Advance Journal of Food Science and Technology 2(2): 125-133, 2010
ISSN: 2042-4876

Submitted Date: January 23, 2010 Accepted Date: February 08, 2010 Published Date: March 10, 2010

Production and Quality Assessment of Instant Baobab (*Adansonia digitata* L.)

[1]A.A. Abdalla, [1]M.A. Mohammed and [2]H.A. Mudawi
[1]Department of Biochemistry and Food Science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, P.O. Box .160. Elobied, Sudan
[2]Department of Food Science and Technology, Faculty of Agriculture, University of Khartoum, Shambat, Sudan

Abstract: In this study three baobab fruit pulp samples were obtained from three different locations (Kordofan, Blue Nile and Darfur) and subjected to physicochemical analysis. In addition, Kordofan baobab which is available and highly acceptable by consumers was used to produce different types of spray dried powders. The three baobab samples showed the same protein, fat, Ca, P and color levels, but significantly ($p \leq 0.05$) different fiber, total sugars, ascorbic acid, K and Fe contents. Spray drying significantly ($p \leq 0.05$) elevated fat, total sugars, K and P contents as well as bulk density and pH, while significantly ($p \leq 0.05$) reduced moisture, protein, fiber, ash, ascorbic acid, Na, Ca and Fe contents. On the other hand color, reducing and non reducing sugars were not affected. Solubility of the sprayed powder was significantly ($p \leq 0.05$) reduced as a result of treatment with gum Arabic, sugar and Carboxy Methyl Cellulose (CMC). The spray dried powder obtained from the pure extract of the pulp showed significantly ($p \leq 0.05$) better reconstitution properties (wetability, dispersibility and solubility) in comparison to those prepared by addition of CMC or gum Arabic. The overall quality of the reconstituted drink prepared from the sprayed powder that produced from the pure 12% TSS extract (Ext pure) proved to be significantly ($p \leq 0.05$) better than that of the other products.

Key words: *Adansonia digitata*, ascorbic acid, minerals, organoleptic quality, proximate composition, spray drying

INTRODUCTION

Baobab (*Adansonia digitata* L.) is a deciduous tree belongs to the plant family Bombacaceae found in the savannas of Africa and India, mostly around the equator. Fruit of the tree differ in shape among the varieties from baloney and cylinder to ovoid, measuring 12-40 cm length, 7-17 cm in diameter, filled with a white to roseate, floury acidic pulp (Von Maydell, 1990).

The dry pulp often chewed, sucked and can be eaten raw together with milk and porridge or milk alone. Also the pulp is served as a refreshing drink or can be made into light porridge (nesha). In Nigeria the fruit pulp is used as sweetener for many local foods and as curding agent for milk (Fleuret, 1980). In Sudan, especially western people traditionally depended on the pulp of *A. digitata* for treatment of dysentery, diarrhea, gastro-enteritis and colic's.

The baobab dry fruit pulp was reported (Manfredini *et al*., 2002) to contain 2.3% protein, 0.27% lipids, 5.2% soluble and insoluble fiber, 75.6% carbohydrates. Concerning minerals, Baobab Fruit Company (2002) reported high Ca, Mg and P contents (4310, 2090 and 733 mg/100g, respectively) and moderate Fe, Zn and Na contents (17, 10.4 and 54.6 mg/100g, respectively). Fruit pulp proved to be rich in pectin, most of it being water soluble with a low content of propectin, low degree of esterification and intrinsic viscosity values of about one fifth of those of commercial apple pectin (Nour *et al*., 1980).

Special attention has been given to measuring vitamin C (ascorbic acid), a powerful antioxidant and extremely important in human nutrition, in baobab fruit pulp due to occasional reports of high content (Nour *et al.* 1980), Ighodalo *et al*. (1991), Saka *et al.* (1994), Dos-Santos and Damon (1996) and Manfredini *et al.* (2002)). Sidibe and Williams (2002) stated that the daily recommended dose of vitamin C (65 mg per day) can be obtained from 23 g of baobab powder, the daily saturation of the vitamin C pool in the body (140 mg per day) requires 50 g of baobab powder; the special dosage for convalescents is 90 g.

The water-soluble fraction of the fruit pulp showed stimulating effects on the proliferation of Bifido bacteria in vitro. In fact, soluble dietary fibers, such as those in the pulp (about 25%), are known to have prebiotic effects, which means they stimulate the growth and the metabolic activity of beneficial organisms (Milza, 2002). In recent

Corresponding Author: A.A. Abdalla, Department of Biochemistry and Food Science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, P.O. Box .160. Elobied, Sudan

years in Europe, a market has developed for food and beverages products that provide a specific positive impact on health. These products are called functional foods and functional drinks. Food and beverages with a prebiotic function has always been around, but the claim was not previously promoted. Due to new clinical studies, which show positive health effects from these substances, and the consumer interest that followed, today these health claims have a strong influence on marketing. Another important health claim for functional food is anti-oxidation. Baobab fruit pulp, due to the combination of health claims (such as prebiotic and anti-oxidation properties, high calcium content, and anti-inflammatory effect) and food technological functions (due to its high pectin and fiber content, baobab fruit pulp gives beverages a thicker consistency and can be also used as filler), is a very interesting candidate for a new generation of functional foods and drinks. Hence the objectives of this study were to determine the difference in the physicochemical properties of baobab pulp from different parts of Sudan, to prepare instant spray dried product from baobab pulp and to investigate the effect of processing on the proximate compositional, minerals content, vitamin C level and some physical properties of the final product.

