1. INTRODUCTION

1.1. Mesquite (*prosopis sp.)*

The natural distribution of the genus *prosopis* include arid and semi-arid zones of Americas, Africa and Asia. The native range of *prosopis* species is classified into five regions, namely; Asia, Africa, north America, central America and south America . The Asian species of *prospis* are native to the Middle East and stretching east to India, north to Georgia and west to Algeria along the north Africa coast. Whereas, *prosopis* Africana is native to the Sudano Guinean zone and neighboring areas, from Senegal in the west to the Sudan and Kenya in the east .

Prosopis trees have been introduced widely during the last 100- 150 years, this is because of their multiple utilizations and high yield (1-8 tons/ha/yr) under poor conditions (drought and poor soils), compared with fruits yields from other trees growing in similar environment. **(Nas, 1980; lima, 1990).**

In addition to that, medicines are usually prepared as an aqueous solution or tea from the different parts of the plant. Also, the plant leaves, buds and gums are used to treat eye infections, as laxative, purgative or for treating sore throats, mouse infections, ear ache, scorpion stings and snake bites. Moreover, the plant extract is used against lung carcinoma, lymphocytic leukemia and other carcinomas (**Felker, 1977**; **Nerzabani**, **1979**; **Ahmed and Sultana**, **1989**; **Cruz, 1986** and **Davidow**, **1999**).

On the other hand, the *prosopi* pod is considered as a valuable source of energy and protein for both human and livestock, as it contains high levels of carbohydrates (30.0 – 75.0 %), protein (7 - 17%), crude fiber (12.0 - 32.0%), fat (1.0 - 6.0%) and ash (3.0 - 8.0%) (**Odoul , 1986 etal; Galera, 1992; Anttilla, 1993** and **FAO, 1997**) .

1.2 Aim of the study

The main objective of this research programme is to study the nutritional value of *prosopis* pods and their suitability for jam manufacturing. Hopefully, the produced jam could be of great help to achieve the following expected outpouts:

1- To minimize the high incidences of protein- energy malnutrition among young children and mothers in areas where mesquite trees are available.
2- Production of jam from local indigenous food material could effectively make the product more popular and cheaper than the imported jams, which are often beyond the buying capabilities of low income groups in Sudan.
3- To increase farmers income through improving the management of *prosopis* trees in Sudan.

2. LITERATURE REVIEW

2.1 Mesquite tree (*Prosopis* sp.)

2.1.1 Botanical description

As reported by **Burkart (1976)**, *Prosopis* species are trees or shrubs of varying size (rarely sub-shrubs), predominately xerophilous, spiny or rarely unarmed. The leaves are pinnate and on the rachis of the pinnate the leaflets are small rarely large, mostly opposite, linear, oblong, fusiform, entire and of the same colour on both sides. The venation is also pinnate and not very prominent. Shoots in most *Prosopis* species are dimorphic with long megablasts, flexuous and becoming knotty with age. Brachyblasts or short shoots emerge from multiple axillary buds from which develop the cauline spines when extant, leaf fascides and racemes.

Also, he described the flowers as small, actinomorphic, pentamerous hermaphroditic. Aestivation is valuate and the calyx is campanulate. The corolla has linear petals which are fused or more or less free, glabrous or pubescent, frequently villous or pilose inside the tip. The androecium is of 5 + 5 free stamens. Anthers are elliptic, dorsifixed, introse with an apical, pedicellate, globose or ovoid connectional gland. Pollen grains are simple, isopolar, tricolporate, sub-spheroidal to probate. The exine pertectate and baculate, while the sexine is bigger than the nexine with large or small pollen grains.The ovary is stipitate, villous or sometimes glabrous. Racemes are spike-like, amentiform, axillary, mostly densiflorous, but sometimes in globose heads.The fruit is a modified, indehiscent, fleshy legume called a drupaceous lament. The mesocarp is sugary or fibrous containing endocarps that divided into one-seeded coriaceous to bony segments. The seeds are ovoid, compressed, hard, brown with mucilaginous endosperm, typical to that of the mimosoideae and surrounding the embryo. Cotyledons are flat, rounded and epigeous in germination.

2.1.2 Distribution

The natural distribution of the genus *Prosopis* includes arid and semi-arid zones of the Americas, Africa and Asia. The native range of *Prosopis* species can be approximately divided into five regions: simply defined as Asia, Africa, North America, Central America and South America. Although there is some overlap on to neighboring continents, each of the five regions are geographically distinct. Asian *Prosopis* species are native to the Middle East and stretching east to India, north to Georgia and Turkmenistan and west to Algeria along the north Africa coast, while *P. africana* is native to the Soudano-Guinean zone and neighboring areas, from Senegal in the west to Sudan and Kenya in the east without any overlap between the ranges of *P. africana* and that of the other old world species. The majority of the species is native to the Americas and can be approximately divided into three geographic areas. In fact, *P. juliflora*, *P. pallid* are found northern South America, Southern Central America and the Caribbean **(Mares, 1977)**.

Prosopis species are also considered to have some negative allelopathic effects on neighboring plants, particularly herbaceous and grass species. In costal formation, *Prosopis* are abundant with multi-stemmed shrubs and small trees often close to sea level. Also, tree forms are more common on inland flats, with trees size affected by soil depth, availability of moisture and competition from other species. However, a relationship was found between total biomass, basal area and plant density **.**

2.1.3 Utilization

2.1.3.1 Wood

The wood is probably the single most important natural resource from *Prosopis* species for use either as a fuel or for structural purpose. As a fuel it can be burnt directly or made into charcoal, and as or it can be used as poles or round wood or cut into boards and cants. The use of the wood from *Prosopis* depends very much on the form of each *Prosopis* species, with the shrubby species having limited value as a fuel and no value at-all for structural purpose. Tree species with the potential of producing larger volumes of straighter branches and trunks have always had greater importance as sources of fuel and timber for local populations. *Prosopis* species produce a wood

with a very high quality fuel, having a high calorific value of approximately 5000 kcal/kg **(NAS, 1989; FAO, 1997)**.

The wood contains aromatic hydrocarbons and the smoke rising from some species is said to impart a pleasant flavour to food cooked over it **(Maga, 1986**). Although the wood burns better when dry, a great advantage was found over some other species in an ability to burn well when freshly cut or "green". The charcoal obtained from the wood of *Prosopis* species is also of very high quality and can be produced as easily from green wood. Ten kg of green wood will make 1-2 kg of charcoal using traditional kilns, normally in 2-4 days **(Lea, 1996; Varshney, 1996)**. Fuel from *Prosopis*, whether as fresh or dry wood or as charcoal is very often the preferred fuel of local populations **(Vimal and Tyagi, 1986)**. *Prosopis* species also, have growth characteristics that make them very suitable as a source of fuel.

The heart wood of *Prosopis* species is strong, durable, hard and heavy. The specific gravity of wood of different species is given as 0.7 – 1.0 **(NAS, 1980)**, but the wood density is ranged between 700 – 1200 kg/m^3. The heart wood is usually dark red to dark brown in colour, very distinct from the much lighter, often yellow – coloured sapwood which is generally much more susceptible to attack by insects and is more quickly degraded. The colour of the heart wood tends to be lighter when freshly cut and it becomes with more intense colour after exposure to light. Branches or coppice shoots of various dimensions serve as posts for fencing, chosen in preference to those of other species because of their availability, suitable size and durability for fence posts, relatively with straight branches and shoots over 1.5 m long and they will often last at least ten years, with up 30 – 40 years recorded in some arid areas in Hawaii **(Esbenshade, 1980)**. Larger dimension round wood is used in the construction of rustic housing, for pillars, supports, roof beams, door, window frames and also for pilings and ship building **(Felker, 1977; Cruz, 1986**).

The wood of *prosopis* tree can be cut and worked for the production of house hold items and agricultural tools, it can also be cut into cants and boards for variety of uses, as the wood of *prosopis sp.* is preferred over other species, again for its strength and durability. Summer cut wood is less durable, however, being readily attacked by wood boring beetles, and requires treating before structural use. This was traditionally carried out by either scorching or drying around a fire, or soaking in water for a week

and sun-drying. This latter method is said to produce wood that is lighter and easier to transport by pack animals **(Felker, 1977)**.

2.1.3.2 Pods

As mentioned by **Simpson (1977),** *Prosopis* trees produce a greater yield of pods in years of low average rainfall but may produce low yields of pods in very wet years. Fruiting season varies with one or two periods of main fruit production or fruiting may be almost continuous. These characteristics make the tree very suitable as a source of food and/or fodder, because their deep roots accessing water tables making them less dependent on rainfall for fruits production. This is a very important attribute in arid and semi-arid zones, where the production of other food crops is highly dependent on the rainfall. The need for alternative, unfailing crops is important for human populations living in desert regions.

Pods are considered as an essential food source for indigenous people throughout the Americas. The pod also, helps to sustain human life by providing available source of food for animal species in most tropic levels of the ecosystems in turn supports biodiversity and system stability **(Felker, 1979).** *Prosopis* trees produce high yields of fruit compared with fruit yields from other tree species growing in similar environments. *Prosopis* trees generally initiate flowering and fruiting in the third or fourth year after germination, much earlier under optimal conditions, but often considerably later under drought conditions or very poor soils. Fruit yields increase gradually up to 10 – 20 years and may be expected to continue at this high level for several decades **(Lima, 1990)**.

Fruit production is in general inversely correlated to rainfall and in sub-tropical climates, also to minimum winter temperature. Yields as 100 kg/yr, and often 20 – 50 kg/yr have been recorded for single trees, per hectare production is highly variable ranging from 1 to 8 t/h/yr **(lee and Felker, 1992)**.

