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Functional property of complementary blends of soybean and cowpea with malted or unmalted maize

V.A. Obatolu [a,*], A.H. Cole [b]

[a]Farming System Research and Extension Programme, Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, P.M.B. 5029, Ibadan, Nigeria
[b]Department of Human Nutrition, Faculty of Basic Medical Sciences, University of Ibadan, Ibadan, Nigeria

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Abstract

Complementary food mixtures were prepared with malted or unmalted maize using extrusion cooking. The maize was fortified with cowpea and soybean at a ratio of 45:35 and 55:25%, respectively. The mixtures were subjected to functional characteristic evaluation. The blends had good functional characteristics with a particularly low viscosity in the cowpea with malted maize mixture. Minimum nitrogen solubility index values were observed around pH 4 and 5 for both malted and unmalted mixtures. The malted-based blends had a higher water absorption capacity and a lower emulsification property, while the oil absorption was not significantly affected. The addition of malted maize to cowpea significantly affected the gelation value of the mixture. Gluten was the most abundant protein in all the mixtures while globulin and albumin were, respectively, next to it in malted-based mixtures. Sensory evaluation showed that malting improved the flavour of the mixtures. © 2000 Published by Elsevier Science Ltd. All rights reserved.

1. Introduction

Complementary foods, in most developing countries, are mainly from cereals with animal proteins being used as supplements. However, because of the high cost of animal protein, attempts have been made to look into alternative sources of protein, especially from plant sources.

In efforts to improve the nutrition of children in regions of chronic and acute malnutrition, various kinds of economical protein-rich plant mixtures are used for different areas in Africa (Mosha & Svanberg, 1990). The combination of such food ingredients often alters the food composition of the food product and may change the functional and sensory properties (Kinsella, 1976). Acceptable sensory properties are essential in new food products. Colour, odour, flavour and texture are the key attributes of a new product that determines its acceptability. Off-flavour may be due to contaminants of the new food ingredients or may be generated during subsequent processing and storage of the formulated food (Kinsella). Utilisation of foods with perceptible mild and delicate flavours, such as soybean (Wolf, 1975), is recommended (Kinsella). This can be achieved by the use of food ingredients with appropriate and compatible functional properties (Hermansson, 1973). Processing, if not carried out under controlled conditions, may decrease nutritional value of the food product and lower the level of acceptance for eating. Extrusion cooking and malting offer significant potential for central processing of nutritive foods (Harper, 1980; Molina et al., 1983). Various blends of cereals fortified with legumes have been developed through extrusion cooking (Mosha & Svanberg). Functional properties have frequently been neglected in such formulation, more emphasis being place on quantity and quality of protein. The incorporation of plant protein into cereal in the processing of complementary foods, is assumed to have an effect on the functionality of the product. There is, however, the need for such food blends to possess functional characteristics that will enable them compete, in terms of sensory appeal and cost advantage, with the conventional product.

Functional properties largely determine the utilisation of concentrated seed protein as food ingredients (Fleming, Sosulki & Hamman, 1975). Functional properties, such as solubility, gelation, viscosity, water and fat

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[*] Corresponding author.

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binding properties, reflect the level of protein interaction with water, while fat absorption and emulsion determine protein and fat interaction. Nitrogen solubility is a good index of the functional potential of protein-rich products (Wanasundara & Shahidi, 1994). In high-protein drinks, solubility is important and this keeps viscosity low, inhibits settling and eases problems of uniform distribution (Snyder & Kwon, 1987). Viscosity is an important functional property of foods that affects mouth-feel and textural quality of fluid food. Sathe and Salunkhe (1981) have shown that viscosity is a function of, not only the solid concentration, but also the type of protein.

Fleming et al. (1975) have reported that protein concentration, especially the globulin fraction, is an interaction between proteins, carbohydrates and lipids. This interaction is responsible for the gelation capacity of legume and oilseed protein. Water binding by proteins is a function of several parameters, including size, shape, conformational characteristics, steric factors, hydrophilic-hydrophobic balance of amino-acids in the protein molecules, lipids and carbohydrates associated with the protein (Sathe & Salunkhe, 1981). Oil absorption is related to the physical entrapment of oil and to the number of nonpolar side chains on the proteins that bind hydrocarbon chains on the fatty acids (Kinsella, 1976).