MATERIALS AND METHODS

The present study was conducted during 2007-2009 at the laboratories of the Industrial Research and Consultancy Centre, Khartoum, Sudan.

Materials: Baobab fruit was obtained from three different locations: North Kordofan State (central Sudan), South Darfur State (western Sudan) and Blue Nile State (eastern Sudan).

Gum Arabic and CMC powder (Carboxy Methyl Cellulose) were kindly supplied by the Gum Arabic Company and Elnasir Factory, respectively.

Sample preparation: Edible portion of the baobab (pulp) was collected after removal of the inedible portion (bark, fiber and seeds), then hand pounded to pass through sieve 40 mesh size, and kept for analysis and preparation of reconstitution drinks.

Analytical methods:

Proximate composition: Moisture, crude protein, fat, crude fiber and ash were determined according to the standard methods of AOAC (1990). The total carbohydrate was calculated by difference.

pH determination: Thirty grams of each sample were dissolved in 70 ml distilled water. The pH was then measured using Philips PW 9418 pH meter.

Ascorbic acid determination: Ascorbic acid (vitamin C) was determined according to the indophenols method (AOAC, 1990).

Minerals determination: Sodium (Na), potassium (K) and calcium (Ca) were determined according to AOAC (1990) using flame photometer (Coring 400). Iron and phosphorus were determined according to the methods of Hanson (1973), Chapman and Pratt (1982), respectively using spectrophotometer (Jenway 6305 vis/uv) at wavelengths 508 and 440 nm, sequentially.

Sugars: Total and reducing sugars were determined according to Lane and Eynon titrometric method (AOAC, 1990). Non-reducing Sugars were calculated as follows: None reducing sugars = Total sugars – Reducing sugars.

Physical properties of baobab pulp:

Color: Two grams of powder were weighed into 25 ml beaker with 50 ml distilled water. Then the pH was adjusted to 7 by adding acid (0.2 N HCl) or alkali (40%). After that the solution was filtrated by Whattman filter paper no.1. The color of the liquid was measured in lovibond type colorimeter.

Viscosity: Viscosity was determined by the method of Quinn and Beuchat (1975), using Brookfield viscometer (VII), Spindle No. 2 of speed of 60 rpm at room temperature (25ºC) and viscosity was expressed in centipoises (cps).

Bulk density: The bulk density (BD) was determined by the method described by Wang and Kinsella (1976). Ten grams of the sample were placed in graduated cylinder (50 ml) and packed by gently tapping the cylinder on the bench top (10 times) to form reasonable height. The volume of sample was recorded. Bulk density was expressed as grams per milliliter.

Wettability and sinkability: The test involves spreading of a definite weight of the powder on the surface of a given mass of water, and measuring the time, which elapses between the spreading of the powder and the disappearance of the last particles from the surface of the water. To obtain reproducible results, the powder particles must make contact with the water at the same time and in a homogeneous fashion.

The wettability was measured according to the procedure described by Abdel Kareem and Brennan (1975). Five grams of powder were placed and spread evenly on the surface of filter paper (Whattman No. 5). The filter paper was previously held tightly between the gap of two baby food cans, opened at both end .The assembly of the two cans and filter paper, was mounted

on the glass beaker (500 ml) containing 500 ml distilled water at room temperature. The experiment was started by pulling the filter paper to drop the powder as quickly as possible. The immersion of the powder was watched and the time taken for the powder to be wetted was noted down.

Dispersibility: Five grams of the powder were added at room temperature to 500 ml distilled water, which was agitated using magnetic stirrer at 1100 rpm. After 5 minutes, a sample from the powder dispersion was taken by mean of syringe (5 ml). The sample was centrifuged at 1000 rpm for 5 minutes to remove undispersed lumps and the optical density at wave length 760 nm was then measured using Unican 600 Spectrophotometer. Dispersibility was expressed in terms of optical density units (Abdel Kareem and Brennan, 1975).

Solubility: The solubility test was carried out by adding 10 g material to 250 ml distilled water at room temperature (Abdel Kareem and Brennan, 1975). The mixture was agitated with a magnetic stirrer (fisher, 50-60 HZ, 0.2 A) at position 5. The time required for the material to dissolve completely was recorded.

Particle Size of spray dried powder: Laboratory sieve analysis using a series of standard sieves (150, 125, 95, 90, 65, 45 micron) was used to determine the particle size (BSI, 1976).

Spray drying of baobab pulp:

General considerations: Preliminary attempts to produce acceptable high density concentrates from baobab fruit pulp, which is known to contain substantial amounts of pectin or pectic compounds, by evaporation, were faced by problems of jellification and high viscosity. Such problems can be practically solved by just extracting the pulp by warm water. The ability of concentrated pulp extract to form instant powder will depend, of course, upon the nature of the product itself but in addition will depend upon the spray drying conditions; the temperature, flow rate of feed and drying air. If the initial total moisture content of the baobab concentrate was low enough (high concentrates), the spraying will take place rapidly with best particles size through controlling the above three main effective factors, to maintain the optimum conditions for spray drying without danger that the product become liquefied, gummy, or caked.