The fruit produced by *Prosopis* species are legume pods which are high in sugars, carbohydrates and proteins. Pods have been found as a historic source of food for human populations and more important as a livestock feed during the last few centuries. However, pods are vary considerably in size between species and even between populations and individual trees of some species. Pods of Afro-Asiatic

species tend to be 3 - 12 cm long, while the American species are generally divided into two groups; the smaller and spiraled pods. The size of the first group is ranged between 2–10 cm long which belongs to species of sections *Strombocarpa* and *Monilicarpa*, while that of the second group ranged between 10 – 45 cm long which belongs to species of section *Algarobia*. All American species are heavily attacked by seed eating insects, mostly bruchid beetles which can destroy over 25% of the seeds, affecting most pods **(Odoul, 1986)**.

In general pods of all *Prosopis* species are composed of an exocarp, sometimes a fleshly mesocarp, fibrous endocarps and hard seeds. The form and relative amount of each varies widely between species, with several *Prosopis* species having a high percentage of mesocarp favoured as a source of food and feed. The mesocarp varies in taste from tart and bitter to the sweet pods preferred for human and animal consumption. Succulence also, varies from dry fibrous pods to moist and sweeter pods. Therefore, the chemical composition of the mesocarp varies widely between species and even between individual trees. For a single species, pod protein content tends to be consistent between sites and seasons, whereas sugars content exhibits some variation. However, no anti-nutritional factors were detected in the pods in regard to human consumption **(Becker and Grosjean, 1980; Odoul, 1986; Gradose and Cruz, 1996)**.

Direct consumption of mesquite pods by humans even as a stable food has not resulted in any recorded harmful effects on human health. However, there are some records of illness on livestock, particularly cattle when fed almost exclusively on pods of *Prosopis* species from section *Algarobia*. Symptoms such as facial contortions, an impacted rumen and constipation, occasionally resulting in death have been reported in the USA, Hawaii, Mexico, Brazil, Argentina, Sahelian and India **(Silva, 1990)**.

Pods from species of section *Algarobia* contain 7-22% protein, 30 – 75% carbohydrates, 11 – 35% crude fiber, 1 – 6% fat and 3 – 6% ash. Large variations are observed between species, within species and even between the different trials **(Odoul, 1986; Galera, 1992; Anttila, 1993; FAO, 1997)**.

2.1.3.3 Honey and wax

Prosopis flowers are considered as a valuable source of bee forage. The flowers produce copious quantities of pollen and nectar over relatively long periods of time as a nutritive reward for potential insect pollinators. Larger bee species with longer flight ranges are thought to be the principal pollinating agents **(Simpson, 1977).**

Prosopis honey is light yellow in colour and generally of good quality with a pleasant taste and only a slight aroma. The honey is still collected from wild colonies, but an increasing amount is produced in fixed or mobile hives in a commercial apiculture. Mexico is considered as the world's largest exporter of mesquite honey and much referred to as "acacia" honey. Also, large amounts of top quality honey and wax were exported from Hawaii for several decades, based on the large wood lands of introduced *P. pallida*. The Wax product is used for production of candles and in pharmaceutical preparations **(Esbenshade, 1980)**.

2.1.3.4 Gums Exudates

Prosopis gums were chewed and eaten by some northern American tribes and used in the manufacture of confectionaries. Gum or bark covered with gum was used in north America to produce a *Prosopis* derived paint for skin, pottery and leather or as a basketry dye **(Felker, 1977)**.

Exudate gum is produced from natural wounds in the park of plants that used as a defense mechanism. *Prosopis* exudate gums are water soluble, yellow liquid when fresh, slowly hardening and darkening in colour. Old gum is found in resin pockets in the wood can be very hard, crystalline in structure and almost dark in colour. Water soluble gums have traditionally been produced from *Acacia* species particularly *A. senegal*. This gum is of the highest quality and old gum is the bench-mark with which all other exudates gums are compared. Comparison of *Prosopis* gum with gums from traditional gum producing species show that *Prosopis* species produce gum of similar quality with that of *P. juliflora* being almost identical in chemical composition to that of *A. Senegal* **(Anderson, 1986)**.

The utilizations of *Prosopis* gum as a food additive, emulsifier and thickener, row material for making a adhesives and sizing cloth and in food and pharmaceutical preparations were reported by **Vimal and Tyagi (1986).** In India, the gum is said to have a bitter taste and is used increasingly in the manufacture of textiles and adhesives.

2.1.3.5 Fibers, tannins and dyes

Roots and bark from some *Prosopis* species were used in North America to make strong ropes. Also, the bark and gums from some *Prosopis* sp. were used in production of paints, dyes, cosmetics and hair cleanser **(Felker, 1977).**

The original name of *Prosopis* in north America is "misquitt" from the use of tree bark as a tannin agent, with bark containing 14 – 16% catechol tannins **(Doat, 1978)**. The tannin content of various plant parts from different species of *Prosopis* is 6 – 20%. Bark tannin along with that found in the wood and fruit extracts is used in tanning and curing of animal skin, particularly cattle hides in leather production.

Posopis roots extract was used to prepare a brown purple colorant for the dying of cotton and other materials **(Cruz, 1986).**

2.1.3.6 Medicines

Aqueous and alcoholic extracts from *Prosopis* leaves and pods show some antibacterial activity **(Ahmad and Sultana, 1989).** *Prosopis*-based medicines were occasionally used in the Americas to treat the epidemic diseases. The active chemical compounds which contribute to the medical properties of *Prosopis* have been isolated. The leaves of many *prosopis* species were found to contain many different free amino acids and flavounoids **(Carmen, 1974).**

Also, alkaloids and diketones have been isolated as active ingredients. The concentration of alkaloids in *Prosopis* leaves varies between species and within populations but it ranged between 0.4 – 3.6% (on dry weight basis). The Concentrations were significantly higher in younger rather than in older leaves **(Cates and Rhoades, 1977).** Out of these alkaloids, two piperidine alkaloids have been studied **(Neuwinger, 1996).**

In North America, medicines are commonly prepared as an aqueous solution or tea from the different parts of the plant. Many tribes used the leaves, buds and gums to treat eye infections. also, the leaves, bark and gum are used as laxatives, emetics, cathartics and purgatives. The gum solution is used to treat sore throats and respiratory inflections, while, the leaves, gums and bark are used for diarrhea and other stomach disorders including indigestion and ulcers. The gum is also used as a disinfectant for open wounds and skin disorders **(Felker, 1977).**

In South America, preparations from fresh pods of various species are used to treat conjunctivitis. Leaf preparations are used to mend broken bones or cure didropesia, liver stones, dyspepsia and venereal disease, and are often mixed with other products **(D'Antoni and Solbrig, 1977).** These preparations have also been recorded as treatments for mouth infections, ear ache, scorpion stings and snake bites. Some studies have shown significant activities of the plant extracts against lung carcinoma, lymphocytic leukemia and other carcinomas **(Ahmad and Sultana, 1989).**

In addition to that, many medicinal uses have been recorded for the different parts of *Prosopis* tree, especially for mouth and throat infections including ulcers and bronchitis, internal diseases including general pains, parasites and urinary disorders and skin disorders such as dermatitis and parasitic infections. In Asia, the flowers of native *Prosopis* species are used for the prevention of miscarriage, bark extracts for the treatment of leprosy, dysentery, bronchitis, asthma, leucoderma, tremors and rheumatism. Also, the leaves smoke is used to cure eye infections while their extract is recommended against snake-bites and scorpion stings **(ICFRE, 1993)**. In Africa, the native *Prosopis* species are considered as a valuable source of medicines (**Neuwinger, 1996)** and it is used as anti-biotic or anti-bacterial **.**

2.2 Pods nutritional value

The chemical composition of *Prosopis* pods was studied by **Cruz (1990).** The protein, fiber and ash were found to range between 9-12%, 14-23% and 3-5%, respectively. The main soluble solid of the pulp is sucrose (46%), representing over 90% of the total soluble sugars, while the reducing sugars, glucose, fructose and xylose are present in very small amounts **(Cruz etal; 1987, Saenz *etal*; 1987).**

Talpada (1985) found the sugars content of *P. Juliflora* pods to vary from 13-20% in different seasons and years showing a strong environmental effect on pod compositions as did **Lee and Felker (1992).** The soluble sugars from pericarp of *P. juliflora* from Ecuador comprise 75% sucrose, 12% fructose, 5% inositol and 1% raffinose (**Marangoni and Alli, 1988**).

High iron levels have also been reported in *P. julifora* from Ecuador and Brazil **(Figueiredo 1975, Marangoni and Alli ,1988)**, while the vitamins (C, B_6) and calcium pantothenate are present in significant amounts in the pulp from *P. pallida* pods **(Gradose and Cruz, 1996).** The seeds of *p. pallida* comprise 32% endosperm, 48% cotyledons and 20% episperm (seed coat), which contain 65% protein. the amino acids composition of the cotyledon proteins has been determined **(Cruz *etal*;1987)**.

No significant quantities of antinutritional factors have been isolated from *Prosopis* pod fractions. Each fraction of the fruit has been investigated for poly-phenols and tannins **(Salazar, 1993; Bravo *etal*; 1994)**.

