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Chemical composition and functional properties of raw and roasted Nigerian benniseed (*Sesamum indicum*) and bambara groundnut (*Vigna subterranean*)

A.A. Yusuf[a,*], H. Ayedun[b], L.O. Sanni[c]

[a] *Department of Chemistry, University of Agriculture, Abeokuta, Ogun State, Nigeria*
[b] *Department of Science Laboratory Technology, Federal Polytechnic, Ilaro, Ogun State, Nigeria*
[c] *University of Agriculture, Abeokuta/International Institute of Tropical Agriculture, Ibadan, Nigeria*

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Abstract

Benniseed and bambara groundnut seeds were roasted at 80 and 120 °C for 10–60 min. For both flours, the effects of roasting temperature and time on selected functional properties and chemical composition were determined, as were the effects of pH on the emulsification capacity and nitrogen solubility. The chemical constituents of the raw flours were present at higher concentrations than those of the roasted flours except for fat and ash. Protein concentrates of both flours contained 80.5–81.5% crude protein as the major constituent. Nitrogen solubility was lowest at pH 4.0 for raw and roasted benniseed flour and pH 5.0 for raw and roasted bambara groundnut flour. Roasting generally lowered the nitrogen solubility and increased the water and oil absorption capacities while decreasing the foaming capacity and emulsification capacity of both flours.

Keywords: Benniseed; Groundnut seed; Roasting; Chemical; Functional; Properties

1. Introduction

In developing and under-developed countries, there is an urgent need for additional or new plant foods to meet the nutritional requirements of ever-increasing populations (Prakash & Misra, 1988). Large segments of the populations from these countries suffer from malnutrition (Akubor, Isolokwu, Ugbane, & Onimawo, 2000). In Nigeria for example, popular legumes, such as cowpea, beans and groundnut, are widely consumed to complement the low protein contents of grains (rice, maize) and tubers (cassava and yam); animal proteins such as meat, milk and eggs are expensive and relatively difficult to acquire. Therefore, other rich protein sources need to be identified. Benniseed and bambara groundnut are examples of such legumes. However, for efficient utilisation and consumer acceptance of these legume seed flours, studies of their desirable functional properties are important. Previous studies on the functional properties of flours have focused mainly on popular legumes, such as soybean, cowpea, pigeon pea, and mucuna beans (Giami, 1993; Oshodi & Ekperigin, 1989; Wolf, 1970; Yusuf & Adewuyi, 2003).

Roasting, which is a common local processing method in Africa, has been reported to affect the properties of legume seeds. For example, drying wetted cowpeas at temperatures between 80 and 120 °C decreased cowpea flour functional properties, such as solubility, foam formation and stability (Enwere & Ngoddy, 1986; Ngoddy, Enwere, & Onuorah, 1986). This study was undertaken to assess chemical composition and functional properties of benniseed and bambara groundnut flour and their protein concentrates. Also, the effects of roasting temperature and pH on their functional properties were investigated, in

* Corresponding author. Tel.: +234 08033924499.
E-mail address: yusufaa2000@yahoo.com (A.A. Yusuf).

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order to develop applications for these legumes in food formulations.

2. Materials and methods

2.1. Materials

Benniseed (1 kg; *Sesamum indicum* – white type) and bambara groundnut (1 kg; *Vigna subterranean*) were obtained from Lafenwa market, Abeokuta, Nigeria. The seeds were manually dehulled after soaking in distilled water at room temperature for 4 h, sun-dried (30 ± 2 °C) for 24 h and ground to pass through a 60-mesh sieve (British Standard), to give raw seed flours (Dashak & Fali, 1993).

2.2. Roasting of seeds

The benniseeds and bambara groundnut were spread thinly on different aluminium trays and heated in an air convection oven at 80 or 120 °C for 10, 15, 20, 30 and 60 min. These temperatures and times were chosen because both samples' seeds start roasting from 80 °C and burning (over-roasting) above 120 °C and the maximum time before over-roasting or burning is 60 min. The roasted seeds were dehulled manually and ground to pass through a 60-mesh sieve (British Standard). All experiments were conducted in triplicate.

