noticed when the samples were washed three times in water after soaking the seeds in cold water for 12 and 24 hours both in forest and non forest samples. Rincon *et al.* (1993); Ragab *et al.* (2010) and Udensi *et al.* (2010) also indicated an increase loss of potassium with intensive processing

treatments. Mathew (2010) also indicated a loss of potassium in the processed bamboo shoots due to leaching of minerals in water.

The iron content of the flour of cycas seeds collected from forest and non forest areas was found to be 1.89 mg and 1.78 mg $100g^{-1}$ respectively. Slightly higher iron content was noticed in the flour of cycas seeds collected from forest areas. This variation might be due to the difference in the environmental factors, soil nutrition, nutrient uptake and efficiency of plants to accumulate minerals from soil as reported by Gupta (1983); Singh (1985); Cemeroglu and Acar (1986); Brennan (2006) and Ragab *et al.* (2010). Contradictory to the present observation, Miller *et al.* (1993) indicated slightly higher iron content of 4.6 mg $100g^{-1}$ in *Cycas armstrongii*. This variation may be due to the difference in the species.

During processing, a slight decrease in the iron content was observed in which the content decreased upto 1.31 mg $100g^{-1}$ in forest samples and 1.22 mg $100g^{-1}$ in non forest samples. Thus, it was seen that iron content decreased upto 31 per cent during processing both in seeds collected from forest and non forest areas (Table 24). Maximum reduction was observed in the seeds which were soaked in cold water for 24 hours and then powdered and washed in water three times. Thus, with an increase in the time of soaking and increase in the temperature of soaked water as well as with an increase in the number of washings, the loss of iron also increased gradually. Duhan *et al.* (2002) also indicated an increased loss of iron with an increase in the period of soaking in pigeon pea seeds. As the time of soaking increased the percentage of iron lost from the seeds also increased. The loss is mainly due to the draining of iron in the water used for processing. Siddhuraju and Becker (2003); Pugalenthi *et al.* (2007); Vadivel *et al.* (2008) and Akintunde (2008) also indicated a loss of iron during soaking in mucuna seeds, *Arbus precatorious*, *Entada scandens* and bell pepper due to leaching out into soaked medium by the enhanced permeability of the seed coat. Rincon *et al.* (1993); Saharan *et al.* (2001); Mubarak (2005) and Ragab *et al.* (2010) also indicated loss of iron in pulses during soaking due to draining in water used for soaking. Lestienne *et al.* (2005) indicated significant loss of iron during soaking in

Table 23. Percentage decrease in the potassium content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	68.76	61.82
T_2	84.50	73.09
T_3	80.00	74.28
T_4	83.91	93.57
T_5	98.21	97.68
T_6	99.91	98.72

Table 24. Percentage decrease in the iron content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	3.70	7.26
T_2	8.47	12.29
T_3	14.29	20.11
T_4	17.46	22.35
T_5	26.46	26.82
T_6	30.69	31.84

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

cereals and pulses like sorghum, rice, soybean, maize, cowpea and mung bean and attributed that the loss occurred due to leaching of iron into the soaked medium.

The zinc content of the flour of cycas seeds collected from forest areas was found to be high (0.63mg $100g^{-1}$) when compared to the seeds collected from non forest areas (0.56 mg $100g^{-1}$). This variation might be due to the difference in the environmental factors, soil nutrition, nutrient uptake and efficiency of plants to accumulate minerals from soil as reported by Gupta (1983); Singh (1985); Cemeroglu and Acar (1986); Brennan (2006) and Ragab *et al*. (2010). Miller *et al.* (1993) reported slightly higher zinc content of 1.2 mg $100g^{-1}$ in *Cycas armstrongii*. This increase could be accounted due to the variation in the species selected for the study.

During processing, zinc content decreased gradually as the time and temperature of soaking increased. When the flour was washed in water after soaking for 12 and 24 hours the loss of zinc further increased. The percentage loss of zinc varied from 14.29 and 63.49 per cent in forest samples and 10.71 to 58.93 percent in non forest samples (Table 25). Maximum loss was observed in T_6 both in forest and non forest samples in which the flour prepared was washed thrice in water after soaking the seeds in cold water for 24 hours. As in the case of other minerals the decrease in the zinc content could also be attributed due to the leaching of the minerals into the soaked medium. Studies conducted by Rincon *et al.* (1993) and Ragab *et al.* (2010) noticed reduction of zinc due to the leaching of the minerals in the water. Saharan *et al*. (2001) and Lestienne *et al.* (2005) also indicated significant loss of zinc in different cereals and pulses due to leaching into soaking medium.