This study aimed at looking into the functional properties of extruded complementary food from malted or unmalted maize fortified with soybean or cowpea.

2. Materials and methods

2.1. Materials

Maize (flints), soybean (TGX 536 028) and cowpea (T835-818) were obtained from the seed store of the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria.

2.2. Pre-processing

Soybean and cowpea were dehulled. The maize was malted using the method described by Kulkani, Kulkani and Ingle (1991) for cereal germination with some modification. The maize was soaked for 12 h in volume of water 3 times its weight and drained using a woven basket. It was then spread on a wide wooden box for germination under ambient temperature (32 ± 2°C) for 72 h and watered twice daily. The germinated maize was washed and dried to a moisture content of 10% in the forced-air oven designed by Hotpack, Phila, PA, USA at 60°C for a period of 16 h. The malted grain was crushed and winnowed of sprouts and hulls.

The dehulled soybean, dehulled cowpea, malted maize (MM) and unmalted maize (UM), were milled into a coarse grit and separated using a Hammer mill with screen designed to give meals of about 500 μm size. They were put into a thick polythene bag and stored in a cold room (4°C) until used. The soybean and cowpea were mixed with either malted maize or unmalted maize (MS, MC, UMS, and UMC) before extrusion cooking at a ratio of 75:25% for soybean mixtures, and 65:35% for cowpea mixtures. Though different ratios of soybean and cowpea were used, they both contributed 10% of the total protein in each of the mixtures. Whole malted and unmalted maize were used as controls.

2.3. Extrusion cooking

The mixtures were cooked in a single screw 600 Jr. Insta pro extruder at 120°C with a pressure of 300 psi. The extruder specifications were, 10.01 mm for the barrel bore diameter, 12.5 mm for screw length, 9.01 mm for screw diameter and 1.27 mm for opening. The mixtures were fed to the extruder with an Insta Pro 8600.02 volumetric feeding system, with the feed rate held constant at 300 kg/h. The moisture was varied by the amount of water delivered by the metering pump (Insta-Pro water manifold and injector). The hot extrudates were fed directly into rotating drum cooler (Insta-Pro model 400 conditioner) for drying the extruded material.

2.4. Functional properties

2.4.1. Viscosity test

The starch-pasting properties of the blends were determined by a computerised Rapid Visco Analyser (RVA) method with slight modification. A slurry, containing 3 g of sample based on 100% dry matter (60 g of sample in 400 ml of distilled water, was mixed with 25 ml distilled water in the RVA cup and stirred. The RVA machine was loaded and set at 40°C to run for 20 min. The viscosity of formulated blends was compared with that of whole malted maize (MM) and unmalted maize (UM).

2.4.2. Emulsifying capacity (EC)

The EC of each blend was determined by the method of Yasumatsu et al. (1972). The blend (1.25 g) was homogenised with 50 ml of water for 30 s, with the use of a Polyton homogeniser at 10,000 r/min. Pure soybean oil (25 ml) was added to each sample, and the mixture was homogenised for 90 s. The emulsions obtained were divided evenly into four tubes, and were centrifuged at 1100 *g* for 5 min. EC was calculated by dividing the volume of the emulsified layer by the volume of emulsion before centrifuging and expressing the result as percentage.