The crud protein content of the pulp from *P. pallid* is surprisingly high (8%) considering that seeds are not included. All the essential amino acids are found to present in amounts which fulfill the requirements of the FAO\WHO standard protein, thus indicating an acceptable nutritional quality of the protein. However, methionine and cysteine are the limiting amino acids (**Marangooni and Alli 1988; Zolfaghari and Harden 1982; Meyer 1984).** Mesquite powder is also high in calcium, magnesium, potassium, iron and zinc, and rich in the amino acid lysine **(Amsden, 2006).**

The fat content of *P. pallid* cotyledon has been reported to be 7% with the major fatty acids found in extracted oil being linoleic acid (39%), oleic acid (29%), palmatic acid (13%) and stearic acid (10%). It is important to note that *Prosopis* pod has a low activity of trypsin inhibitors as well as phytohemagglutinins **(Jimenez and Vergara 1977)**.

2.3 Pod processing

In general, pod processing involves drying, pounding, grinding or milling of pods, either as a single process producing a whole pod extract or with some separation of pod parts for further processing of each fraction. For example, pods processing for animal feed involve milling of whole pods into a coarse homogenous flour, although on some cases the exocarp and the mesocarp (pulp) are separated from the endocarp and seed. Whereas, pod processing into human food, the separation of pod parts is generally undertaken with the mesocarp (pulp) fraction undergoing further processing steps. Dried pods are usually pounded in pestle or in stone mills. For hand grinding or milling in particular, an adequate drying step is essential to reduce the problems caused by moist mesocarps sticking during processing **(Ochoa, 1996)**.

Two traditional products obtained from *Prosopis* in Peru are mainly based on the soluble sugars of the pulp. The rest of the fruit, including the endocarp, insoluble fiber and seeds is often discarded. Also mesquite pods played an important role in the Sonoran desert in North America, where the Indian tribes cooked the green pods with meat. The flour and dough may be made with the dried or toasted ripe pods. Moreover, a kind of durable cake and fermented beverage are also made after removing the seeds from the endocarp hulls.Today in Northern Argentina, flour made from the sugary pulp of posopis species is known as "patay" and is still consumed **(Ochoa,1996).**

In addition to that, a syrup "algarrobina" is made from whole or crushed pods after being soaked in water for two hours, pressing, filtering and finally concentrating the liquid by evaporation. The modern processes are much quicker and require no heating as they use a finely ground floor from. *P. pallid.* The flour is converted into an instantly soluble powder and could be used as a cocoa powder substitute. Coffee substitute has been also made from *P. juliflora* by roasting the coarse pulp flour at 120° C until it becomes dark brown during which time it agglomerates into large granules requiring further grinding. The final product is used in the same way as filter coffee granules. Furthermore, good quality glactomannan gums for use in food and pharmaceutical industries could be made from *P. pallid* seeds but the process is complicated.

Also, the flour from mesquite pods can add a sweet, nutty taste to breads or used to make jelly or wine. When flour is used in backing, the flour is used in combination with other flours-substitute (1/4cup or1/2cup). Mesquite flour is also used in pancakes, muffins, cakes and even cookies. Pods from *P. juliflora and P. pallida*complex could be used to supplement human diets **(Fleger, 1977; Fisher, 1977).**

In Peru, *Prosopis* syrup "Algarrobina" is consumed in different ways in Peru, some people recommend taking a spoon daily as a healthy food or it may be added to fruit juice or milk. In urban zones, the syrup is used as an ingredient in home confectionery and to prepare a tasty drink "cocktail algarrobina" which is a mixture of a small quantity of "algarrobina" with brandy and milk **(Cruz, 1999).**

Another food product from *Prosopis* is "yupisin" a beverage which is obtained after water extraction of sugars from *Prosopis* pods. Also, a fermented beverage is known in Argentina as "anapa", "aloja" is obtained from *Prosopis* "anapa" pods and is used as a substitute for beer or wine **(Cruz, 1986; Ochoa, 1996).**

2.4 Jam

2.4.1 Definition

Jam is generally known as solid gel made from fruit pulp or juice, sugar and added pectin. The jam can be made from a single fruit or a combination of fruits. The fruit content should be at least 40 % with a total sugars content of not less than 68% **(ICUC, 2004)**

2.4.2 Jam processing methods.

Jam can be commercially produced by using two methods. The first one is the open pan method which gives the product a traditional flavour with some carmelization of sugars. In the second commercial process, jam is produced under vacuum to reduce its boiling temperature to 65-80 ^{0}C. The lower boiling temperature enables the water to be driven off, retaining more of the volatile flavouring compounds from the fruit, preventing sugar carmelization and of course reducing the over-all energy required to make the product **(Wikipedia, 2010).**

2.4.3 Jam processing steps

2.4.3.1 Fruit preparation

The fruits for jam making should be fully mature, possess a rich flavor with most desirable texture. Firstly the fruits are washed thoroughly with water to remove any adhering dirts or dust, then must be carefully sorted, peeled, and if needed they are cut or crushed **(Hui, 2006).**

2.4.3.2 Cooking

Jam cooking is the most important step in jam making and the main purpose of cooking is to increase sugar concentration to the point where jelling occurs. Jam cooking in commercial practice is usually conducted under vacuum. The fruit juice or pulp should be skimmed if necessary to remove coagulated materials with continuous mixing. The cooking is continued until the desired consistency is reached. The concentration of the mixture at the desired consistency depends mainly upon the concentration of pectin, acid and sugar. The most common method of determining the end point is by allowing the liquid mixture to sheet from a wooden paddle or a large spoon. If it drips from the instrument as thin syrup, the process is not complete. and if it partly solidifies and breaks from the spoon in sheets form or jelly like sheet on the side of the spoon, the cooking is considered to be completed. However, the proper control during jam cooking by using a hand Refractometer is necessary to avoid over concentration of soluble solids, over inversion of sugar and pectin hydrolysis **(Hui, 2006).**

2.4.3.3 Filling, sealing and packaging

The clean empty jars are packed into trays that move on a roller conveyer to the filling operators. After filling, glass jars and large containers should be cooled by air, by passing them slowly through a tunnel fitted with an air blast or by keeping them in a cooling room until the jam is well set. Automatic filling machines that measure a definite volume of jam into each container are used in large factories and greatly reduce the cost of filling as compared to the manual filling with more uniform net content. The final step in jam production process is jars or cans sealing and packaging which can be done manually or automatically **(Hui, 2006).**

2.4.4 Jam quality and specifications

In general, good jam should be clear, bright with a characteristic colour, well set but not too stiff with a distinct fruit flavour **(Saeed and El- Mubark, 1974).** Also, as mentioned by **Onsa (2007)**, good quality jams should have total soluble solids, pH, acidity and reducing sugars between 67-70%, 3.2-3.4, 0.3-0.8% and 20-28% or 28-32%; respectively.

3. MATERIALS AND METHODS

3.1 Materials

Sample of mesquite *(Prosopis sp.)* pods were collected from Khartoum North, Khartoum State. Then, the pods were cleaned from foreign materials (leaves, stems and stones) and tightly packed in poly-ethylene bags and stored at -18˚C until needed for investigations.

3.2 Methods

3.2.1 Chemical methods

3.2.1.1 Moisture content

The moisture content was determined according to the standard method of the **Association of Official Analytical Chemists (AOAC, 1990).**

Principle : The moisture content in a weighed sample is removed by heating the sample in an oven (under atmospheric pressure) at 105 ± 1 ºC.Then, the difference in weight before and after drying is calculated as a percentage from the initial weight.

Procedure : A sample of 5 gm ± 1 mg was weighed into a pre-dried and tarred dish. Then, the sample was placed into an oven **(**Kat-NR.2851, Elektrohelios, Sweden **)** and left to dry at 105 ± 1 Cº until a constant weight was obtained. After drying, the covered sample was transferred to a desiccator and cooled to room temperature before reweighing. Triplicate results were obtained for each sample and the mean value was reported as moisture to two decimal points according to the following formula :

Calculation

$$\text{Moisture content [\%]} = \frac{[m2-m3]}{[m2-m1]} \times 100\% \qquad \text{(eq. 1)}$$

Where:

m_1 = mass of dish + cover

m_2 = mass of dish + cover + sample before drying

m_3 = mass of dish + cover + sample after drying

The dry matter (DM) as percent was calculated by subtracting the percentage of moisture content from 100%.

3.2.1.2 Crude protein

The crude protein content was determined in all samples by micro-Kjeldahl method using a copper sulphate-sodium sulfate catalyst according to the Official Method of the **AOAC (1990).**

Principle : The method consist of sample oxidation and conversion of nitrogen to ammonia, which reacts with the excess amount of sulphuric acid forming ammonium sulphate. The solution is made alkaline and the ammonia is distilled into a standard solution of boric acid (2%) to form the ammonia-boric acid complex which is titrated against a standard solution of HCL (0.1). Accordingly, the crude protein content is calculated by multiplying the total N % by 6.25 as a protein conversion factor.

Procedure : 0.5gm ± 1mg sample was accurately weighed and transferred together with 2-3 glass pellets, kjeldahl catalyst (No 33064, BDH, England) and 20ml concentrated sulphuric acid (No 18474420, Mark AG, Germany) into kjeldahl digestion flask. After that, the flask was placed into a kjeldahl digestion unit (Tecator, Sweden) for about 3hours until a colourless digest was obtained. Following, the flask was left to cool to room temperature and the distillation of ammonia was carried out in 30 ml boric acid (2 %) by using 40 ml distilled water and 60 ml sodium hydroxide solution (33 %). Finally, the distillate was titrated with standard solution of 0.1N HCL in the presence of 2-3 drops of Bromocreasol-green and Methyl-red as an indicator until a brown reddish colour was observed.