The flour of cycas seeds collected from forest and non forest areas had a crude alkaloid content of 1.56 mg and 1.60 mg $100g^{-1}$ respectively. The variation observed between the two samples was found to be statistically significant.

When the cycas seeds were processed by different methods, a decrease in crude alkaloid content was noticed and the content varied from 0.54 mg to 1.46

mg $100g^{-1}$ in forest samples and 0.66 mg to 1.40 mg $100g^{-1}$ in non forest samples. In the case of forest and non forest samples a significant decrease in the crude alkaloid content of cycas seeds was noticed in all treatments except T_1 of forest sample. About 7 to 65 per cent crude alkaloids was lost in forest samples in different processing treatments and 13 to 59 per cent was lost in non forest samples (Table 26). The decrease is mainly due to the leaching out of water soluble antinutrients.

Nwosu (2010) reported soaking helped in the removal of the soluble antinutrients like alkaloids in Asparagus bean flour and with an increase in the time of soaking the loss of antinutrients also increased. This result was in agreement with the report of Phillips and Abbey (1989) and Ijeh *et al.* (2010) in which the authors indicated that steeping hydrates the grain and induces the leaching out of water soluble antinutrients such as alkaloids. When the cycas seeds were soaked in cold water for 12 and 24 hours and then in boiling water for two hours (T_3 and T_4) the loss of crude alkaloid further increased to 36 to 44 per cent in forest samples and 29 and 36 per cent in non forest samples. Nwaoguikpe *et al.* (2011) reported reduced concentration of alkaloids in *Mucuna pruriens* seeds during soaking. In the cycas seeds which were soaked in cold water for 12 and 24 hours and then powdered and washed in water three times *ie*. in T_5 and T_6, the alkaloid content further decreased upto 0.54 mg $100g^{-1}$ in forest sample and 0.66 mg $100g^{-1}$ in non forest samples. Thus, about 65 and 59 per cent alkaloids were lost in T_6, in forest and non forest samples respectively. It was seen that with an increase in the time of soaking and increase in temperature of soaked water and with more number of washings, more alkaloids were lost from the cycas seeds. Nwosu (2010) indicated that the leaching effect of crude alkaloids occurred during 28 to 48 hours of soaking and did not observe any variation in the crude alkaloid content of Asparagus bean flour which were soaked for 12 to 24 hours.

Hydrocyanic acid was not present in the flour of cycas seeds collected from forest and non forest areas.

Table 25. Percentage decrease in the zinc content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	14.29	10.71
T_2	29.98	16.07
T_3	34.92	32.14
T_4	41.27	41.07
T_5	50.79	50.00
T_6	63.49	58.93

Table 26. Percentage decrease in the crude alkaloid content of the flour of processed cycas seeds

Treatments	Forest	Non forest
T_1	7.05	13.12
T_2	20.51	25.00
T_3	35.89	29.38
T_4	44.23	36.25
T_5	54.49	50.63
T_6	65.38	58.75

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 – T_1 + Soaked in boiling water for 2 hours.

T_4 – T_2 + Soaked in boiling water for 2 hours.

T_5 – T_1 + Powdered and washed in water three times.

T_6 – T_2 + Powdered and washed in water three times.

When the flour of cycas seeds collected from forest and non forest areas were compared for the presence of different nutrients, it was seen that the seeds collected from forest areas had more starch, total carbohydrate, crude fibre, calcium, sodium, iron, zinc and potassium. Protein and fat were found to be relatively high in cycas seeds collected from non forest areas. Thus, cycas seeds collected from forest areas were found to be relatively rich in most of the nutrients when compared to non forest samples. This might be due to the underexploited nature of forest soils which adds to the extra nourishment to the plant.

5.2. Selection of the most desirable processing method

To select the best method of processing cycas seeds on the basis of maximum nutrients and minimum crude alkaloids, the cycas flour prepared by different processing methods (T_1 and T_6) were ranked based on the most desirable value for each of the constituents namely protein, starch, total carbohydrate, crude fibre, fat, calcium, sodium, iron, zinc, potassium and crude alkaloid.

For each nutrient highest rank of one was assigned for maximum nutrient content. For crude alkaloid the rank one was given for the treatment having the least alkaloid content. The ranking was made for above constituents separately for the cycas seeds collected from forest and non forest areas. The details of the constituents along with their ranked order are furnished in Table 27 and 28.