2.4.3. Nitrogen Solubility Index (NSI)

The NSI of each sample of the blends was determined according to the method of AACC (1976). 5 g of sample was weighed into a 250 ml Erlenmeyer flask and 200 ml distilled water added to it in small portions while stirring thoroughly to obtain uniform dispersion. The content of each flask was mixed at room temperature for 2 h by using a barrel wrist-action shaker. The mixture was transferred carefully into a 250 ml volumetric flask and two drops of antifoam A were added to it. The mixture was diluted to the mark with water while being thoroughly mixed. A 40 ml aliquot was centrifuged for 10 min at 1500 *g*. The supernatant was passed through a funnel equipped with a glass wool plug and 25 ml of the clear liquid were transferred to Kjeldahl tubes for subsequent nitrogen determination. The amount of water-soluble nitrogen in the blend was determined, and the NSI was obtained by expressing the content of water-soluble nitrogen as a percentage of that of total nitrogen in the meal. The pH was adjusted from 2.0 to 12.0 by addition of a 1% (v/v) of HCl or NaOH.

2.4.4. Water absorption capacity (WAC)

The WAC determined using a combination of the AACC (1976) and Beuchat (1977) methods. A sample (2 g) was dispersed in 20 ml of distilled water and mixed for 30 s every 10 min over a period of 60 min and the supernatant was carefully decanted. The tube was inverted and drained for 15 min before weighing. The absorbed water was expressed as a percentage increase in the sample weight.

2.4.5. Protein fraction

Protein fractions of the blends were determined using the method of Marfo, Oke and Afolabi (1986) with slight modification. Duplicate 2.5 g samples were put in bottles with screw caps. Each of the samples was extracted twice with 50 ml of distilled water for 30 min with continuous shaking. The extract was separated from the residue by centrifugation at 3000 rpm for 15 min. The clear supernatant was collected and the residues were successively extracted and centrifuged in a similar way with 5% KCl solution, 70% ethanol and 0.2% NaOH solution. The remaining residue, after the successive extractions was the insoluble residue. The protein contents of the four extracts of each sample and residue were determined by the micro-Kjeldahl method (AOAC, 1990).

2.4.6. Gelation

The method of Sathe and Salunkhe (1981) was used in determining the least gelation concentration of the blends. Sample suspensions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v) were prepared in 5 ml distilled water. The test tubes containing the suspensions were heated for 1 h in a boiling water bath followed by rapid cooling under cold running tap water. The test tubes were further cooled for 2 h at 40°C. The least gelation concentration was determined when the sample from the inverted test tube did not fall or slip.

2.4.7. Foam capacity (FC)

The method of Padmashree, Vijayakshami and Puttaraj (1987) was used for the determination of FC. A sample (2 g) of the mixture was blended with 100 ml water in a Waring blender. The suspension was whipped at 1600 rpm for 5 min. The mix was poured into a 250 ml measuring cylinder and the volume was recorded after 30 s. FC was expressed as percentage increase in volume using the formula of Lawton, Henderson and Derlatka (1972).

$$\text{Foam capacity} = \frac{\text{Volume after whipping-volume before whipping}}{\text{Volume before whipping}} \times 100$$

2.5. Sensory evaluation

The four formulated blends were prepared into gruel and presented to 50 trained consumers at a temperature of 40°C. The trained consumers were selected women previously trained on what to expect and familiar with the conventional product, that is the control. The consumers were women of child-bearing age and they scored the blends for colour, flavour, taste, texture and overall acceptability. Each consumer sat in an enclosed area designed for sensory evaluation and water was served to rinse mouths before tasting each of samples. Cerelac and Nutrend (two commercial complementary foods) served as control. Cerelac and Nutrend are highly nutritious weaning foods for babies from 4 months of age in Nigeria. They are maize-based mixtures fortified with other nutrients. Consumers were presented with a scored sheet using a 9-point hedonic scale, where; 1 was extremely disliked and 9 extremely liked.

The results were examined statistically on thrice replicated samples by analysis of variance and Duncan's multiple range test was applied to separate the means.

3. Results

3.1. Functional properties

Table 1 shows the pasting characteristics of the blends. The data gave a peak viscosity of 135, 214, 91 and 136 (SNU) for malted maize/soybean blend (MS), unmalted maize/soybean blend (UMS), malted maize/cowpea blend (MC) and unmalted maize/cowpea blend (UMC), respectively. The temperature at peak viscosity for all the blends ranged from 39.4 to 39.8 °C while time to gelatinise was from 3.73 to 4.40 min.