2.3. Chemical analysis

The crude protein (Kjeldahl, N × 6.25), fat (solvent extraction), crude fibre, ash and moisture were determined according to AOAC (1984) methods. The digestible carbohydrate was calculated by difference, with all analyses performed in triplicate.

2.4. Protein isolation

Five hundred gramme of benniseed and bambara groundnut flour were dispersed in 5 l of distilled water in separate plastic containers. The pH was adjusted to 8.0 with 1 M NaOH, to facilitate protein solubilisation. The solution was stirred for 4 h at room temperature. The pH of the supernatant, obtained after centrifuging at 4000*g* for 40 min, was adjusted to 4.0 with 0.5 M HCl, to precipitate the protein concentrate, which was obtained by centrifugation at 5000*g* for 40 min (Nath & Narasinga Rao, 1981). Protein isolation was carried out on both raw and roasted samples, separately.

2.5. Nitrogen solubility

Nitrogen solubilities of both benniseed and bambara groundnut flours in water at 5% (w/v) were determined over a pH range from 1 to 12, according to the method of Beuchat, Cherry, and Quinn (1975). The suspensions were stirred under different pH conditions at 30 °C for 40 min and then centrifuged at 3000*g* for 40 min. The supernatants were freeze dried, weighed and analysed for their nitrogen content (Kjeldahl). Samples roasted at 80 °C were used for nitrogen solubility determinations because the amounts of protein in these samples were similar to raw ones (Table 1) and the functional properties of the sample roasted at 80 °C for 20 min are better than those roasted at 120 °C (Tables 4 and 5).

2.6. Functional properties

The water absorption capacity (WAC) was determined using the method of Sosulski (1962) at room temperature. The oil absorption capacity (OAC) was determined by the method of Sosulski, Humbert, Bui, and Jones (1976), using a 4 g flour sample and refined peanut oil (density 0.9 g/ml). The oil absorption capacity determinations were carried out at room temperature and the values were expressed as g of oil absorbed by 1 g of flour or protein.

Foaming capacity (FC) and foam stability (FS) were determined using the method of Nath and Narasinga Rao (1981), with slight modifications. 2.5% (w/v) flour suspension (100 ml) was whipped at low speed in a 250 ml bowl, using a Waring blender for 5, with foam volumes recorded after 30 s. Foaming capacity (FC) was expressed as percent increase in foam volume, measured after 30 s, and foam stability (FS) was determined by measuring the FC, after standing for 10, 15, 20, 30 and 60 min. Both FC and FS were reported as a function of time.

Emulsification capacity was determined by the procedure of Beuchat et al. (1975) at room temperature. A 2 g flour sample and 23 ml distilled water were blended for 30 min at 1600 rpm using a Braun blender. After complete dispersion, refined peanut oil was added continuously from a burette and blending continued until the emulsion breakpoint was reached, when there was separation into two layers. Emulsification capacity determinations were carried out at room temperature and the values are expressed as g of oil emulsified by 1 g of protein. Samples roasted at 80 °C were used because the amount of protein in these samples was similar to raw flours (Table 1).

The method of Coffman and Garcia (1977) was employed for determining the gelation capacity.

2.7. Statistical analysis

Data were evaluated using analysis of variance, as described by Steel and Torrie (1980), where mean differences were determined as significant at $p > 0.05$.

3. Results and discussion

3.1. Chemical composition

The chemical compositions of raw and roasted benniseed and bambara groundnut flours are presented in Table

Table 1
Chemical composition of raw and roasted (80 °C for 20 min) benniseed and bambara groundnut flours

	Raw benniseed	Roasted benniseed	Raw bambara groundnut	Roasted bambara groundnut
Moisture (%)	3.90 ± 0.04	0.25 ± 0.01	4.30 ± 0.20	1.82 ± 0.08
Fat (%)	36.10 ± 2.11	40.30 ± 2.85	6.00 ± 0.63	10.39 ± 1.54
Crude protein (%)	18.1 ± 1.25	16.4 ± 1.37	20.7 ± 1.82	18.5 ± 1.91
Ash (%)	11.20 ± 0.85	12.70 ± 0.94	4.40 ± 0.62	6.31 ± 0.62
Crude fibre (%)	14.10 ± 1.71	10.87 ± 0.21	3.30 ± 0.81	3.01 ± 0.60
Carbohydrate (%)	16.6 ± 1.31	19.5 ± 1.50	61.3 ± 2.58	60.0 ± 2.72

All values are means ± standard deviations of triplicate analyses.