Injection of the fresh baobab fruit pulp extracts (of about 12-15 %TSS), at temperatures ranging from 100-150 ºC was employed. It is quite obvious that an incoming air at this temperature will evaporate or completely spray dries the feed in powdery form in a part of seconds. In this type of processing the concentrates are transformed to powder by injection of gas into liquid through the nozzle.

Preparation of the fresh baobab fruit pulp concentrates: Kordofan sample, was chosen because it is available and highly acceptable by consumers. Seeds together with pulp were collected from the crushed fruits after removal of the inedible portions. Hereinafter the collected material will be referred to as the raw material.

12% (TSS) concentration: Three liter of distilled water were added to each 2 kg of raw material in plastic container, after 15 minutes stirred sufficiently and sieved through test sieve No (52) mesh to remove seeds and fiber. Filtrate was then passed through another test sieve (N0.0118 inches) to get rid of smaller particles .The concentration of the clear filtrate (12% TSS) was then measured using hand refractometer (Ermo, Tokyo, No 5317, WSRO-50), and fed to the spray drier (Ext pure). To decrease the amounts of the precipitated powder during the preparation of the soft drink, spray dried gum Arabic (10 g/l) or CMC (1g/l) was added to two other batches of the 12% TSS filtrate before spray drying (Ext gum and Ext CMC, respectively).

15% (TSS) concentration: Refined sugar was added to another batch of the above clear filtrated juice to obtain a juice with concentration of 15% TSS, and fed to the spray drier (Ext sugar).

Processing: Four spray dried products (Ext pure, Ext gum, Ext CMC and Ext sugar) were produced using ANHYDRO LABORATORY SPRAY DRYER No. 1 (Copenhagen, Denmark) with the following specifications: Evaporation capacity at inlet/outlet temperature of 300/90ºC of 7.5 kg/h, Power supply of 0.736 kw, Compressed air consumption of 120 l/min, Netto weight of 250 kg.

In order to start the process, the circular cover was placed above the air distributor, the long plastic feed pipe was fitted one end on the sight glass under the feed bowl, and the other end on the nozzle feed nipple.

The powder duct and the cyclone were attached tightly with unions and hook spanner so that all joints are tightly connected, a powder bucket was fixed under the cyclone and a thermometer over it and the air filter on the fan was cleaned and positioned correctly. After removing the cap of the nozzle the drying chamber door, with door gasket free from impurities, was closed. The reducing valve was closed by unscrewing the spindle and compressed air was connected to the regulating valve.

The main switch was turned to the first position to start the fan and then the electrical air heater was turned on by turning the main switch to the kilowattage corresponding to the required inlet air temperature (250ºC).

While the plant is being heated, the compressed air was turned on. The reduction valve was adjusted to a pressure of approximately 1 kg/cm^2 applied to the nozzle.

Table 1: Chemical composition of baobab pulp

Sample	Moisture	Fiber	Ash	Protein	Oil	Carbohydrate
Kordofan	8.24 ± 0.10 [b]	4.46 ± 0.25 [a]	5.05 ± 0.03 [b]	5.50 ± 0.39 [a]	1.50 ± 0.35 [a]	75.15
Blue Nile	7.87 ± 0.19 [b]	1.48 ± 0.07 [c]	5.02 ± 0.02 [b]	5.57 ± 0.05 [a]	1.66 ± 0.20 [a]	78.37
Darfur	8.59 ± 0.10 [a]	3.20 ± 0.10 [b]	5.51 ± 0.04 [a]	5.15 ± 0.39 [a]	1.14 ± 0.00 [a]	76.41
spray dried Product	7.78 ± 0.06 *	0.00*	4.25 ± 0.01 *	4.20 ± 0.05 *	1.90 ± 0.32 *	81.82

Each value is an average of three replicates expressed on dry matter basis.
Values are mean ± standard deviation.
Means not sharing a similar superscript letter(s) in a column are significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple Range test.
*: Spray dried product was significantly ($p \leq 0.05$) different compared to Kordofan sample.

The pinchcock was closed completely, and the feed bowl was filled with distilled water (to avoid calcareous deposits in the drying chamber). When the outlet air temperature reached 90ºC, water was fed to the nozzle. The water quantity was regulated so as to keep the temperature constant. After 20 minutes, the in and outlet temperature were stable, and then the operation switched from water to product.

Material to be dried (at initial temperature of 25ºC) was introduced into the feed bowl, the reducing valve for the compressed air was adjusted at 4 kg/cm^2 and the pinchcock was regulated so that the outlet temperature remains constant. Material was then drip fed at rate of 200 ml/min, using the adjustable clamp, through the sight glass to the nozzle atomizer. The drying air was drawn through the air filter by mean of fan, blown through the electrical air heater and through the air distributor, which admits the air into the drying chamber with slightly rotating motion. The drying air temperature was regulated stepwise using the main switch to temperature range of 100-150ºC by selecting the corresponding kilowattage heating element.

The material was dispersed into a mist in the two fluids nozzle by mean of the compressed air. The nozzle, which is situated in the middle of the drying chamber, was spraying upwards, thus giving the particles the longest trajectory obtainable in the compact plant and permitting the production of coarser particles.