The emulsion capacities, water and oil capacities, gelation properties and foam capacities of the blends are presented in Table 2. The unmalted maize-based blends had higher emulsification properties than the malted maize blends while malted blends had higher WAC values than their corresponding unmalted blends. A significantly higher ($P < 0.05$) emulsion capacity was observed for whole maize blends. The values obtained for the oil absorption of the formulated blends were not significantly different. However, lower value was recorded for oil absorption and gelation properties of the whole maize bends. The soybean-based blends were also observed to have higher WAC values than cowpea and whole maize blends. A zero foam capacity was observed for all blends except whole unmalted maize.

The NSI, as a function of pH, is shown in Fig. 1. The minimum NSI value (7% and 8%) was observed for all the blends around pH 4 and 5 (isoelectric pH). Maximum NSI value of about 40, 25 and 32% at pH 10, 9, 10, and 10 were, respectively, observed for UMC, MC, UMS, and MS. Although there were no significant differences in the minimum NSI value obtained for all blends at between pH 4 and 5, a significant higher maximum NSI value at pH 10 was obtained for unmalted-based blends.

Fig. 2 shows the protein distribution in the mixtures in terms of albumin, globulin, prolamin and glutelin. Total extractable protein results in soybean-based samples were higher than cowpea-based samples.

Table 1
Pasting characteristic of the formulated blends [stirring number unit (SNU)][a]

Blends	V_p	T_p	t_g	T_g	V_{95}	t_p (min)
MS	135	39.4	4.15	76.6	50	20
UMS	214	39.8	4.40	79.2	92	20
MC	91	39.8	3.73	71.4	38	20
UMC	136	39.8	4.13	77.2	54	20
UM	525	39.7	3.15	78.6	60	20
MM	285	38.9	2.42	73.5	35	20

[a] V_p, peak viscosity; T_p, temperature at peak viscosity (°C); t_g, time to gelatinisation, T_g, time of gelatinisation (min); V_{95}, cooking viscosity; t_p, time to peak.

Table 2
Emulsification capacity, oil and water absorption capacities, gelation property and foam capacity of the blends

Blends	EC (%)	OA (%)	WAC (%)	Gelation (%)	FC (%)
MS	51.7	3.5	78.0	28.0	0
UMS	56.5	3.0	74.0	28.0	0
MC	49.3	3.5	70.0	19.0	0
UMC	55.9	3.0	68.0	24.0	0
UM	68.5	2.4	73.0	7.5	0
MM	62.4	2.0	65.0	12.0	2.6

3.2. Sensory evaluation

Sensory evaluation, using a 9-point hedonic scale (Table 3), revealed that there was no significant difference in the level of overall acceptance of the complementary foods

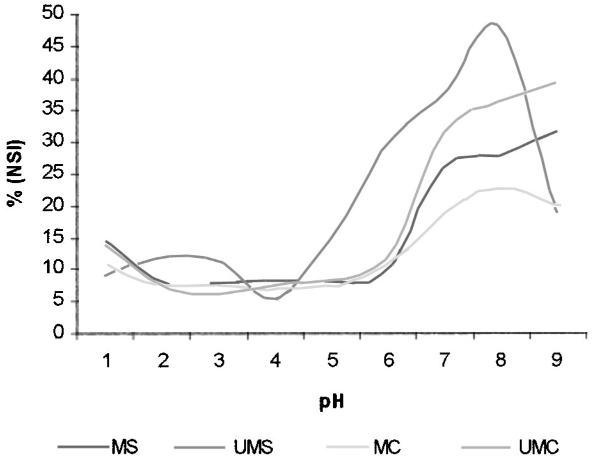

Fig. 1. Nitrogen solubility index of the blends.