From the Table it is clear that all the nutrients were retained at an higher level in T_1 both in cycas seeds collected from forest (Table 27) and non forest (Table 28) areas in which the seeds were soaked for 12 hours in cold water. As the soaking time and temperature of soaked water increased there was a gradual increase in the amount of nutrients lost from the seeds. Maximum amount of nutrients was lost in T_6 in which the flour was washed in water thrice after powdering the seeds which were soaked in water for 24 hours. The same trend was observed in the seeds collected from forest and non forest areas. Crude alkaloid content was found to be very low even in raw seeds and during

Table 27. Effect of different processing methods on the chemical constituents of cycas seed flour ($100g^{-1}$)

(Forest sample)

Treatments	Protein (g)	Starch (g)	Total carbohydrate (g)	Crude fibre (g)	Fat (g)	Calcium (mg)	Phosphorous (mg)	Sodium (mg)	Iron (mg)	Zinc (mg)	Potassium (mg)	Crude alkaloid (mg)	Hydro cyanic acid(µg)	Cycasin (g)	Total score
T_0	8.30	54.45	74.33	2.83	4.42	17.03	0	18.87	1.89	0.63	494.30	1.56	0	*	-
T_1	7.90 (1.00)	52.50 (1.00)	65.67 (1.00)	2.25 (1.00)	3.83 (1.00)	14.10 (1.00)	0	18.87 (1.00)	1.82 (1.00)	0.54 (1.00)	154.40 (1.00)	1.46 (6.00)	0	*	16.00
T_2	7.27 (4.00)	50.10 (2.00)	62.33 (2.00)	1.92 (2.50)	3.75 (2.00)	12.07 (2.00)	0	16.60 (2.00)	1.73 (2.00)	0.46 (2.00)	76.63 (2.00)	1.24 (5.00)	0	*	27.50
T_3	7.62 (2.00)	46.95 (3.00)	58.83 (3.00)	1.67 (4.50)	3.25 (3.00)	11.30 (3.00)	0	13.30 (3.00)	1.62 (3.00)	0.41 (3.00)	98.83 (3.00)	1.00 (4.00)	0	*	34.50
T_4	7.23 (5.00)	45.30 (4.00)	55.33 (4.00)	1.50 (6.00)	3.17 (4.00)	10.52 (4.00)	0	7.73 (6.00)	1.56 (4.00)	0.37 (4.00)	79.53 (4.00)	0.87 (3.00)	0	*	48.00
T_5	7.38 (3.00)	40.95 (5.00)	51.83 (5.00)	1.92 (2.50)	3.08 (5.00)	9.78 (5.00)	0	10.40 (4.00)	1.39 (5.00)	0.31 (5.00)	8.87 (5.00)	0.71 (2.00)	0	*	46.50
T_6	6.90 (6.00)	36.75 (6.00)	49.50 (6.00)	1.67 (4.50)	3.00 (6.00)	9.00 (6.00)	0	8.63 (5.00)	1.31 (6.00)	0.23 (6.00)	0.44 (6.00)	0.54 (1.00)	0	*	58.50

Figures in parenthesis are mean rank score

* Cycasin could not be estimated

T_1 - Soaked in cold water for 12 hours.

T_2 - Soaked in cold water for 24 hours.

T_3 - T_1 + Soaked in boiling water for 2 hours.

T_4 - T_2 + Soaked in boiling water for 2 hours.

T_5 - T_1 + Powdered and washed in water three times.

T_6 - T_2 + Powdered and washed in water three times.

Table 28. Effect of different processing methods on the chemical constituents of cycas seed flour ($100g^{-1}$)
(Non forest areas)