Hot drying air, which was simultaneously introduced through an annular opening in the drying chamber ceiling, mixed continuously with the mist of the atomized material and instantaneously evaporates the volatiles of the material. The non-volatile part was left in form of small dry particles of powder. On account of the rapid evaporation, the heat in the air was absorbed so quickly that the temperature in the drying zone was very low throughout the entire period of drying. It was only when the particles are drying that their temperature gradually rose towards the temperature of the outlet air (60-70ºC).

Product obtained follows the air stream down towards the outlet aperture on the conical bottom of the drying chamber and pass out with the outlet air through the powder duct to the dynamic cyclone separator where it was separated from the drying air and falls down the cyclone sides into the powder bucket. The moist drying air was discharged from the top of the cyclone through the exhaust duct. When replacing full powder buckets by empty ones, the flap valve was temporarily closed to prevent the powder from leaving cyclone.

When the feed bowl was almost empty, some distilled water was fed to the nozzle, in order to clean the feed pipe and nozzle, and to avoid overheating. The current for the heating elements was then switched off and supply of water was gradually decreased to maintain the outlet air temperature at constant level (90ºC). When the temperature of the inlet air reached about 130ºC the water supply was completely cut off. When the inlet temperature decreased to 80°C the dryer was stopped by turning the atomizer regulator and the master switch to their zero position. Finally the feed system, cyclone and the powder duct were removed.

Organoleptic test: In this investigation, six different types of reconstituted drinks were prepared from the three unprocessed baobab pulp (Kordofan, Blue Nile and Darfur) together with three other spray-dried products (Ext pure, Ext gum and Ext CMC). Reconstituted drinks were prepared as follows: To ten gram powder 10 g sugar and 150 ml water were added in a plastic jug then stirred for a few seconds (5% TSS).

Samples were subjected to panel test which was carried out at the labs of Food Science and Technology Department, Faculty of Agriculture, University of Khartoum, using ranking test as described by Ihekoronye and Ngoddy (1985). Panelists were asked to exanimate the samples according to quality attributes and then rank the samples from the best (rank 1) to the least in quality (last rank). Results were statistically analyzed by tables provided by Ihekoronye and Ngoddy (1985) at 5% level of significance.

Statistical analysis: Data assessed by analysis of variance (ANOVA) (Snedecor and Cochran, 1987) using CRD with three replicates. Means were compared using Duncan's Multiple-Range Test (Duncan, 1955) with probability ($P \leq 0.05$).

RESULTS AND DISCUSSION

Chemical composition: The chemical composition of raw baobab fruit pulp obtained from three different locations (Kordofan, Blue Nile and Darfur States) as well as the spray dried product processed from Kordofan raw material is shown in Table 1.

Proximate composition: Moisture content was found to be 8.24, 7.86 and 8.59% for Kordofan, Blue Nile and Darfur raw pulp, respectively. Darfur sample showed significantly ($p \leq 0.05$) higher moisture content, while those from Kordofan and Blue Nile were found to contain the same level of moisture. These values were higher than the value of 6.7% reported by Nour *et al.* (1980), but lower if compared to the range of 11.1-13.6% given by Gaydou *et al*. (1982). The spray-dried product obtained from Kordofan raw pulp, showed a significantly ($p \leq 0.05$) reduced moisture content compared to Kordofan sample.

Ash content was 5.05% for Kordofan sample and 5.02% for that from Blue Nile. Results showed no significant difference ($p \leq 0.05$) between the two raw materials. Present findings were lower than the value of 7% stated by Okoho (1984). Spray drying significantly ($p \leq 0.05$) lowered ash content to 4.25%, which could be related to volatization of some elements during the process.

As shown in Table 1, pulp collected from baobab procured from Kordofan, Blue Nile and Darfur was found to contain sequentially 4.46, 1.48 and 3.20% fiber. Data indicated that the three materials were significantly ($P \leq 0.05$) different. Results obtained were markedly lower compared to the values varying from 5.4 to 9% earlier mentioned in the literature (Nour *et al.*, 1980; Okoho, 1984; Arnold *et al*., 1985). The reduced fiber content could be ascribed to the variations in methods of crushing of the fruit, removal of the inedible portions and sieving. Interestingly, the spray dried product showed nil fiber content. The extensive sieving and filtration before spray drying, in order to prevent clogging of the nozzle during the process, may be the probable reason for diminishing fiber in the final product.

Protein content of baobab fruit pulp was found to range from 5.15 to 5.57% with overall mean of 5.24% without significant difference ($p \leq 0.05$) among the three samples. Results reported here were slightly lower than the value of 6.2% mentioned by Nour *et al.* (1980) for Sudanese baobab, but higher than the 2.3% concentration given by Manfredini *et al.* (2002). Protein content of the sprayed powder (4.20%) proved to be significantly ($p \leq 0.05$) lower compared to its starting raw material. This might be due to the effect of the thermal process on protein structure.