Calculation

Crude Protein [%DM] =

$$\frac{[\text{ml Hcl sample} - \text{ml Hcl blank}] \times 0.1 \times 1.4 \times 6.25 \times 100}{[\text{sample weight (g)} \times [100 - \text{sample moisture (\%)}]} \quad \text{(eq. 2)}$$

1.0 ml HCL [0.1] = 1.4 mg nitrogen

Protein conversion factor = 6.25

3.2.1.3 Fat content

The crude fat in the samples was determined according to the standard analytical method of the Member Companies of Corn Refiners Association, Inc. (1995).

Principle: The method determines the substances which are soluble in petroleum ether (B.P, 40 – 60º C) and extractable under the specific conditions of Soxhlet Extraction method. The dried ether extract is weighted and reported as percentage of the dry matter as crude fat.

Procedure: A sample of 5g ± 1mg was weighed into an extraction thimbles (30 ×100 mm) and covered with cotton that previously extracted with petroleum ether. Then, the sample and a pre-dried and weighed Erlenmeyer flask containing about 100 ml petroleum ether (No 1622, BDH, England) were attached to the extraction unit (Electrothermal, England) and the temperature was adjusted to produce about 150 to 200 drops of the condensed solvent per minute for 16 hours. At the end of the distillation period, the flask was disconnected from the unit and the solvent was redistilled. Later, the flask with the remaining crude ether extract was put in an oven at 105º C for 3 hours, cooled to room temperature in a desiccator, reweighed and the dried extract was registered as crude fat (% DM) according to the following formula.

Calculation

$$\text{Crude fat [\%DM]} = \frac{\text{weight of dry extract (g)} \times 100\%}{\text{sample wt(g)} \times [100 - \text{sample moisture(\%)}]} \quad \text{(eq. 3)}$$

3.2.1.4 Sugars determination

Total sugars, reducing and non-reducing sugars were determined following Lane And Eynon method as described by the **Association of Official Analytical Chemists (AOAC, 1990).**

Principle: Reducing sugars in pure solution or in plant materials after suitable pre-treatment (to remove interference substances) may be estimated by using copper sulphate as oxidizing agent in standard Fehling's solution.

Sample preparation

A. Reducing sugars

5g ± 1mg sample was weighed and transferred to 250 ml beaker. Then, 50 ml water was added, boiled gently and left to cool at room temperature. After that, the sample solution was transferred to a 250 ml volumetric flask and 2 ml of standard lead acetate (No 5032 , Analar, England) was added with stirring and left to stand for 10 min at room temperature. Finally, the excess amount of lead acetate was precipitated by using an appropriate amount of potassium oxalate solution (22%) and the solution was made up to and filtered.

B. Total sugars

From the previous sample solution, 50 ml was pipetted into a 250 ml conical flask and 5 g of citric acid and 50 ml water were added. Then, the mixture was boiled for 10 min to complete the inversion of sucrose and left to cool at room temperature. After that, the solution was transferred to a 250 ml of volumetric flask, neutralized with 1.0 N NaOH by using 2-3 drops of phenolphthalein (No 8987 J.T. Baker Holland) as an indicator and the sample was made up to volume.

Procedure: ten ml of the mixed Fehling's solution was pipetted into a 250ml conical flask. Then, sufficient amount of the clarified sugars solution was added to reduce Fehling's solution in the conical flask. After that, the solution was boiled until a faint blue colour is obtained, few drops of methylene blue indicator was added to Fehling's solution and titrated under boiling with sugars solution until a brick-red colour of precipitated cuprous oxide was observed. Finally, the titer volume was recorded and the amount of invert sugar was obtained from lane and Eynon table.

Calculation:

Reducing sugars (% DM) =

$$\frac{\text{invert sugar (mg)} \times \text{dilution factor} \times 100\%}{\text{titer} \times \text{wt.of sample (g)} \times (100\% - \text{moisture\%}) \times 1000} \qquad \text{(eq. 4)}$$

Total sugars (%DM) (as invert sugar) =

$$\frac{\text{invert sugar (mg)} \times \text{dilution factor} \times 100}{\text{titer} \times \text{wt. of sample (g)} \times (100\% - \text{moisture\%}) \times 1000} \qquad \text{(eq .5)}$$

Non Reducing sugars (% DM) =

$$\text{total sugars (\%)} - \text{reducing sugars (\%)} \qquad \text{(eq.6)}$$

3.2.1.5 Crude fiber:

The crude fiber content in the different samples was estimated according to the method that described by **Ranganna (2001)**.

Principle: The crude fiber is determined gravimetrically after the sample is chemically digested in a chemical solution. The weight of the residue after ignition is then corrected for ash content and is considered as a crude fiber.

Procedure: About 2.0gm ± I mg was weight in a digestion flask followed by addition of 200ml digestion solution (0.255N Sulphuric acid). Then, the flask was connected to 200ml digestion unit and the sample was boiled exactly for 30min.

After that, the flask was removed from the digestion unit, filtered and the precipitate was repeatedly rinsed with distilled boiled water, followed by 200 ml of

sodium hydroxide (0.313 N) under reflux condenser. After that, the precipitate was filtered through Gooch crucible and washed with hot distilled water followed by 15ml of ethyl alcohol. Finally, the crucible was dried at 105^0C to a constant weight, cooled (in a desiccator), weighed and ashed in a muffle furnace (carbolite, tybe ELF146B, England) at 550-600^0C until a constant weight was obtained. After cooling to room temperature, the difference in weight was considered as crude fiber.

Calculation

Crude fiber (%DM) =

$$\frac{(\text{dry residue+crucible (g)}- (\text{ignited residue+crucible (g)} \times 100\%}{\text{sample wt.(g)}\times(100\%-\text{sample moisture (\%)})} \quad \text{(eq.7)}$$

3.2.1.6 Total carbohydrates

The total carbohydrate percent was calculated by subtracting the total sum of moisture, protein, fat and ash as a percentage from100%.

3.2.1.7 Available carbohydrates

The percent of available carbohydrates on dry basis was calculated by subtracting the sum of protein, fat, crude fiber and ash as a percentage from 100% as it was described by **West, et.al.(1988).**

Food metabolizable energy value

The energy value of mesquite jam product was calculated based on Atwater factors for protein, fat and available carbohydrate .

Fat factor = 8.37 (k.cal/g)

Protein factor = 3.87 (k.cal/g)

Carbohydrate factor = 4.12 (k.cal/g)

1 k cal = 4.184 (kj)

3.2.1.8 Ash content

The standard analytical method of the Member Companies of Corn Refiners Association, Inc. (1995**)** was used for determination of ash content in the samples.

Principle: The inorganic materials which vary in concentration and composition are customary determined as a residue after being ignited at a specified temperature degree.

Procedure: A ground sample of 5g ± 1mg was weighed into a pre- heated, cooled weighed and tarred porcelain crucible. Before ashing, the sample was pre-ashed on an electrical pre-asher and placed into a muffle furnace (Carbolite, Sheffeild, England) at 525 to 600 ºC until a constant weight was obtained. The weight of the residue after ashing was defined as ash content and expressed as a percentage based on the dry matter content in the ground sample.

Calculation

$$\text{Ash content [\%DM]} = \frac{\text{residue weight (g)} \times 100}{[\text{sample wt (g)} \times [100 - \text{sample moisture (\%)}]} \quad \text{(eq. 8)}$$

3.2.1.9 Minerals content

Minerals in raw mesquite pods and mesquite jam were measured according to the standard method of the **Association of Official Analytical Chemists (AOAC, 1980),** by using Atomic Adsorption spectroscopy.

Principle: the element in the sample is subjected to radiations at excitation wavelength from an external source. Thus, the total amount of energy absorbed by the sample element to achieve the exited state is equivalent to the concentration of the element in the sample.

Procedure: A sample of 5.0 gm ± 1mg was placed in a porcelain crucible and ashed in a muffle furnace at $550C^0$ until a constant weight was obtained. Then, 5-10 ml HCL (6N) was added to each crucible and the solution was heated just to boil, cooled , filtered through an ashless filter paper and the filtrate was collected and made up to

volume with distilled water. After the apparatus conditions were set, the reading of a standard solution was noted and the standard curve of metals concentration (mg/ml) against absorption was drawn.

After that, the minerals concentration in the sample solution was measured and the concentration of each mineral was detected from the standard curve.

Calculation:

$$\text{Mineral content (ppm)} = \text{concentration} \times 10^6 \qquad \text{(eq.9)}$$

3.2.2 Physico-chemical methods

3.2.2.1 Hydrogen ions concentration (pH)

The pH is defined as the logarithmic concentration of hydrogen ions in gram per liter. The pH of the different samples measured following the method that described by **Ranngana (2001).**

Principle : The pH of a sample is measured potentiometerically with a pH-meter after standardization of the meter electrodes with buffer solutions and the reading is taken when the equilibrium potential across the electrodes is achieved .

Procedure: After standardization of the pH-meter (pH-meter model - pHs – 2F) electrodes with two buffer solutions (pH 4.01-7.0), the electrodes of the pH- meter was rinsed with distilled water , immersed in the sample solution (20◦ C) and left to stand until the reading is being stable. All the reading were expressed as pH to the nearest two decimals (0.00) pH units.

3.2.2.2 Total soluble solids (TSS %)

The total soluble solids of mesquite fruit extract and mesquite jam were measured by using a hand Refractometer (Erma-Tokyo No. 40382 "45-82", and Erma-Tokyo No. 50015 "0-32", Japan) .

3.2.2.3 Titrable acidity

The titrable acidity was determined according to the method described by **Ranngana (2001)**. A sample of 10gm ±1mg was weighed, diluted with 100ml distilled water, boiled for 30 min in a water bath and then filtered by using Whatman filter paper No. (4). Then, 10 ml from the cleared sample solution was titrated against 0.1 N sodium hydroxide by using phenolphthalein as an indicator. The total acidity (mg/ 100gm) expressed as % citric acid.