Treatments	Protein (g)	Starch (g)	Total carbohydrate (g)	Crude fibre (g)	Fat (g)	Calcium (mg)	Phosphorous (mg)	Sodium (mg)	Iron (mg)	Zinc (mg)	Potassium (mg)	Crude alkaloid (mg)	Hydro cyanic acid µg)	Cycasin (g)	Total score
T_0	8.50	51.90	72.17	2.58	4.70	15.22	0	8.87	1.79	0.59	276.43	1.60	0	*	-
T_1	8.17 (1.00)	51.30 (1.00)	62.17 (1.00)	2.25 (1.00)	4.33 (1.00)	12.12 (1.00)	0	8.00 (1.50)	1.66 (1.00)	0.50 (1.00)	105.53 (1.00)	1.40 (6.00)	0	*	16.50
T_2	7.97 (3.00)	46.20 (2.00)	59.50 (2.00)	2.17 (2.00)	4.00 (2.00)	10.20 (2.00)	0	7.10 (3.00)	1.57 (2.00)	0.47 (2.00)	74.40 (2.00)	1.20 (5.00)	0	*	27.00
T_3	8.07 (2.00)	41.40 (3.00)	50.33 (3.00)	1.83 (5.00)	3.83 (3.00)	9.93 (3.00)	0	8.00 (1.50)	1.43 (3.00)	0.38 (3.00)	71.10 (3.00)	1.13 (4.00)	0	*	33.50
T_4	7.88 (4.00)	40.05 (4.00)	45.17 (4.00)	1.50 (6.00)	3.58 (4.00)	9.30 (4.00)	0	6.63 (5.00)	1.39 (4.00)	0.33 (4.00)	17.77 (4.00)	1.02 (3.00)	0	*	46.00
T_5	7.60 (5.00)	36.60 (5.00)	41.00 (5.00)	2.08 (3.00)	2.75 (5.00)	8.23 (5.00)	0	7.30 (4.00)	1.31 (5.00)	0.28 (5.00)	6.40 (5.00)	0.80 (2.00)	0	*	49.00
T_6	7.55 (6.00)	33.60 (6.00)	37.33 (6.00)	1.92 (4.00)	2.67 (6.00)	7.53 (6.00)	0	6.40 (6.00)	1.22 (6.00)	0.23 (6.00)	3.53 (6.00)	0.66 (1.00)	0	*	59.00

Figures in parenthesis are mean rank score
* Cycasin could not be estimated

T_1 - Soaked in cold water for 12 hours.
T_2 - Soaked in cold water for 24 hours.
T_3 - T_1 + Soaked in boiling water for 2 hours.
T_4 - T_2 + Soaked in boiling water for 2 hours.
T_5 - T_1 + Powdered and washed in water three times.
T_6 - T_2 + Powdered and washed in water three times.

processing also the content gradually decreased with an increase in the soaking time and increase in temperature of soaked water. Thus, the processing of cycas seeds by soaking in water for 12 hours was found to be the best to retain the nutrients.

The processing methods are adopted for cycas seeds mainly to reduce the toxic constituents present in them. Since, cycasin could not be estimated in the present study, a final conclusion on the best processing treatment could be drawn only after determining the cycasin content of raw and processed cycas seed flour.

SUMMARY

SUMMARY

The study entitled, "Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)" was undertaken to evaluate the nutritional and antinutritional constituents of cycas flour prepared from seeds collected from forest and non forest areas and also to study the effect of processing on the chemical constituents present in the flour.

Fresh and matured cycas seeds were collected from forest and non forest areas of Thrissur district during the month of August 2010. Forest samples were collected from different locations of Peechi and Thamaravellachal and non forest samples were collected from different locations of Kandassakadavu and Marottichal. The collected seeds were sundried for 8 to 10 days and pooled separately as forest and non forest samples. The samples were processed by six different methods. The methods included soaking in cold water for 12 and 24 hours (T_1 and T_2), soaking in cold water for 12 and 24 hours and then in boiling water for 2 hours (T_3 and T_4), soaking in cold water for 12 and 24 hours and then powdering and washing three times in cold water (T_5 and T_6). The unprocessed seeds were taken as the control (T_0). The processed seeds (T_1 to T_6) and the control (T_0) were powdered and dried in a cabinet drier at 60 ± 5° C to attain a moisture content of 10 to 12 per cent.

The prepared flour was analysed for different constituent namely moisture, protein, starch, total carbohydrate, crude fibre, fat, calcium, phosphorous sodium, potassium, iron, zinc, crude alkaloid, cycasin and hydrocyanic acid.

The moisture content of the flour of cycas seeds collected from forest and non forest areas were found to be 10.74 g $100g^{-1}$. In the processed seeds the moisture content varied from 10.36 to 10.79 g $100g^{-1}$ in forest sample and 10.81 to 11.16 g $100g^{-1}$ in non forest samples.

The flour of cycas seeds collected from forest and non forest areas had a protein content of 8.30 and 8.50 g $100g^{-1}$ respectively. When the cycas seeds were processed by different methods, the protein content decreased upto 6.90 g in forest and 7.55 g $100g^{-1}$ in non forest samples. Maximum decrease was observed in which the cyacs seeds were powdered and washed in water thrice after soaking the seeds in cold water for 24 hours (T_6).