As indicated in Table 1, chemical analysis revealed that the three samples of baobab pulp contained the same level of crude fat. Values were ranged from 1.14% (for Darfur) to 1.66% (for Blue Nile) with average value of 1.43%. No significant ($p \leq 0.05$) differences were observed among the three locations. In contrast, the fat content of the spray-dried powder (1.9%) was found to be significantly ($p \leq 0.05$) higher if compared to its respective raw pulp.

The three unprocessed samples of baobab pulp were found to contain 75.15-78.37% available carbohydrates with a mean value of 76.64%. The manufactured powder recorded markedly higher content of 81.82%. Data obtained were in a good agreement with values ranging from 73.7 to 81% previously reported by Gaydou *et al.* (1982), Okoho (1984) and Arnold *et al*. (1985).

Table 2: Total, reducing and non reducing sugars of baobab pulp

Sample	Total sugars	Reducing sugars	Non reducing sugars
Kordofan	31.24 ± 0.34 [a]	8.80 ± 0.21 [a]	22.54 ± 0.12 [a]
Blue Nile	28.70 ± 0.02 [c]	8.91 ± 0.03 [a]	19.73 ± 0.04 [b]
Darfur	29.36 ± 0.04 [b]	7.40 ± 0.20 [b]	22.57 ± 0.22 [a]
spray dried product	32.50 ± 0.01 *	8.90 ± 0.03 [a]	20.53 ± 5.15 [a]

Each value is an average of three replicates expressed on dry matter basis.
Values are mean ± standard deviation
Means not sharing a similar superscript letter in a column are significantly different at $p \leq 0.05$ as assessed by Duncan's Multiple Range Test.
*: Spray dried product was significantly ($P \leq 0.05$) different compared to Kordofan sample.

Sugars: Concerning total sugars, Table 2, values obtained were 31.24, 28.70 and 29.36% for Kordofan, Blue Nile and Darfur samples, respectively, which were slightly higher than the range of 16.9-25.3% (Gaydou *et al*., 1982). Significant differences ($p \leq 0.05$) were observed among the three raw materials. Processing significantly ($p \leq 0.05$) elevated the total sugars content from 31.24% (Kordofan) to 32.50% (sprayed powder).

In this study, pulp of Kordofan and Blue Nile baobab were found to be similar in their reducing sugars content with mean value of 8.85%. On the other hand Darfur baobab pulp showed significantly ($p \leq 0.05$) lower content (7.4%) compared to the rest of samples. Processing insignificantly ($p \leq 0.05$) increased reducing sugars from 8.80% in the raw material to 8.90% in the final product. It is clear that spray drying have no effect on the reducing sugars level.

Interestingly, Kordofan and Darfur samples contained the same non-reducing sugars concentration (22.54% and 22.57%, respectively). Pulp collected from Blue Nile baobab fruit demonstrated a significantly ($p \leq 0.05$) lower value of 19.73%. In respect of their non reducing sugars contents, statistical analysis revealed no significant difference between the spray dried product and its corresponding raw material.

Minerals: Minerals of the three samples and the sprayed powder are viewed in Table 3.

Chemical analysis revealed significant ($p \leq 0.05$) variation in Na contents of the three samples. Values obtained were found to range from 19.07 mg/100 g (for Kordofan) to 46.10 mg/100 g (for Darfur). Data indicated that spray drying significantly ($P \leq 0.05$) reduced Na content of baobab pulp to 18.20 mg/100 g in comparison with the unprocessed material.

With respect to K, values obtained were 12.47, 38.35 and 35.12 mg/100 g for Kordofan, Blue Nile and Darfur samples, respectively. The three commodities were significantly ($p \leq 0.05$) different in their K content.

Table 3: Mineral content of baobab pulp

Sample	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	Fe (mg/100g)	P (mg/100g)
Kordofan	19.07 ± 0.11 [c]	12.47 ± 0.49 [c]	399.46 ± 8.76 [a]	6.69 ± 0.04 [a]	90 ± 0.10 [a]
Blue Nile	33.20 ± 0.10 [b]	38.35 ± 0.04 [a]	394.66 ± 1.52 [a]	6.00 ± 0.12 [c]	92 ± 0.10 [a]
Darfur	46.10 ± 1.00 [a]	35.12 ± 0.08 [b]	386.53 ± 1.52 [a]	6.49 ± 0.04 [b]	91 ± 0.00 [a]
Spray dried product	18.20 ± 0.11 *	17.77 ± 0.66 *	288.80 ± 7.04 *	2.86 ± 0.28 *	97 ± 0.10 [a]

Each value is an average of three replicates expressed on dry matter basis.
Values are mean ± standard deviation
Means not sharing a similar superscript letter in a column are significantly different at $p \leq 0.05$ as assessed by Duncan's Multiple Range Test.
*: Spray dried product was significantly ($p \leq 0.05$) different compared to Kordofan sample.

Significant increase ($p \leq 0.05$) to 17.77 mg/100g in K content was noticed due to spray drying process.

As demonstrated in table 3, calcium content of baobab fruit pulp ranged from 386.53 to 399.46 mg/100g with average value of 393.55 mg/100g, without significant differences among the three locations. Previously, Nour *et al.* (1980) and Manfredini *et al.* (2002) reported higher values of 655 and 670 mg/100g, respectively. Relevant to the spray dried product it was found to contain significantly ($p \leq 0.05$) reduced Ca content of 288.8o mg/100 g.