Table 2
Chemical composition (g/100 g dry weight) of protein concentrates extracted from raw and roasted (80 °C for 20 min) benniseed and bambara groundnut flours

	Bennissed		Bambara groundnut	
	Raw	Roasted	Raw	Roasted
Moisture (%)	0.20 ± 0.01	0.18 ± 0.01	1.10 ± 0.02	0.89 ± 0.01
Fat (%)	ND	ND	ND	ND
Crude protein (%)	80.5 ± 2.01	78.9 ± 1.99	81.5 ± 1.67	80.2 ± 1.88
Ash (%)	10.14 ± 0.11	8.11 ± 0.10	3.38 ± 0.02	2.19 ± 0.01
Crude fibre (%)	10.06 ± 0.71	7.25 ± 0.59	4.47 ± 1.64	2.99 ± 1.13
Carbohydrate (%)	7.95 ± 1.02	9.17 ± 1.12	9.13 ± 2.31	11.4 ± 1.98

All values are means ± standard deviations of triplicate analyses.
*ND: not determined.

1. Raw bambara groundnut was higher in all chemical constituents than was raw benniseed, except in fat and ash contents. The high fat content of both raw and roasted benniseed (36.10% and 40.30%, respectively) is comparable to that of other commercially produced sources, e.g., coconut kernel, reported to have 34.70–44.10% oil content (Chakraborty, 1985). Therefore commercial exploitation of the oil from benniseed is economically viable. The low moisture contents of both flours studied (3.90–4.30%) fall within the standard range of 0–13%, as reported by James (1995). This moisture content range has been reported to be suitable for storage and processing of flours without microorganism degradation of the triglyceride (James, 1995).

The crude protein content of bambara groundnut (18.5–20.7%) is slightly greater than that of benniseed (16.4–18.1%). From the context of viable commercial exploitation, the extractions of proteins from studied samples may have to be carried out along with carbohydrate and fat. Table 1 shows that roasting (80 °C, 20 min) decreases the moisture, crude protein and crude fibre contents of benniseed and bambara groundnut, while increasing the fat and ash contents. These differences were not statistically important.

The chemical compositions of protein concentrates isolated from benniseed and bambara groundnut flours are shown in Table 2. These results indicate that the fat component of the flours is largely removed during protein concentrate preparation. However, the concentrate from the roasted samples was lower in moisture, crude fibre, ash and crude protein contents, with higher carbohydrate levels, when compared to the respective raw sample flour concentrate (Table 2).

3.2. Nitrogen solubility

Raw benniseed flour had a minimum nitrogen solubility of 25% around pH 4.0 (Fig. 1), increasing either side of this pH. About 70% of nitrogen was soluble at pH 2.0 and at pH 11.0 was about 92% soluble. Beyond pH 11.0, no marked improvement in nitrogen solubility was observed. The solubility behaviour was similar to that of soy and raw winged bean flour (Narayana & Narasinga Rao, 1985). Nitrogen solubility decreased in roasted benniseed flour at all pH conditions studied (Fig. 1). At pH 4.0, a minimum nitrogen solubility of 11.2% was observed, compared to 25% with raw flour. At pH 11, it was 65%, compared to 92% with raw benniseed flour. The nitrogen solubility profiles for raw and roasted bambara groundnut are presented in Fig. 1. The trends and patterns for bambara were quite similar to that of raw and roasted benniseed. At pH 4.8, a minimum nitrogen solubility of 21% was observed for raw bambara groundnut, compared to 10.5% for the roasted flour. At pH 9.5, the nitrogen solubility was 80% for raw bambara groundnut flour, compared to 52.5% for the roasted flour (Fig. 1).