The starch content in the flour of cycas seeds was found to be significantly high in samples collected from forest areas (54.45 g $100g^{-1}$) when compared to non forest samples (51.90 g $100g^{-1}$). In the processed cycas seeds, the flour had a starch content in the range of 36.75 to 52.50 g 100 g^{-1} (forest sample) and 33.60 to 51.30 g $100g^{-1}$ (non forest sample). Thus, a significant decrease in the starch content was noticed with an increase in the time of soaking, temperature of soaked water and number of washings given to the flour.

The total carbohydrate in the cycas seeds collected from forest and non forest areas were found to be 74.33 and 72.17 g $100g^{-1}$. The variation observed in the samples collected from forest and non forest areas with respect to total carbohydrate content was statistically insignificant. During processing, a significant decrease in the total carbohydrate content was observed and content decreased upto 49.50 g $100g^{-1}$ in forest samples and 37.33 g $100g^{-1}$ in non forest samples. Here also, with an increase in the time of soaking, the loss of carbohydrate from the seeds increased.

The crude fibre content of cycas seeds collected from forest and non forest areas were found to be 2.83 and 2.58 g $100g^{-1}$. During processing, the crude fibre content of cycas seeds collected from the two areas decreased significantly except in T_1 which was soaked in the cold water for 12 hours. Among the different processing methods employed maximum decrease was found in T_4 which was soaked in cold water for 24 hours and then in boiling water for 2 hours both in forest and non forest samples.

The flour of cycas seeds collected from forest and non forest areas had a fat content of 4.42 and 4.70 g $100g^{-1}$ respectively. When the cycas seeds were processed by different methods the fat content decreased upto 3.00 g $100g^{-1}$ in forest and 2.67 g $100g^{-1}$ in non forest samples. Maximum decrease was observed in which the cycas seeds were powdered and washed in water thrice after soaking the seeds in cold water for 24 hours (T_6).

The calcium content of the cycas seed flour collected from forest and non forest areas were found to be 17.03 mg $100g^{-1}$ and 15.22 mg $100g^{-1}$ respectively. In the processed seeds the calcium content varied from 9.00 to 14.10 mg $100g^{-1}$ in forest sample and 7.53 to 12.12 mg $100g^{-1}$ in non forest samples. Thus, with an increase in the time of soaking, temperature of soaked water and number of washings given to the flour the loss of calcium also increased.

Phosphorous was not observed in the flour of cycas seeds collected both from forest and non forest areas.

The sodium content of the cycas seeds collected from forest and non forest areas were found to be 18.87 mg $100g^{-1}$ and 8.87 mg $100g^{-1}$. The variation observed in the samples collected from forest and non forest areas with respect to sodium was statistically significant. During processing, the sodium content decreased upto 7.73 mg $100g^{-1}$ in forest samples and 6.40 mg $100g^{-1}$ in non forest samples. Among the different processing methods employed, maximum decrease was found in T_6, which was soaked in cold water for 24 hours and then powdered and washed in water thrice in non forest samples.

The flour of cycas seeds collected from forest and non forest areas had a potassium content of 494.30 mg $100g^{-1}$ and 276.43 mg $100g^{-1}$ respectively. When the cycas seeds were processed by different methods the potassium content decreased upto 0.44 mg $100g^{-1}$ in forest and 3.53 mg $100g^{-1}$ in non forest samples.

Maximum decrease was observed in T_6 in which the cycas seeds were powdered and washed in water thrice after soaking the seeds in cold water for 24 hours.

The iron content of the flour of cycas seeds was found to be 1.89 mg $100g^{-1}$ in forest samples and 1.79 mg $100g^{-1}$ in non forest samples. In the processed cycas seeds the flour had an iron content in the range of 1.31 to 1.82 mg 100 g^{-1} (forest sample) and 1.22 to 1.66 mg $100g^{-1}$ (non forest sample).

The zinc content of the flour of cycas seeds collected from forest and non forest areas were found to be 0.63 and 0.56 mg $100g^{-1}$ respectively. In the flour of processed cycas seeds the zinc content varied from 0.23 to 0.54 mg $100g^{-1}$ in forest samples and 0.23 to 0.50 mg $100g^{-1}$ in samples collected from non forest areas.