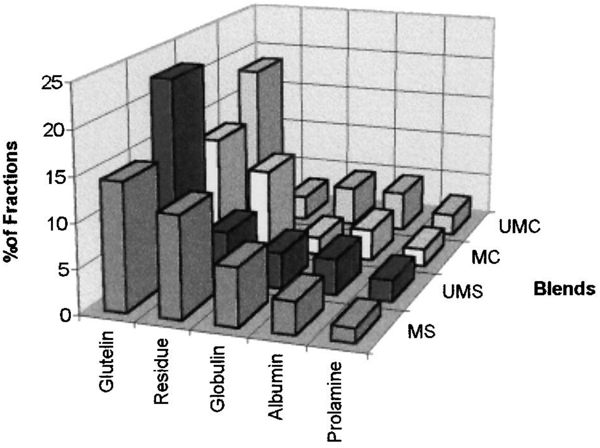

Fig. 2. Protein fractions of blends.

Table 3
Sensory evaluation of formulated blends compared with two commercial complementary formulas[b]

Blends	Colour	Flavour	Taste	Texture	Overall acceptability
MS	5.90c	7.50a	6.60b	6.20a	6.75a
UMS	6.75ab	5.90b	6.25b	6.25a	6.65a
MC	5.85c	7.10a	6.25b	6.18a	6.40a
UMC	6.80ab	6.15b	6.45b	6.35a	6.40a
CE[a]	7.35a	5.75b	7.15a	6.65a	6.90a
NU[a]	6.50c	6.35b	6.75ab	6.45a	6.80a

[a] Commercial complementary formula in Nigerian market.

[b] a-c = Different letters in the same column are significantly different at 5% level.

when compared to two commercial baby formulas (Cerelac and Nutrend). The colours of unmalted-based blends were comparable to CE (Cerelac) and had a significantly higher ($P > 0.05$) score than malted-based blends that compared well with Nutrend (NU). Malted-based blends had significantly higher ($P > 0.05$) scores for flavour than the other tested formulas. The flavour of CE was lowest scored while NU (Nutrend) compares with the formulated blends. The consumers rated the taste of CE higher. All blends were, however, acceptable to the consumers.

4. Discussion

The soybean-based blends took longer to gelatinise than the cowpea based blends and also had a significantly ($P < 0.05$) higher value for peak viscosity and cooking viscosity than cowpea-based blends. Malting significantly ($P < 0.05$) lowered the values of peak and cooking viscosity of the blends. The addition of malted maize to cowpea and soybean significantly ($P < 0.05$) reduced the viscosity of both cowpea and maize based blends while the reduction in soybean based was not significant ($P < 0.05$). The reduction in viscosity of malted-based blend is attributed to starch degradation caused by the action of alpha and beta amylase that developed during the malting process. Some of the desirable effects of malting of cereal are the reduction of viscosity, decrease in tannin content, degradation of phytic acid and increase in availability of some amino acids (Hansen, Pedersen, Munck & Eggum, 1989; Pederson, Hansen, Munck & Eggum, 1989). Likimani, Sofos, Maga and Harper (1991) observed a lower viscosity in extruded corn and soybean mixture with inclusion of α-amylase. This is attributed to the dextrinogenic effect (viscosity reducing) of amylolytic enzyme in malted maize on cowpea starch. Similar observations are made by other authors (Mosha & Svanberg, 1990; Marero, Payumo, Lobrando, Lainez, Gopez & Homna, 1988). Based on cooking viscosity, meals with 20 to 30% (10 g/50 ml–15 g/50 ml) dry matter can be prepared from any of the blends and still give a consumable slurry. This meal will have an energy density above 1 kkal/ml, which is the minimum level of energy density recommended for a weaning diet by the United Nations (1990).