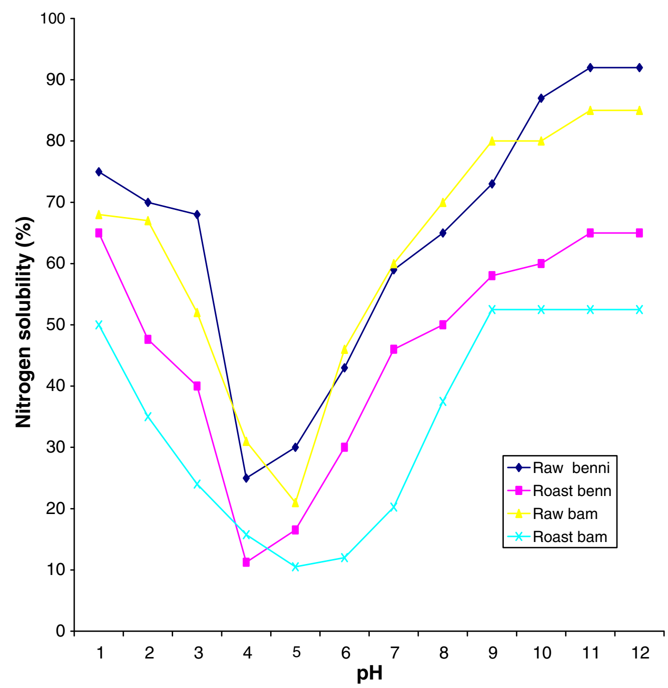

Fig. 1. Nitrogen solubility *vs* pH profile of raw and roasted (80 °C for 20 min) benniseed and banbara groundnut flours.

Reduction in the nitrogen solubility due to the heat processing has been reported for soy and peanut flours (McWatters & Holmes, 1979). This suggests that roasting or heating denatured the proteins of benniseed and bambara groundnut flours, and reduced their solubilities in water at different pH values.

3.3. Functional properties of raw flours

The functional properties of raw benniseed and bambara groundnut flours are presented in Table 3. The WAC of bambara groundnut flours (174%) was higher than that of benniseeds. The higher WAC of bambara groundnut may be due to the higher polar amino acid residues of benniseed proteins having an affinity for water molecules (Narayana & Narasinga Rao, 1985).

The OAC of bambara flour was higher than that of benniseed flour (Tables 4 and 5). This suggests that bambara flour may have more hydrophobic proteins than benniseed flour (Lawal & Adebowale, 2004). Since Kinsella (1976) established that more hydrophobic proteins demonstrate superior binding of lipids, the foaming capacity (FC) of benniseed flour (82%), as expected, was higher than that of bambara groundnut flour (72%) but lower than those of sunflower (230%) and soy (170%) (Lin, Humbert, & Sosulski, 1974). In addition, bambara foam was found to be more stable than was benniseed flour. Grahams and Phillips (1976) and Akintayo, Oshodi, and Esuoso (1998) linked good foamability with the flexible protein molecules, which reduce surface tension, while highly ordered globular protein, which is relatively difficult to surface denature, results in low foamability. One may therefore suggest that the studied flours had high concentrations of globular protein. Benniseed flour has a higher emulsion capacity (83.0) than has bambara groundnut (78.5) because benniseed contains lower amounts of carbohydrates (Ramanatham, Ran, & Urs, 1978) and this may be attributed to the high fat content of benniseed (Table 1).

Table 3
Functional properties of raw benniseed and bambara groundnut flours

	Benniseed	Bambara groundnut
Water absorption capacity (%)	100 ± 2.50	174 ± 2.40
Oil absorption capacity (%)	130 ± 3.72	150 ± 3.62
Foaming capacity (%)	82 ± 1.62	70 ± 1.23
Foaming stability (%)	80 ± 1.81	83 ± 1.95
Least gelation (%)	38 ± 1.22	28 ± 1.11
Emulsion capacity (g oil/g protein)	83.0 ± 5.38	78.5 ± 4.25

All values are means + standard deviations of triplicate analyses.
*All means + S.D. of triplicates.