The crude alkaloid content of the flour of cycas seed was found to be 1.56 mg $100g^{-1}$ and 1.60 mg $100g^{-1}$ in samples collected from forest and non forest areas. In the processed cycas seeds the flour had a crude alkaloid content in the range of 0.54 to 1.46 mg $100g^{-1}$ (forest sample) and 0.66 to 1.40 mg $100g^{-1}$ (non forest sample). Thus, a significant decrease in the crude alkaloid content was noticed with an increase in the time of soaking, temperature of soaked water and number of washings given to the flour.

Cycasin could not be estimated in the samples. Hydrocyanic acid was not present in the unprocessed as well as processed cycas flour prepared from seeds collected from forest and non forest areas.

All nutrients were retained at an higher level in T_1 both in cycas seeds collected from forest and non forest areas. Cycas seed flour prepared from seeds collected from forest areas was nutritionally superior. As the soaking time and temperature of soaked water increased the loss of nutrients from the seeds

gradually increased and maximum loss occurred in T_6. The crude alkaloid content was found to be very low in T_6.

Since, the processing of cycas is mainly intended to remove toxic constituents, the best processing method can be identified only after estimating the cycasin content of raw and processed samples.

Cycas seed flour was found to be rich in various nutrients especially carbohydrate and mineral constituents. The presence of antinutritional and toxic factors limits its usage. However, the indigenous communities are using the flour in the preparation of various products and consume this as a source of carbohydrate after removing antinutritional and toxic factors by using their own indigenous techniques. By different processing methods, the antinutritional and toxic factors could be removed effectively with considerable loss of nutrients. But, processing is highly essential for cycas seeds to be used as a food ingredient and for product diversification.

As a future line of this study following areas are suggested.

1. Effect of other processing methods adopted by the indigenous communities on the chemical constituents of cycas seeds.
2. Product development using processed cycas seeds and their quality evaluation.
3. Evaluation of toxic constituents of cycas seeds and the effect of processing on the toxic constituents.

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*Originals not seen.

ABSTRACT

NUTRITIONAL EVALUATION OF CYCAS SEED FLOUR

(*Cycas circinalis* L.)

By

ANITHA. S.

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ABSTRACT OF THE THESIS

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ABSTRACT

The study entitled "Nutritional evaluation of cycas seed flour (*Cycas circinalis* L.)" was undertaken to evaluate the nutritional and antinutritional constituents of cycas flour prepared from seeds collected from forest and non forest areas. The study also aimed to evaluate the effect of processing on the chemical constituents present in the cycas flour.

Fresh and matured cycas seeds were collected from forest and non forest areas of Thrissur district during August 2010. The collected seeds were sun dried for 8 to 10 days and pooled separately as forest and non forest samples. The samples were processed by six different methods. The methods included were soaking the seeds in cold water for 12 and 24 hours (T_1 and T_2), soaking in boiling water for 2 hours after cold water treatment for 12 and 24 hours (T_3 and T_4) and washing of powdered flour of T_1 and T_2 for three times in water (T_5 and T_6). The flour prepared from unprocessed seed was taken as the control (T_0). The processed seeds and the control were powdered and dried in a cabinet drier at $60 \pm 5^{\circ}$ C to a moisture level of 10 to 12 per cent. The prepared flour was analysed for different constituents like moisture, protein, starch, total carbohydrate, crude fibre, fat, calcium, phosphorous, sodium, potassium, iron, zinc, crude alkaloid, cycasin and hydrocyanic acid.

The flour of cycas seeds collected from forest area was found to be relatively high in starch, total carbohydrate, crude fibre and minerals when compared to the flour prepared from seeds collected from non forest area. The crude alkaloid content was found to be relatively low in forest samples. During processing, the rate of nutrient loss from cycas seed flour increased gradually with advancement in the duration of soaking and increase in the temperature of soaked water. Among the different processing methods, maximum retention of nutrients was noticed in cycas flour prepared from seeds soaked in cold water for 12 hours. The percentage loss of

protein, starch, total carbohydrate, crude fibre and fat varied from 2 to 48 per cent. Among minerals, the leaching of potassium was found to be very high. Maximum loss of nutrients was observed in $T_{6,}$ in which the flour was prepared by soaking the seeds in cold water for 24 hours and washed thrice in water. The mean crude alkaloid content in unprocessed cycas flour was 1.58 mg $100g^{-1}$ (T_0) and it reduced to 0.60 mg $100g^{-1}$ during processing (T_6).

The cycas flour prepared from the seeds collected from forest area was found to be more nutritious. The processing of cycas seed could reduce the antinutritional constituents with considerable loss in nutrients. But, processing is highly essential for cycas seeds to be used as a food ingredient and for product diversification.