Calculation

$$T.A\% = \frac{\text{Titer (ml)} \times 0.1N \times \text{dilution factor} \times \text{equivalent wt.} \times 100\%}{\text{Sample (g)} \times \text{sample volume taken for estimation} \times 1000} \quad \text{(eq. 10)}$$

3.2.3 Experimental processing methods

3.2.3.1 Mesquite juice extraction methods

For determination of optimum conditions that should be followed for production of mesquite juice extract, two different extraction methods were used:

(A) Cold extraction method:

In this method, the cleaned mesquite fruits (100gm) were soaked in distilled water overnight (16h) at room temperature (27˚C) at different fruit water ratios (1:2, 1:4, 1:5, 1:6, 1:8, 1:10). After that, the mixtures were blended (molinex, type 2766, france) for 5min and immediately filtered with a coarse silk sieve and weighed. Then, the filtrates were checked for the pH, total soluble solids (T.S.S), colour, dry matter(%DM) and yield %. The yield of each extract was calculated by using the following equation:

Yield (%) =

$$\frac{\text{extract TS} \times \text{weight of extract} \times 100\%}{\text{sample weight } (100\% - \text{moisture}\%)} \qquad \text{(eq.11)}$$

(B) Hot extraction method:

In this method, the cleaned mesquite fruits (100gm) were soaked in hot distilled water (100˚C) for one hour (1h) with the same fruit: water ratios that used in the previous method. After that, the mixtures were blended for 5min, immediately weighed, filtered and checked for the pH, TSS%, DM%, colour and yield%.

3.2.3.2 Mesquite jam processing method

Mesquite pods (4 kg) were firstly soaked in tap water for 30 min at room temperature (27˚C) and washed to remove some of the fruits bitterness and dust. After that, the cleaned fruits were soaked again in tap water (16 kg) overnight (16 hour) at room temperature(27˚C). Then, the mixture was blended for (5 min) with an electric mixer and sieved with a coarse silk sieve. When, the pH and the total soluble solids (T.S.S) of the extract were being checked, the required amounts of citric acid, pectin and sugar were calculated according to the method adopted by **Saeed and EL.mubarak, (1974)**. Then, mesquite extract with the proper amount of sugar (20kg) were placed in an open kettle and the mixture was boiled until the soluble solids reached (64^{o} Brix). After that, citric acid (160gm) and pectin (260gm) as solutions were immediately added with continuous boiling until the T.S.S% of the mixture reached 68 ^{o}Brix. Finally, the kettle was put down and the mesquite jam was filled hot in dried glass jars, closed, quickly cooled and stored until needed for chemical, physic - chemical and organoleptic evaluations. The mesquite Jam processing method and the recipe used in this study are shown in Fig (3.1) and Table (3.1), respectively.

3.2.4 Anaylsis of microbial loods

The microbiological analysis of mesquite fruits determined as flows:

3.2.4.1 Total bacterial count

One ml of the suitable dilation was transferred aseptically into sterile petri dishes immediately and 15ml of the melted agar medium that cold to 45 ^{o}c were poered into petri dishe. Alquats were mixed with agar medium and allowed to solidify. When medium was solidified, the dishes were inverted and incubated at 37 ^{o}c for 48hr. plates were examined and the colonies on every plate were counted then the total viable count was determined as colony forming units per ml (c f u/ ml)**. (Harrigan and Macance, 1976)**

3.2.4.2 coliform count

Asample from dilution (0.1ml) was deposited into the solidified Brilliant green agar medium. The sample was spread over the surface of the agar medium using asterile glass rod, and then dishes were inverted and incubated at 37 ^{o} c for48.

3.2.4.3 Yeasts and molds count

0.1 ml from samples dilution was pipette into sterile petri dishes dishes were incubated at 28 ^{o}c for 2-3 days. All colonies were counted by using a colony counter.

The number of yeasts and mold were computed per gram by multiplying the reciprocal of the dilution used (**Harrigan and macance,1976**).

3.2.5 Organoleptic evaluation method

All The samples of mesquite jam were sensory evaluated according to the Hedonic Scoring Test method as described by **Ranganna (2001).**

In this method, 20 trained panelists from Food Sciences and Technology Department, College of Agricultural Studies, Sudan University of Sciences and Technology were asked to evaluate the products with respect to their taste, colour, flavour and overall quality using the following Hedonic Scale, 1= excellent, 2 = very good, 3 = good, 4 = acceptable, 5 = unacceptable.

3.2.6 Statistical method

The results obtained in this study were subjected to statistical analysis using the Statistical Package for Social Science (SPSS) programme. While , the mean values were tested by using the Analysis of Variance (ANOVA) programme. A probability of 0.05 was used to indicate the differences between the samples as mentioned by **Mead and Gurnow (1983)**.

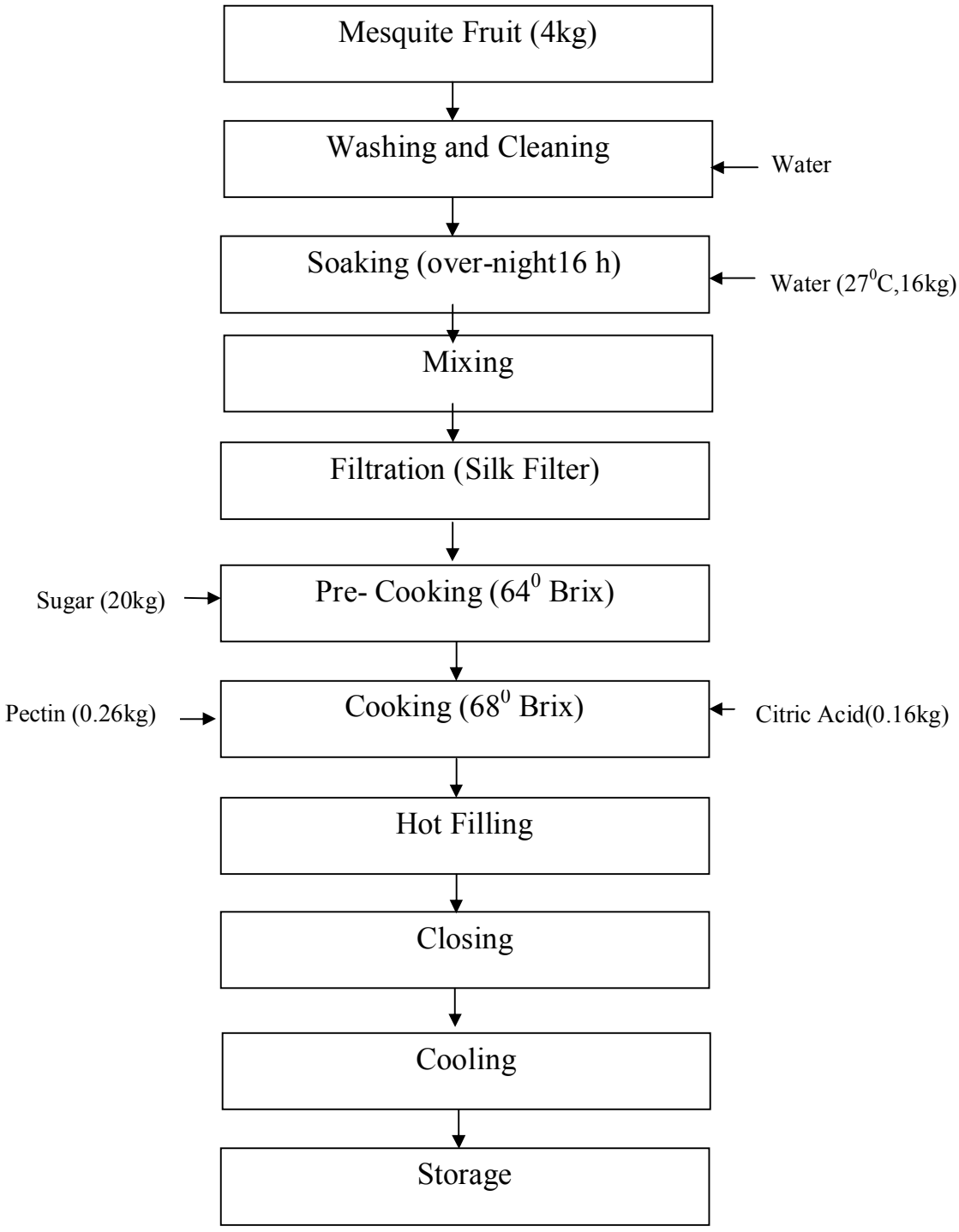

Fig. (3.1): Mesquite jam processing method

Table (3.1): Mesquite jam recipe

Ingredients	Quantity (kg)	Formula (%)
Mesquite fruit extract	16.00	43.93
Sugar	20.00	54.92
Citric acid	00.16	00.44
Pectin	00.26	00.71
Total	36.42	100.00

4. RESULTS AND DISCUSSION

4.1 Physical characteristics of fresh mesquite fruits

Table (4.1) shows the physical characteristics of fresh mesquite fruits at the beginning and at the end of the harvesting season (January - June, 2010).

The fresh mesquite fruits were classified into three different sizes (big, medium and small) according to their weight, length and width which were found to range between 4.01-4.83gm, 18.83-22.87cm and 0.95-1.02cm at the beginning and by the end of the season, respectively for the big fruits size. While, the weight, length and width of the medium fruits size ranged between 2.77-3.35gm, 14.41-18.74cm and 0.89-0.94, respectively. The weight, length and width of the small size ranged between 1.62-2.78gm, 9.80-15.24cm and 0.83-0.90cm, respectively at the beginning and by the end of the harvesting season (2010).