3.4. Effect of roasting on functional properties

The effects of roasting temperature and time on some of the functional properties of benniseed and bambara groundnut protein concentrates are shown in Tables 4 and 5. The WAC of flour seeds roasted at 80 °C increased with increasing roasting time. A similar trend was reported for winged bean (Narayana & Narasinga Rao, 1985), cowpea (Giami, 1993) and African breadfruit kernel flour (Akubor et al., 2000). At 120 °C, the WAC increased with increased roasting time, up to 20 min (Table 5). Wolf (1970) showed that these properties enable bakers to add more water to the dough, resulting in improved handling characteristics and maintenance of bread freshness. During roasting major proteins dissociate into sub-units, which might have more water binding sites than have the native or oligomeric proteins (Akubor et al., 2000). Gelatinisation of carbohydrates and swelling of crude fibre may also occur during roasting, leading to increased water absorption (Akubor et al., 2000).

The OAC of the seed flour at both roasting temperatures (80 and 120 °C) increased with increased roasting time up to 20 min and thereafter decreased. Prior to roasting at 80 °C, the OAC was 150% for benniseed and 162% for bambara groundnut flour. These values increased to 250% and 300%, respectively, at 20 min, and subsequently decreased to 220% and 285%, respectively at 60 min. The samples roasted at a higher temperature (120 °C) exhibited similar trends (Table 5). The OAC values were higher at 80 °C for each of the roasting times. Therefore, high temperature and prolonged roasting time are not desirable for processing benniseed and bambara groundnut flour for foods where water and/or oil absorption are of prime importance.

Table 4
Effect of 80 °C roasting temperature on the functional properties of benniseed and bambara groundnut flours

Time (min)	WAC[A]		OAC[A]		FC[A]		FS[A]	
	Benniseed	BG/nut[B]	Benniseed	BG/nut	Benniseed	BG/nut	Benniseed	BG/nut
0	100[a]	174[a]	150[a]	110[a]	82[a]	72[a]	80[a]	83[a]
10	105[a]	190[c]	210[b]	230[b]	77[a]	61[a]	75[a]	77[a]
15	110[b]	200[c]	230[b]	270[c]	70[b]	55[b]	70[a]	73[b]
20	122[c]	245[b]	250[c]	300[c]	61[c]	50[b]	65[b]	68[c]
30	126[c]	250[b]	270[c]	290[c]	55[d]	45[c]	55[c]	59[d]
60	130[c]	255[b]	220[b]	285[c]	50[d]	38[c]	50[c]	54[d]

Means of three determinations. Means within a column with the same letter are not significantly different ($p > 0.05$).
[A] WAC = water absorption capacity; OAC = oil absorption capacity; FC = foaming capacity; FS = foam stability.
[B] Bambara groundnut.

Table 5
Effect of 120 °C roasting temperature on the functional properties of benniseed and bambara groundnut flours

Time	WAC[A]		OAC[A]		FC[A]		FS[A]	
	Benniseed	BG/nut[B]	Benniseed	BG/nut	Benniseed	BG/nut	Benniseed	BG/nut
0	100^a	174^a	130^a	150^a	82^a	70^a	80^a	83^a
10	102^a	180^a	135^a	155^a	50^b	35^b	78^a	81^a
15	106^a	192^b	142^b	160^b	45^b	30^b	82^a	89^b
20	115^b	210^c	150^c	170^c	40^b	28^b	75^b	77^c
30	112^b	200^b	145^b	165^b	35^c	25^c	70^b	72^c
60	98^a	190^b	140^b	155^a	30^c	20^c	65^b	68^d

Means of three determinations. Means within a column with the same letter are not significantly different ($p > 0.05$).
[A] WAC = water absorption capacity; OAC = oil absorption capacity; FC = foaming capacity; FS = foam stability.
[B] Bambara groundnut.