Investigation showed that the Fe content was 6.69 mg/100 g for Kordofan sample, 6.00 mg/100 g for Blue Nile baobab and 6.49 mg/100 g for that from Darfur. Iron content was found to be significantly different among the three locations. These results were slightly lower compared with the findings of Nour *et al.* (1980) who reported 8.6 mg/100 g Fe. Processing drastically reduced Fe content of the spray dried powder to 2.86 mg/100 g.

In this study the three samples were found to have the same level of P (90-92 mg/100 g) with a mean value of 91 mg/100 g. Values reported were higher than the value of 50.8 mg/100 g mentioned by Nour *et al.* (1980), but marginally lower than the range of 96-118 mg/100 g (Baobab Fruit Company, 2002). Phosphorus content of the sprayed powder (97 mg/100 g), was significantly ($p \leq 0.05$) higher in comparison with the original sample.

Ascorbic acid (vitamin C) content: As presented in Table (4), raw pulp collected from baobab fruit procured from Blue Nile State had the highest ascorbic acid content (370.66 mg/100 g) followed by Kordofan sample (357.33 mg/100 g), while that from Darfur showed the lowest vitamin level (347.33 mg/100 g). In this research, the mean separation showed significant ($P \leq 0.05$) differences in ascorbic acid content among the three samples. Spray drying brought about a significant ($p \leq 0.05$) reduction in vitamin C content.

pH: Values of pH for baobab fruit pulp from different locations are depicted in Table 4. Pulp obtained from Darfur sample, in water suspension, had a pH value of 3.2, which significantly ($p \leq 0.05$) higher compared to the value of 3.0 demonstrated by both Kordofan and Blue Nile samples. Similarly the spray-dried powder produced from Kordofan raw material was found to have

Table 4: Ascorbic acid content (mg/100g) and pH of baobab pulp

Sample	Ascorbic acid	pH
Kordofan	357.33 ± 2.51 [b]	3.03 ± 0.02 [b]
Blue Nile	370.66 ± 4.04 [a]	3.04 ± 0.02 [b]
Darfur	347.33 ± 2.51 [c]	3.20 ± 0.01
Spray dried product	308.33 ± 7.63 *	3.26 ± 0.01 *

Each value is an average of three replicates expressed on dry matter basis.
Values are mean ± standard deviation
Means not sharing a similar superscript letter in a column are significantly different at $p \leq 0.05$ as assessed by Duncan's Multiple Range Test.
*: Spray dried product was significantly ($p \leq 0.05$) different compared to Kordofan sample.

Table 5: Physical properties of baobab pulp

Sample	Color	Viscosity	Bulk density
Kordofan	1.30 ± 0.95 [a]	44.66 ± 0.57 [b]	0.47 ± 0.05 [a]
Blue Nile	1.76 ± 0.51 [a]	55.00 ± 1.00 [a]	0.42 ± 0.04 [a]
Darfur	1.36 ± 0.51 [a]	44.66 ± 0.57 [b]	0.32 ± 0.01 [b]
Spray dried product	1.30 ± 0.56 [a]	0.00*	0.52 ± 0.01 [a]

Each value is an average of three replicates expressed on dry matter basis.
Values are mean ± standard deviation
Means not sharing a similar superscript letter in a column are significantly different at $p \leq 0.05$ as assessed by Duncan's Multiple Range Test.
*: Spray dried product was significantly ($p \leq 0.05$) different compared to Kordofan sample.

significantly ($P \leq 0.05$) higher pH value of 3.3. The higher pH values of Darfur sample as well as the sprayed powder possibly can be due to their respective lower ascorbic acid contents.

Physical properties of baobab pulp: Table 5, shows some physical properties (color, viscosity and bulk density) of the raw and spray dried pulp.

Interestingly, raw materials obtained from three different locations (Kordofan, Blue Nile and Darfur States) together with the sprayed product showed significantly ($p \leq 0.05$) the same level of color with average value of 1.46. The high temperature short time (HTST) treatment during the drying of Kordofan sample, insignificantly ($p \leq 0.05$) improved color from 1.30 to 1.43 in the final product.

Viscosity was found to be 45, 55 and 44 centipoises (cps) sequentially for Kordofan, Blue Nile and Darfur raw materials. Statistical analysis revealed no significant difference between Kordofan and Darfur samples, while that from Blue Nile acquired significantly ($p \leq 0.05$) higher viscosity compared to the other samples.

Table 5, indicates that the bulk density of the powdered pulp of Kordofan and Blue Nile samples were 0.47 and 0.42 g/ml, respectively. The separation showed that there was no significant ($p \leq 0.05$) difference in bulk density for the two samples, whereas that from Darfur

Table 6: Physical properties of a spray dried products

Sample	Solubility	Wet ability and sink ability	Optical density	Size (micron) (%) >125	(%) 45-125	(%) <45
Ext. pure	48.66 ± 3.21 [c]	32.33 ± 2.52 [d]	0.434 ± 0.01 [b]	15.2	70.6	14.2
Ext. sugar	58.66 ± 2.65 [b]	43.33 ± 3.79 [c]	0.944 ± 0.05 [a]	4.4	66.6	19.0
Ext. CMC	64.67 ± 4.31 [b]	62.33 ± 2.52 [b]	0.335 ± 0.00 [c]	16.4	47.0	36.6
Ext. gum	75.00 ± 5.00 [a]	72.33 ± 2.52 [a]	0.382 ± 0.04 [b]	28.2	29.6	42.2

Each value is an average of three replicates expressed on dry matter basis
Values are mean ± standard deviation
Means not sharing a similar superscript letter in a column are significantly different at $p \leq 0.05$ as assessed by Duncan's Multiple Range Test

showed a significantly ($p \leq 0.05$) lower value of 0.32 g/ml compared to the above materials. Concerning the effect of spray drying on the bulk density, statistical analysis revealed a highly significant ($p \leq 0.05$) difference between the final product and its starting raw material.