The results for emulsion capacity indicated that germination had a reducing effect on emulsion capacity of the blend. Pawar and Ingle (1988) made a contrary observation on moth bean. Soybean-based blends had higher emulsion capacities than their corresponding cowpea-based blends. Yasumatsu et al. (1972) observed that addition of soybean to products, improved the emulsifying properties. The low emulsion capacity observed in all blends might be due to extrusion cooking used in processing the blends. Dry heating has been shown to decrease emulsion capacity (Rahama & Mostafa, 1988). The initial extrusion treatments produce a lower consistency by cleavage of starch molecules, thereby achieving an energy density of 0.8 kcal in the absence of malt flour (Mosha & Svanberg, 1990). Germinated-based blends had higher WAC and oil absorption capacity than the ungerminated blends. Pawar and Ingles observed a similar result when moth bean was germinated for 72 h. Padmashree et al. (1987) reported increased fat absorption in germinated blends. This was attributed to changes in the quality of protein upon germination. The slight increase in the oil absorption was attributed to the capacity of the malted based blends to hold the fat globules as the amount of lipophilic protein increased (Narayana & Narasinga, 1984) due to changes in the quality of protein upon germination.

The least gelation concentration of the blends indicates that the soybean-based blends did not form a gel up to the 28% (w/v) concentration range (Table 2). This might be due to the high globulin fraction observed in soybean based blends. Catsimpoolas and Meyer (1970) reported that the gelling ability of soybean occurred in the globulin fraction. Sathe and Salunkhe (1981), however, showed that gelation is not only a function of quantity of protein but the type of protein as well as non-protein components. There was no difference in the least gelation concentrations of soybean-based blends while a decrease in least gelation concentration was observed for cowpea with malted maize. This result indicated that the amylase in malted maize would have interacted with the starch in cowpea. Pawar and Ingle (1988) observed a similar result, whereby least gelation concentration increased in germinated moth bean flours.

The zero foam capacity observed is similar to those observed with heat-treated flours by other authors (Kinsella, 1976; Padmashree et al., 1987; Richest et al., 1974) probably due to denatured protein. Richest et al. reported that mild heat treatment causes surface denaturation of proteins and results in better foaming properties. The zero foam stability observed in the present study is attributed to complete denaturation of protein during extrusion cooking. Prinyawatkul, McWatters, Beuchat and Phillips (1997) also observed that heating eliminated foamability of cowpea. Denaturation has been reported to decrease protein solubility, which in turn decreased foam capacity (Abbey & Ibeh, 1988; Enwere & Ngoddy, 1986; Giami, 1993; Prinyawatkul et al., 1997). Foam volume and specific gravity are indices of texture lightness of food products (Prinyawiwatkul et al., 1994).

The higher NSI value exhibited by the blends at alkaline pH is similar to that observed by Wanasindara and Shahidi (1994) on oil seed meals. The minimum of 7–8% NSI observed at pH between 4 and 5, is similar to that reported by Smith and Circle (1972) and Pawar and

Ingle (1988). The lower NSI values observed in this study might be due to the processing of the blends.

The high level of globulin and albumin in soybean-based blends is attributed to higher level of lysine in the blends. Albumin and globulin are soluble in sodium chloride solution and have the highest amounts of lysine, in comparison to other protein fraction. Any increase in percentage distribution would naturally increase its lysine (Nelson, Mertz & Bates, 1965). The decrease in glutelin and the increase in albumin plus globulin in malted-based blends were in agreement with Taylor's (1983) observation on malted sorghum. The glutelin fraction declined by about 15–20% in malted-based blends. This observation was attributed to degradation or hydrolysis of this protein by protease. Protein hydrolyses, due to protease, have been found to occur during the initial 48 h of germination (Duvick, 1961). The high glutelin fraction in the blends shows the extent of maize incorporation. Harvey and Oaks (1974) reported glutelin as one of the major classes of maize protein. The reducing effect of malting on albumin content in the present study is contrary to the observation made by Ruitz and Bressani (1990).

The scores obtained for the sensory attributes show that all the formulated blends were acceptable and indicate that the functional properties of the food ingredients used in the blends were compatible. Compatibility of functional properties of food ingredients when mixed together has been reported to determine their acceptability as food (Hermansson, 1973; Kinsella, 1976).

Small-scale industrialists can exploit maize fortified with soybean or cowpea in the preparation of inexpensive complementary blends using extrusion cooking.

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