Roasting decreased the foaming capacity (FC) of the seeds. The FC was dependent on the roasting time, at both 80 and 120 °C, the FC decreased with increasing roasting time (Tables 4 and 5). Roasting has been reported to increase the antioxidant activity (Jeong, Kim, Nam, Ahn, & Lee, 2004) and inactivate the anti-nutritional factors (Thangadurai, 2005) of benniseed flour. A similar heat effect on peanut flour has been reported (Rahma & Mustafa, 1988). The FS of both benniseed and bambara groundnut flours decreased with roasting and showed similar trends to the FC. This finding is in agreement with that reported by Rahma and Mustafa (1988) for peanut flour, which was attributed to protein denaturation.

3.5. Effect of pH on emulsification capacity

The effects of pH on the emulsification capacities of the raw and roasted benniseed and bambara groundnut flours were determined over the pH range 1–12 (Fig. 2). The emulsification capacity of raw benniseed flour was higher than those of for all other flours at all pH conditions studied. The emulsification capacity *vs* pH profile (Fig. 2**)** relationship resembled the nitrogen solubility *vs* pH profile (Fig. 1) of the studied flours. This suggests that emulsification is due to the solubilised proteins (Crenwelge, Dill, Tybor, & Landmann, 1974; Nath & Narasinga Rao, 1981; Ramanatham et al., 1978) reported similar relationships between emulsification capacity and pH for soybean, groundnut and guar proteins.

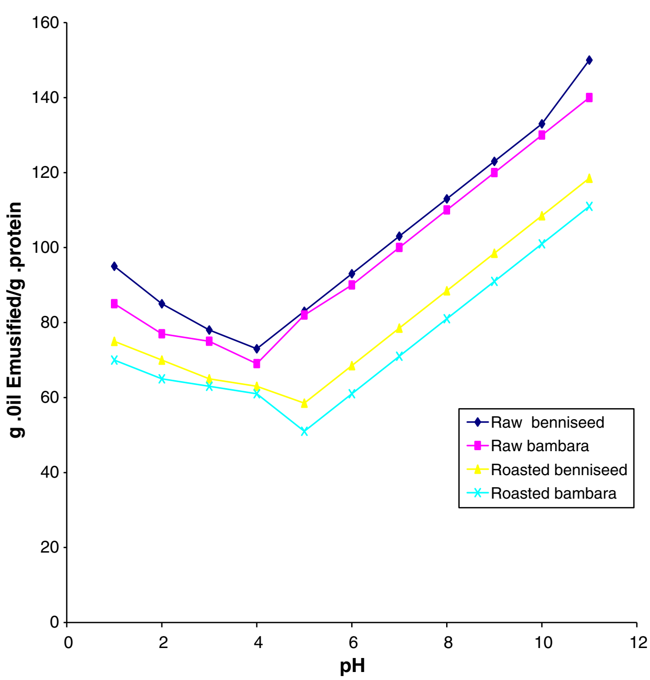

Fig. 2. Effect of pH on the emulsification capacity of raw and roasted (80 °C for 20 min) benniseed and bambara groundnut flours.

Roasting the seeds markedly reduced the emulsification capacities of both benniseed and bambara groundnut flours at all pH conditions studied (Fig. 2), and reduced both the nitrogen solubility and emulsification capacity of the flours. McWatters and Holmes (1979) observed that soy flour and peanut flour are sensitive to moist heating, and the heating time was the primary determinant in the reduction of nitrogen solubility and emulsification capacity.

4. Conclusion

This research has revealed that benniseed and bambara groundnut flours seem to be a potential source of proteins, to supplement the dietary requirements of humans, and a source of oil, in the case of benniseed. Roasting activated the WAC and OAC, but inactivated the FC and FS of both benniseed and bambara groundnuts. The emulsification capacities of the studied samples are greatly affected by pH. However, raw samples are less affected by the pH. Information given in this work showed that benniseed and bambara groundnut flours may be potential ingredients for future feed supplements and/or formulation of baby foods.

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