In general, the results obtained in this study indicated that the weight, length and width in each mesquite fruit size significantly increased by the end of the season (June) in comparison with those recorded at the beginning of the season (January). However, the results in this study were found to agree well with those reported by **Odoul etal; (1986).**

4.2 Nutritional value of mesquite fruits

4.2.1 Chemical composition

Tables (4.2) and (4.3) show the chemical composition of mesquite fruits at the beginning and by the end of the harvesting season (January-June, 2010) on wet and dry weight basis, respectively.

The moisture, protein, fat, total carbohydrates, crude fiber, total sugars, tannins, and ash contents were found to range between 4.81-4.59%,17.20-9.68%, 2.55-2.40%, 67.99-79.71%,13.59-17.75%, 8.24-21.38%, 0.48-0.53% and 7.45-3.63%, at the beginning and by the end of the season, respectively on fresh weight basis (table 4.2).

Table (4.1): Physical characteristics of fresh mesquite fruits

Parameters	Mesquite fruit size											
	Big				Medium				Small			
	[n = 10 ± SD]											
	At the beginning of the season[1]	By the end of the season[2]	$Lsd_{0.05}$	SE±	At the beginning of the season[1]	By the end of the season[2]	$Lsd_{0.05}$	SE±	At the beginning of the season[1]	By the end of the season[2]	$Lsd_{0.05}$	SE±
Weight (gm)	04.01 ± 0.70 [b]	04.83± 0.66 [a]	0.625*	0.097	2.77± 0.50 [b]	03.35± 0.35 [a]	0.891*	0.081	1.62± 0.30 [b]	02.87± 0.79 [a]	0.439*	0.065
Length (cm)	18.83± 1.60 [b]	22.87± 0.68 [a]	3.561**	1.862	14.41±0.50 [b]	18.74± 0.77 [a]	2.642**	3.567	9.80± 1.00 [b]	15.24± 0.49 [a]	5.879**	4.638
Width (cm)	0.95± 0.30 [b]	01.02± 0.14 [a]	0.029*	0.005	00.89±0.10 [b]	00.94± 0.10 [a]	0.036*	0.091	0.83±0.40 [b]	00.90±0.14 [a]	0.076*	0.071

[1]≡January , 2010 .[2] ; June , 2010 .

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within columns are significantly different (P≤0.05).

* ≡ Significant at (P≤0.05).

** ≡ Highly significant at (P≤0.01).

$Lsd_{0.05}$ ≡ Least significant difference at (P≤0.05).

SE± ≡ Overall experimental error.

Table (4.2): Chemical composition of mesquite fruits on fresh weight basis

Sample collection period	At beginning of the season	By the end of the season	$Lsd_{0.05}$	SE±
Chemical composition	[% , n = 3 ± SD]			
	January, 2010	June, 2010		
Moisture	04.81 ± 0.05^{a}	04.59 ± 0.05^{a}	0.369^{ns}	0.035
Protein	17.20 ± 0.01^{a}	09.68 ± 0.20^{b}	4.864^{*}	1.756
Fat	02.55 ± 0.00^{a}	02.40 ± 0.10^{a}	0.368^{ns}	0.022
Total carbohydrates	67.99 ± 0.70^{b}	79.71 ± 0.70^{a}	7.061^{*}	2.530
Available carbohydrates	54.41 ± 0.50^{b}	61.96 ± 0.60^{a}	2.872^{*}	0.768
Crude fiber	13.59 ± 0.30^{b}	17.75 ± 0.40^{a}	1.966^{*}	0.722
Reducing sugars	02.59 ± 0.10^{a}	02.12 ± 0.10^{a}	0.520^{ns}	0.081
Non-reducing sugars	05.37 ± 0.00^{b}	18.30 ± 0.30^{a}	8.258^{**}	4.115
Total sugars	08.24 ± 0.20^{b}	21.38 ± 0.00^{a}	10.469^{**}	4.061
Tannins	00.48 ± 0.00^{a}	00.53 ± 0.00^{a}	0.465^{ns}	0.019
Ash	07.45 ± 0.20^{a}	03.63 ± 0.20^{b}	1.754^{*}	0.022

SD ≡ Standard deviation.
n ≡ Number of independent determinations.
Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different ($P \leq 0.05$).
* ≡ Significant at ($P \leq 0.05$).
** ≡ Highly significant at ($P \leq 0.05$).
n.s ≡ Not significant.
$Lsd_{0.05}$ ≡ Least significant difference at ($P \leq 0.05$).
SE± ≡ Overall experimental error.

Table (4.3): Chemical composition of fresh mesquite fruits on dry weight basis

Sample collection period	At beginning of the season	By the end of the season	$Lsd_{0.05}$	SE±
Chemical composition	[%,n = 3 ± SD]			
	January, 2010	June, 2010		
Dry matter	95.19 ± 0.15[a]	95.41 ± 0.80[a]	0.625[ns]	0.021
Protein	18.06 ± 0.50[a]	10.15 ± 0.30[b]	5.994[*]	1.998
Fat	02.68 ± 0.00[a]	02.51 ± 0.00[a]	0.541[ns]	0.035
Total carbohydrates	71.43 ± 0.20[b]	83.54 ± 0.30[a]	8.625[*]	2.764
Available carbohydrates	57.16 ± 0.60[b]	64.93 ± 0.70[a]	4.861[*]	0.842
Crude fiber	14.28 ± 0.70[b]	18.61 ± 0.60[a]	2.756[*]	0.743
Reducing sugars	02.72 ± 0.20[a]	02.22 ± 0.10[a]	0.674[ns]	0.067
Non-reducing sugars	05.64 ± 0.20[b]	19.18 ± 0.90[a]	10.487[**]	4.770
Total sugars	08.66 ± 0.20[b]	22.41 ± 0.60[a]	12.033[**]	5.846
Tannins	00.51 ± 0.00[a]	00.56 ± 0.00[a]	0.648[ns]	0.021
Ash	07.82 ± 0.20[a]	03.81 ± 0.20[b]	2.997[*]	0.015

SD ≡ Standard deviation.
n ≡ Number of independent determinations.
Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different (P≤0.05).
* ≡ Significant at (P≤0.05).
** ≡ Highly significant at (P≤0.05).
n.s ≡ Not significant.
$Lsd_{0.05}$ ≡ Least significant difference at (P≤0.05).
SE± ≡ Overall experimental error.

During the season, the available carbohydrates, crude fiber, non-reducing sugars and total sugars contents significantly increased from 57.16%, 14.28%, 5.64% and 8.66% at the beginning of the season to 64.93%, 18.61%, 19.18%, and 22.41%, by the end of the season, respectively on dry weight basis (Table4.3). While, the contents of protein and ash significantly decreased from 18.06% and 7.82% at the beginning of the season to about 10.15%and 3.81%, respectively by the end of the harvesting season (June, 2010).

The results obtained in this study were in a good agreement with those reported by **Cruz (1990); Galera (1992); Anttila (1993); Diaz (1995) and FAO (1997).**

4.2.2 Minerals content

Table (4.4) and (4.5) present the minerals content of mesquite fruit at the beginning and by the end of the harvesting season (January-June, 2010) on wet and dry weight basis, respectively as mg/100g fruit.

From the results in table (4.5), mesquite fruits were very rich in sodium, potassium, calcium and magnesium which were found to range between 361.40-335.40, 276.30-619.40, 268.90-485.30 and 184.90-181.30 mg/100g fruit, at the beginning and by the end of the season, respectively (on dry weight basis). In contrast, the fruit was found to be very poor in zinc (1.4-3.0mg/100g) and moderately rich in iron (10.9mg/100g) by the end of the season (June, 2010). The lead was not detected in mesquite fruits at the beginning and by the end of the season.

The results obtained in this study are in agreement with those reported by **Gradose and Cruz (1996); Amesden (2006)** and different from those reported by **Figueiredo (1975); Marangoni and Ali (1988).**

Table (4.4): Minerals content of fresh mesquite fruits

Sample collection period	At beginning of the season	By the end of the season	$Lsd_{0.05}$	SE±
Minerals	[mg/100g,n = 3 ± SD]			
	January, 2010	June, 2010		
Sodium [Na]	344.00[a]	320.00[b]	18.462[*]	3.625
Potassium [K]	263.00[b]	591.00[a]	27.913[**]	5.427
Calcium [Ca]	256.00[b]	463.00[a]	181.233[**]	8.188
Magnesium [Mg]	176.00[a]	173.00[b]	1.990[*]	1.023
Iron [Fe]	3.70[b]	10.90[a]	5.703[**]	0.709
Manganese [Mn]	12.00[a]	2.90[b]	9.016[**]	2.856
Lead [Pb]	N.D	N.D	-	-
Zinc [Zn]	1.40[b]	3.00[a]	0.926[*]	0.069

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different (P≤0.05).

* ≡ Significant at (P≤0.05).

** ≡ Highly significant at (P≤0.05).

ND ≡ Not detected.

$Lsd_{0.05}$ ≡ Least significant difference at (P≤0.05).

SE± ≡ Overall experimental error.