Spray dried products: In this study, the raw material from Kordofan sample was used to prepare four different spray dried products from the following extracts: 12% TSS pure extract (Ext pure), 12% TSS extract with CMC, 1 g/l (Ext CMC), 12% TSS extract with gum Arabic, 10 g/l (Ext gum) and 12% TSS extract concentrated to 15% TSS by addition of sugar (Ext sugar).

Physical properties of the spray dried products: The physical properties (solubility, dispersibility, wetability and size) of the above mentioned products are shown in Table 6.

Results indicated that the solubility of Ext pure powder was the best (48.66 sec) compared to the rest products. There was no significant ($p \leq 0.05$) variation in solubility between Ext sugar (58.66 sec) and Ext CMC (64.67 sec) products, while Ext gum showed a significantly lower solubility (75 sec). It was obvious that treatment with both CMC and sugar negatively affected the solubility of the sprayed powder. Addition of gum Arabic tremendously prolonged the solubility time of the spry dried product.

As indicated in Table 6, Ext sugar product showed significantly ($p \leq 0.05$) improved dispersibility of 0.944 OD compared to all other products. On the other hand, dispersibility of Ext pure was 0.434 OD, while that of Ext gum was 0.382 OD without significant difference between the two products. Ext CMC showed significantly ($p \leq 0.05$) lower value of 0.335 OD compared to all other product except Ext gum. It is clear that concentration to 15% TSS by addition of sugar greatly enhances the dispersibility of the sprayed powder. In contrast treatment with CMC and gum Arabic reduced dispersibility in comparison with the product prepared from the pure 12% TSS extract (Ext pure).

Both Ext pure and Ext sugar products showed significantly the fastest wetability time (32 and 43 sec, respectively), without significant difference between the two products. Whereas Ext CMC and Ext gum required significantly ($p \leq 0.05$) longer time to get wet (62 and 72 sec, respectively). It seems that treatment with CMC and gum Arabic defect wetability of the sprayed powder.

Concerning the particle size only 15% of Ext pure, Ext sugar and Ext CMC granules were found to be >125 micron. Most particles (47-71%) of the same products showed a diameter range of 45-125 micron, while the size of 14-37% of the granules was <45 micron. On the other hand the majority of Ext gum granules (42%) gave a diameter of <45 micron, about 30% ranged between 45- 125 micron and 28% particles were >125 micron.

Table 7: Organoleptic quality of reconstituting drinks prepared from baobab pulp

Sample	Color	flavor	Body ness	Over all control
Ext pure	31[a]	28[a]	50[b]	31[a]
Ext gum	45[a]	60[b]	45[a]	53[b]
Ext CMC	53[b]	64[b]	47[a]	70[b]
Kordofan	73[b]	52[b]	75[b]	51[b]
Blue Nile	94[c]	99[c]	94[c]	100[c]
Darfur	106[c]	97[c]	98[c]	95[c]

a < 49; b = 49-84; c > 84
Sum of Ranks having different superscript letter in each column differ significantly at $p \leq 0.05$.

Organoleptic quality: Table 7, shows the organoleptic quality of the reconstituted drinks prepared from the spray dried products together with three other unprocessed pulp powders.

Reconstituted drinks prepared from the unprocessed powder of Blue Nile and Darfur samples acquired the same lowest levels of quality attributes studied (color, flavor, bodyness and overall quality) compared to the rest products.

Color of drinks obtained by reconstitution of the spray-dried powder was obviously superior to that of the raw materials. The reconstituted Ext CMC showed insignificantly ($p \leq 0.05$) improved color compared to its corresponding raw pulp. The best color was shown by the reconstituted drinks of Ext pure and Ext gum, which can be attributed to sieving and filtration before spray drying. Addition of gum Arabic insignificantly ($p \leq 0.05$) reduced the color quality of the powder compared to that of Ext pure. In contrast addition of CMC significantly ($p \leq 0.05$) reduced it.

Interestingly, Ext gum and Ext CMC upon reconstitution retained the original flavour of the starting

material, while that of Ext pure was significantly ($p \leq 0.05$) enhanced compared to the rest of the products.

Concerning the bodyness, reconstituted drink made from Ext pure was similar to that from Kordofan raw pulp powder. In contrast, reconstituted Ext gum and Ext CMC showed a significantly ($p \leq 0.05$) better characteristics. It was clear that addition of both gum Arabic and CMC greatly enhance the bodyness of the spray dried products.