Table (4.5): Minerals content of mesquite fruits on dry weight basis

Sample collection period	At beginning of the season	By the end of the season	$Lsd_{0.05}$	SE±
Minerals	[mg/100g,n = 3 ± SD]			
	January, 2010	June, 2010		
Sodium [Na]	361.40^{a}	335.40^{b}	21.269^{*}	5.627
Potassium [K]	276.30^{b}	619.40^{a}	30.343^{**}	4.098
Calcium [Ca]	268.90^{b}	485.30^{a}	199.164^{**}	9.456
Magnesium [Mg]	184.90^{a}	181.30^{b}	2.936^{*}	0.854
Iron [Fe]	003.90^{b}	011.40^{a}	6.729^{**}	1.065
Manganese [Mn]	012.60^{a}	003.00^{b}	8.965^{**}	3.267
Lead [Pb]	N.D	N.D	-	-
Zinc [Zn]	001.50^{b}	003.10^{a}	1.528^{*}	0.072

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different ($P \leq 0.05$).

* ≡ Significant at ($P \leq 0.05$).

** ≡ Highly significant at ($P \leq 0.05$).

n.s ≡ Not significant.

ND ≡ Not detected.

$Lsd_{0.05}$ ≡ Least significant difference at ($P \leq 0.05$).

SE± ≡ Overall experimental error.

4-3 Microbial load of fresh mesquite fruits

Table (4.6) shows the microbiological evaluation of fresh mesquite fruits during January and June, 2010 harvesting periods. The fruits were found free from any bacteria, yeasts, mould and coliform bacterial contamination.

This results agree well with those mentioned by **(Ahmad** and **Sultana (1989**). The aqueous and al coholic extracts from mesquite fruit pods and leave were found to have significant anti-cancer and anti-microbial activities and also used as anti-biotic in Africa **(Neuwinger, 1996).**

4.4 Suitability of mesquite fruits for jam processing

4.4.1 Extraction of mesquite fruits juice

For determination of the optimum method and conditions that should be used during preparation of mesquite fruit juice, two different extraction methods were used separately in this study

4.4.1.1Cold extraction method

In this method mesquite fruit samples were soaked in tap water at room temperature (27° C) for overnight (16 h) for different fruit: water ratios (1:2, 1:3, 1:4, 1: 5, 1:6) then, each sample was blended 5 min. and the mixture was filtered and examined for its hydrogen ions concentration (PH) total soluble solids (T.S.S %), total solids (T.S %) and yield (%) . The results obtained from the experiment are in dictated in table (4.7) .From the results, the yield (%) of mesquite juice was found to increase significantly ($p \leq 0.05\%$) with increasing fruit : water ratio.

In contrast, the T.S.S % was significantly decreased ($p \leq 0.05\%$). However, insignificant differences were found in the PH of the different fruit extracts. Also, among the different fruit : water ratios used in this experiment, the ratio of (1: 4) was found more suitable for production of mesquite fruit extract with suitable PH (4.1), T.S.S (8.5) and yield (36.83).

Table (4.6): Microbiological evaluation of fresh mesquite fruits

Sample collection period	**At beginning of the season**	**By the end of the season**
Parameter	Count (cfu/gm)	
	January, 2010	June, 2010
Total bacterial count	Nil	Nil
Total yeasts and moulds	Nil	Nil
Coliform bacteria	Nil	Nil

Cfu/g ≡ colony form unit per gram.

Table (4.7): Cold extraction of fresh mesquite fruits

Parameters	Fruit: water ratio					$Lsd_{0.05}$	SE±
	1:2	1:3	1:4	1:5	1:6		
	[n=2 ± SD]						
Mesquite fruit weight (g)	100	100	100	100	100	-	-
Extract weight (g)	130.00 ± 1.00^{e}	219.30 ± 1.30^{d}	362.22 ± 0.50^{c}	433.30 ± 0.00^{b}	513.30 ± 0.00^{a}	14.199^{**}	10.166
Extract volume (ml)	140.05 ± 0.00^{e}	199.50 ± 0.20^{d}	348.50 ± 0.60^{c}	400.35 ± 0.00^{b}	500.00 ± 0.00^{a}	11.462^{**}	8.361
Total soluble solids (T.S.S%)	016.50 ± 0.50^{a}	012.50 ± 0.50^{b}	011.35 ± 0.04^{c}	008.50 ± 0.50^{d}	007.50 ± 0.50^{c}	2.097^{*}	1.430
Hydrogen ions concentration (pH)	004.25 ± 0.70^{a}	004.15 ± 0.10^{a}	004.15 ± 0.10^{a}	004.10 ± 0.00^{a}	004.20 ± 0.00^{a}	2.625^{ns}	0.756
Yield % [on wet basis]	021.46 ± 0.50^{c}	027.42 ± 0.98^{d}	041.11 ± 0.50^{c}	036.83 ± 2.00^{b}	038.50 ± 2.49^{a}	5.791^{*}	2.946

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different ($P\leq0.05$).

* ≡ Significant at ($P\leq0.05$).

** ≡ Highly significant at ($P\leq0.05$).

n.s ≡ Not significant.

$Lsd_{0.05}$ ≡ Least significant difference at ($P\leq0.05$).

SE± ≡ Overall experimental error.

4.4.1.2 Hot extraction method

In this experiment mesquite fruit samples were soaked in hot water (100 ˚C) with the same fruit : water ratio used in the cold extraction method, but the soaking time was one hour (1h) then the samples were blended for 5 min, filtered and then examined for their T.S.S, PH, weight, volume and yield %.

From the result in table (4.8) the T.S.S was found to decrease significantly ($p \leq 0.05\%$) with increasing fruit : water ratio but the yield increased significantly ($p \leq 0.05\%$) with increasing fruit : water ratio levels however, insignificant changes were found in the concentration of the (PH) of the different samples.

Table (4.9) shows comparison between hot and cold extraction method of fresh mesquite fruits, the difference in T.S.S between them was very few, but the yield % of the cold extraction method was found better than Hot extraction method and the suitable result for production of mesquite jam the ratio (1:4) in cold extraction .The former method at an extract ratio of 1:4 recorded higher yield (41.11%) and T.S.S(11.35%) in comparison with hot extraction method at the same fruit : water ratio (1:4).

4.4.2 Production of mesquite jam

After determination of the optimum method and conditions for production of mesquite fruit extract, mesquite fruits (4kg) were soaked in tap water (16kg) for overnight for (16) hour. After that, the mixture was blended for 5 min. and the fruit extract was filtered, and used for production of mesquite jam which described previously in fig. (3.1) and table (3.1).

Table (4.8): Hot extraction of fresh mesquite fruits

Parameters	Fruit: water ratio					$Lsd_{0.05}$	SE±
	1:2	1:3	1:4	1:5	1:6		
	[n=2 ± SD]						
Mesquite fruit weight (g)	100	100	100	100	100	-	-
Extract weight (g)	126.50 ± 0.20^{e}	220.50 ± 0.50^{d}	333.50 ± 0.30^{c}	387.00 ± 1.00^{b}	481.00 ± 1.00^{a}	13.025^{**}	9.023
Extract volume (ml)	126.00 ± 1.00^{e}	219.00 ± 1.00^{d}	325.00 ± 0.00^{c}	381.00 ± 1.00^{b}	475.50 ± 0.60^{a}	10.947^{**}	7.695
Total soluble solids (T.S.S%)	016.75 ± 0.25^{a}	012.50 ± 0.50^{b}	010.00 ± 0.00^{c}	008.75 ± 0.25^{d}	007.25 ± 0.25^{e}	1.526^{*}	1.747
Hydrogen ions concentration (pH)	004.15 ± 0.10^{a}	004.00 ± 0.00^{a}	004.10 ± 0.00^{a}	004.10 ± 0.00^{a}	004.10 ± 0.00^{a}	1.093^{ns}	0.632
Yield % [on wet basis]	021.19 ± 0.20^{d}	027.57 ± 0.70^{c}	033.35 ± 1.80^{b}	033.86 ± 0.90^{b}	034.88 ± 1.00^{a}	3.625^{*}	3.498

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different ($P \leq 0.05$).

* ≡ Significant at ($P \leq 0.05$).

** ≡ Highly significant at ($P \leq 0.05$).

n.s ≡ Not significant.

$Lsd_{0.05}$ ≡ Least significant difference at ($P \leq 0.05$).

SE± ≡ Overall experimental error.

Table (4.9): Comparison between hot and cold extraction of fresh mesquite fruits

Parameters	Extraction method	Fruit: water ratio					$Lsd_{0.05}$	SE±
		1:2	1:3	1:4	1:5	1:6		
Mesquite fruit weight (g)	Hot	100	100	100	100	100	-	-
	Cold	100	100	100	100	100	-	-
Extract weight (g)	Hot	126.50±0.20^{e}	220.50±0.50^{d}	333.50±0.30^{c}	387.00±1.00^{b}	481.00 ± 1.00^{a}	13.025**	9.023
	Cold	130.00±1.00^{e}	219.30±1.30^{d}	362.22±0.50^{c}	433.30±0.00^{b}	513.30 ± 0.00^{a}	14.199**	10.166
Extract volume (ml)	Hot	126.00±1.00^{e}	219.00±1.00^{d}	325.00±0.00^{c}	381.00±1.00^{b}	475.50 ± 0.60^{a}	10.947**	7.695
	Cold	140.05±0.00^{e}	199.50±0.20^{d}	348.50±0.60^{c}	400.35±0.00^{b}	500.00 ± 0.00^{a}	11.462**	8.361
Total soluble solids (T.S.S %)	Hot	016.75±0.25^{a}	012.50±0.50^{b}	010.00±0.00^{c}	008.75±0.25^{d}	007.25 ± 0.25^{e}	1.526*	1.747
	Cold	016.50±0.50^{a}	012.50±0.50^{b}	011.35±0.04^{c}	008.50±0.50^{d}	007.50 ± 0.50^{c}	2.097*	1.430
Hydrogen ions concentration (pH)	Hot	004.15±0.10^{a}	004.00±0.00^{a}	004.10±0.00^{a}	004.10±0.00^{a}	004.10 ± 0.00^{a}	1.093^{ns}	0.632
	Cold	004.25±0.70^{a}	004.15±0.10^{a}	004.15±0.10^{a}	004.10±0.00^{a}	004.20 ± 0.00^{a}	2.625^{ns}	0.756
Yield % [on wet basis]	Hot	021.19±0.20^{d}	027.57±0.70^{c}	033.35±1.80^{b}	033.86±0.90^{b}	034.88 ± 1.00^{a}	3.625*	3.498
	Cold	021.46±0.50^{c}	027.42±0.98^{d}	041.11±0.50^{c}	036.83±2.00^{b}	038.50 ± 2.49^{a}	5.791*	2.946

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different (P≤0.05).