With respect to overall quality, Ext pure was the best. This can be ascribed to its excellent wetability, dispersibility and solubility characteristics Table 6. Ext gum demonstrated almost the same overall quality as its respective unprocessed powder, whereas treatment with CMC (Ext CMC) insignificantly ($p \leq 0.05$) lowered the overall quality of the product.

CONCLUSION

Sudanese baobab fruit pulp from different regions of the country proved to be rich in ascorbic acid (vitamin C), Ca and P (average values were 358.44, 393.55 and 91 mg/100g, respectively), it also showed relatively higher protein content (5.2%) compared to the literature. Extraction, filtration and spray drying methods adopted in this study significantly ($p \leq 0.05$) reduced the above mentioned nutrients, except P.

Solubility of the sprayed powder was significantly ($p \leq 0.05$) reduced as a result of treatment with gum Arabic, sugar and Carboxy Methyl Cellulose (CMC). Dispersibility was significantly ($p \leq 0.05$) improved by concentration with sugar, significantly ($p \leq 0.05$) deteriorated as a result of CMC treatment and not affected by addition of gum Arabic. Wetability was significantly ($p \leq 0.05$) reduced due to addition of both CMC and gum Arabic.

RECOMMENDATIONS

The spray dried product obtained from the 12% TSS pure extract of baobab pulp proved to be organoleptically acceptable and of good reconstitution characteristics, therefore, development of such novel product should be encouraged. Further research efforts should be directed to improve the extraction method of baobab pulp (under vacuum) to obtain high concentration in order to minimize the time in the zone of action in the spray dryer, hence prevent deterioration of the pulp nutritive value.

REFERENCES

Abdel Kareem, M.I. and J.G. Brennan, 1975. A study of the reconstitution characteristics of spray dried *Hibiscus sabdariffa* (Karkadeh). Sudan J. Food. Sci. Technol., 7: 52.

AOAC, 1990. Official Method of Analysis. 15th Edn., Association of Analytical Chemists, Washington, D.C.

Arnold, T.H., M.J. Well and A.S. Wehmeyer, 1985. Khoisan Food Plants Taxa with Potential for Economic Exploitation. In: Wickens, G.E., J.R. Goodin and D.V. Field (Eds.), Plants for Arid Lands. Allen and Unwin, London, pp: 69-86.

Baobab Fruit Company, 2002. Nella Tradizione Africana Baoba. From: www.baobabfruitco.com.

BSI, 1976. British Standard Specification for Test Sieves. 4th Revision, Series: BS410. British Standards Institute, London.

Chapman, H.D. and P.F. Pratt, 1982. Methods of Analysis of Soil, Plant and Water. 2nd Edn., University of California Agricultural Division, USA.

Dos-Santos, H.A. and M. Damon, 1996. Manuel de Nutrition Africaine. Karthala Publishing Co., Dakar.

Duncan, B.D., 1955. Multiple range and multiple F-test. Biometrics, 11: 1-42.

Fleuret, A., 1980. Non food uses of plants in Usambara. Econ. Bot., 34: 320-333.

Gaydou, E.M., J.P. Bianchi, A. Ralamanavaro and B. Waegell, 1982. Hydro-carbons, Sterols and Tocopherols in the seeds of six *Adonsonia* species. Phytochem., 21(8): 1981-1987.

Hanson, N.W., 1973. Official Standardized and Recommended Method of Analysis. Society of Analytical Chemistry. London.

Ighodalo, C.E., O.E. Catherine and M.K. Daniel, 1991. Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. Plant Food Hum. Nutr., 41: 151-154.

Ihekoronye, L.J. and P.O. Ngoddy, 1985. Integrated Food Science and Technology for the Tropics. Edu. MacMillan Publishers, London.

Manfredini, S., S. Vertuani, E. Braccioli and V. Buzzoni, 2002. Antioxidant capacity of *Adansonia Digitata* fruit pulp and leaves. Acta Phytotherapeutica, 2: 2-7.

Milza, P., 2002. Una pianta per il futuro: Il Baobab. Erboristeria domani Nr., 10: 40-51.

Nour, A.A., B.I. Magboul and N.H. Kheiri, 1980. Chemical composition of baobab fruit (*Adansonia digitata*). Trop. Sci., 22: 383-388

Okoho, P.N., 1984. An assessment of the protein, minerals and vitamin losses in sun dried Nigerians vegetables. Nutrition Reports International Zaria, Nigeria.

Quinn, M.R. and L.R. Beuchat, 1975. Functional properties changes resulting from fungal fermentation of peanut flour. J. Food Sci., 43: 1270-1275.

Saka, J.D.K., J.D. Msonthi and J.A. Maghembe, 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. Forest Ecol. Manag., 64(2-3): 245-248.

Sidibe, M. and J.T. Williams, 2002. Baobab. *Adansonia digitata*. International Centre for Under-utilized Crops, Southampton, UK.

Snedecor, G.W. and G.W. Cochran, 1987. Statistical Method. 7th Edn., Lowa State University Press, Amers, IA, USA.

Von Maydell, H.J., 1990. Trees and Shrubs of the Sahel: Their Characteristics and Uses. Werkestein, Margrat, Germany.

Wang, C. and J.E. Kinsella, 1976. Functional properties of novel proteins, AIfaIfa leaf protein. J. Food Sci., 41: 286-292.