* ≡ Significant at (P≤0.05).

** ≡ Highly significant at (P≤0.05).

n.s ≡ Not significant.

$Lsd_{0.05}$ ≡ Least significant difference at (P≤0.05).

SE± ≡ Overall experimental error.

4.5 Quality evaluation of the end Product

4.5.1 Quality characteristics of mesquite jam

Table (4.10) shows physical and chemical characteristics of mesquite fruits extract and jam product. From the results mesquite extract was hydrogen ion concentration (pH), titrable acidity (T.A %), total soluble solids (T.S.S%) of mesquite jam found to be 3.2, 0.86 and 68%, respectively. The results are in agood agreement with those published by **ICUC (2004); Hui (2006); Onsa (2007)** and **Nouredeen (2011).**

A good jam as mentioned by the previous authors should contain total soluble solids (T.S.S%) , PH and titrable acidity (T.A %) between 67-70%, 3.2 -3.4 and 0.3 -0.8%, respectively.

4.5.2 Nutritional value of mesquite jam

4.5.2.1 Chemical composition

Table (4.11) presents the chemical composition of mesquite jam samples without flavour (A) and with pineapple flavour (B), on wet basis. From the result, the two products were found to be high level of total carbohydrates (67.39 – 68.45 %) and low levels of protein (0.53- 0.46 %), fat (1.84-1.59%), fiber (0.22- 0.14%), ash (0.71-0.70) and tannins (0.07-0.03) in sample(A) and (B) respectively.

4.5.2.2 Minerals and energy content

Table (4.12) shows minerals and energy contents of mesquite jams (A and B) as per 100g and kilo-calorie or kilo-joule, respectively on dry basis. The two products were found to provide appreciable amounts of sodium (47.21-72.62), potassium (100.07- 79.03), calcium (140.94-284.8), magnesium (84.56-17.88), as mg/100g jam from A and B,respectively. The zinc (Zn) was not detected in both jam samples.

On the other hand, both mesquite jam samples were also found to provide high caloric value per 100g sample which range between 294.19 and 296.53 calorie in sample (A) and (B) respectively.

Table(4.10): Physical, chemical and physio-chemical characteristics of mesquite fruits extract and jam product

Parameters	Mesquite extract	Mesquite jam
Hydrogen ion concentration (pH)	04.20	03.20
Titrable Acidity (%)	00.68	00.86
Total soluble solids (T.S.S %)	06.00	68.00
Weight (kg)	16.00	32.38

Table (4.11): Chemical composition of mesquite jam product

Chemical composition	Mesquite jam samples		$Lsd_{0.05}$	SE±
	A	B		
	[%,n = 3 ± SD]			
Moisture	29.53 ± 0.61^{a}	28.80 ± 0.83^{b}	0.281^{*}	0.005
Protein	00.53 ± 0.00^{a}	00.46 ± 0.00^{b}	0.035^{*}	0.638
Fat	01.84 ± 0.10^{a}	01.59 ± 0.00^{b}	0.196^{*}	0.076
Total carbohydrates	67.39 ± 0.49^{b}	68.45 ± 1.37^{a}	0.038^{*}	0.003
Available carbohydrates	67.17 ± 0.48^{b}	68.31 ± 1.06^{a}	0.097^{*}	0.005
Crude fiber	00.22 ± 0.00^{a}	00.14 ± 0.00^{b}	0.027^{*}	0.081
Tannins	00.07 ± 0.00^{a}	00.03 ± 0.00^{b}	0.054^{*}	0.024
Ash	00.71 ± 0.00^{a}	00.70 ± 0.00^{a}	$0.022^{n.s}$	0.030

A ≡ Mesquite jam without flavour .

B ≡ Mesquite jam with pineapple flavour .

SD ≡ Standard deviation.

n ≡ Number of independent determinations.

Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different ($P \leq 0.05$).

* ≡ Significant at ($P \leq 0.05$).

** ≡ Highly significant at ($P \leq 0.05$).

n.s ≡ Not significant.

$Lsd_{0.05}$ ≡ Least significant difference at ($P \leq 0.05$).

SE± ≡ Overall experimental error.

Table (4.12): Minerals and energy contents of mesquite jams

Mesquite jam sample		**A**	**B**	**$Lsd_{0.05}$**	**SE±**
Minerals		[mg/100g Jam]			
Sodium	[Na]	047.21^{b}	072.62^{a}	19.658^{**}	1.096
Potassium	[K]	100.07^{a}	079.03^{b}	24.862^{**}	1.754
Calcium	[Ca]	140.94^{b}	284.80^{a}	67.761^{**}	3.767
Magnesium	[Mg]	084.56^{b}	017.88^{a}	54.953^{**}	8.135
Iron	[Fe]	002.93^{a}	002.64^{a}	$2.847^{n.s}$	0.077
Manganese	[Mn]	000.07^{a}	000.04^{a}	$0.985^{n.s}$	0.002
Zinc	[Zn]	N.D	N.D	-	-
Energy content: Kilo Calorie Kilo Joule		294.19 1230.89	296.53 1240.68		

A ≡ Mesquite jam without flavour .
B ≡ Mesquite jam with pineapple flavour .
Mean ± S.D value(s) bearing different superscript letter(s) within rows are significantly different (P≤0.05).
** ≡ Highly significant at (P≤0.05).
n.s ≡ Not significant.
N.D ≡ Not detected.
$Lsd_{0.05}$ ≡ Least significant difference at (P≤0.05).
SE± ≡ Overall experimental error.

Therefore, the mesquite jam was found with high nutritional and energy values and it could be used as special diet for young children and mothers during pregnancy and lactating periods especially in the areas where mesquite trees are considered as a serious agricultural problem.

4.5.3 Organoleptic evaluation of mesquite jam products

The organoleptic evaluation of mesquite jam products was carried out by trained panelists from the Department of food Technology, Collage of Agricultural studies of Sudan University and Food Research Center (FRC). Mesquite jam products with flavour (pineapple flavour) or without flavour were evaluated according to the Hedonic method as described by **Ranganna,(2001).**

Table (4.13) show the Hedonic score for the different mesquite jam samples with respect to their colour, taste, flavour, consistancy and overall quality. From the results, the two mesquite jam samples (with flavor and without flavor) were highly accepted by the panelists with significant ($P \leq 0.05$) differences with regard to their colour and taste. However, mesquite jam with pineapple flavour (B) had the better flavor, consistancy and overall quality.

Table (4.13): Organoleptic evaluation of mesquite jams

Jam samples	Quality characteristics				
	Colour	Taste	Flavour	Consistency	Overall quality
	Hedonic scores				
A	1.62 ± 0.89^{a}	1.62 ± 0.89^{a}	2.44 ± 0.89^{a}	2.00 ± 0.82^{a}	1.87 ± 0.96^{a}
B	1.37 ± 0.62^{a}	1.62 ± 0.62^{a}	1.31 ± 0.48^{b}	1.89 ± 0.54^{b}	1.37 ± 0.50^{b}
$Lsd_{0.05}$	0.8551^{ns}	0.580^{ns}	1.032^{*}	0.108^{*}	0.479^{*}
SE±	0.576	0.428	0.264	0.362	0.145

A ≡ Mesquite Jam without flavor .
B ≡ Mesquite Jam with pineapple flavor .
SD ≡ Standard deviation.
Mean ± S.D value (s) bearing different superscript letter (s) within columns are significantly different ($P \leq 0.05$).
* ≡ Significant at ($P \leq 0.05$).
** ≡ Highly significant at ($P \leq 0.05$).
n.s ≡ Not significant.
$Lsd_{0.05}$ ≡ Least significant difference at ($P \leq 0.05$).
SE± ≡ Overall experimental error.

5. CONCLUTION AND RECOMMENDATIONS

5.1 Conclusion

From the results obtained in this study, the physical and nutritional characteristics of mesquite fruits significantly improved by the end of the harvesting season (June). Also, the fruits are found to be easily extracted with cold water (1:4) and suitable for production of jams with high nutritional value and organoleptic characteristics.

5.2 Recommendations

1) Mesquite fruits should be harvested in June as the physical and nutritional characteristics improved by the end of the harvesting season.
2) Mesquite jam which produced in this study could be used as a valuable food to reduce the high incidences of malnutrition among young children and other sensitive groups or as traditional medicine where mesquite trees are considered as a serious agricultural problem.
3) Additional studies are definitely needed to ensure safety, storage conditions, shelf-life, economic feasibility and market demands for the product.
4) Efforts should be directed towards other industrial utilization of mesquite fruits in Sudan.

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Plate (1): Mesquite pods (fruits)

Plate (2): Mesquite jam samples (A = mesquite jam without flavor , B = mesquite jam with pineapple flavour)

Plate (3): Mesquite jam samples