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Full Length Research Paper

Production of tofu from blends of soybean (*Glycine max* Merr) and sesame seed (*Sesamum indicum*)

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Tofu was produced from blends of sesame seed (*Sesamum indicum*) and soybean (*Glycine max* Merr) and the quality attributes were assessed. Soybeans and sesame seeds of selected quality were used singly or in blend viz., 100% soybean, soybean:sesame blend at 70:30, 50:50 and 100% sesame. Soybean was soaked, dehulled and parboiled to soften the beans, while sesame seed was soaked overnight. The samples were washed and ground with added water to a milky slurry. The slurry was heated and filtered to obtain milk. Coagulation was done at 70–80°C through use of calcium chloride and the precipitate was pressed. A soft cake-like tofu resulted which were cut into desired size. Tofu samples were subjected to proximate analysis, microbiological examination, anti-nutrient test and sensory tests. The highest protein content obtained from 100% fried sample of soybean tofu (100% FSO) was 30.89% and found to be significantly the same with the protein content of 30.33% for 70% soybean+ 3. 0% sesame (70:30) tofu blend. Total viable count of the tofu samples ranged from 10^2-10^3 cfu/g while *Escherichia coli* were absent. Anti-nutrients were found to reduce with heat treatment; fried samples had lower anti-nutrients than the unfried ones. It was observed that the phytate and alkaloid in sesame tofu were higher than soy tofu. Soybean tofu were higher in calcium (270.66 mg/kg), iron (14.56 mg/kg) and potassium (200.66 mg/kg), while, sesame tofu were higher in magnesium, phosphorus and sodium. Similar to what obtained from the anti-nutrient results, the mineral content of blends produced a good combination. Sensory quality was found to be highest for the product made from 50:50 blend. The interaction between sesame and soybean yielded the best result at 50:50 proportion, followed by 70:30 proportion.

Key words: Soy-sesame blends, tofu, composition, sensory profile.

INTRODUCTION

Production of composite products from local or underutilized crops would be a very useful approach in achieving national food security and poverty alleviation due to low cost of production. Soybeans are considered to be a source of complete protein amongst many others, for vegetarians and for people who want to reduce the amount of meat they eat (Kulkarni, 2004). Soymilk and tofu are important traditional soy foods made from whole soybeans. Soy foods are high in protein and vitamins, but low in calories, carbohydrates, fats and they contain omega-3 fatty acids, devoid of cholesterol, easily digestible and wonderfully versatile in the kitchen, which positions them as irresistible new food staples for the evolving spectrum of health diets. Soybeans contain phytoestrogens like isoflavones, genistein that have been implicated in the prevention of certain cancers (Anderson and Wolf, 1995; Anderson et al., 1995, 1999). Isoflavones are closely related to the antioxidant flavonoids.

Sesame seed is an underutilized legume, rich in oil (48-58% fat), protein (16.96%) and carbohydrates (26.04%). The dietary fibre content is also high that is (16.9%). The sesame seeds are exceptionally rich in iron, magnesium, manganese, copper, calcium and contains thiamine and

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tocopherol (Bedigian, 2003). Sesame seeds contain lignans, that includes sesamin, which exerts antioxidant and anticancer properties. Sesame seeds also contain phytosterols that are reported to reduce the levels of blood cholesterol (Obiajunwa et al., 2005).

Raw sesame and soybean seeds contain anti-nutrients such as phytate and oxalate usually found in the seed hulls which can adversely affect mineral bioavailability in human nutrition. However, previous researches have shown that processing methods such as soaking, cooking, fermentation and germination can drastically reduce the anti-nutrients (Brandon et al., 1991; Ene-Obong and Obizoba, 1996). In addition, cooking or dry heating destroys the trypsin inhibitor present in soybeans. Heat treatment increases the digestibility of the protein and enhances the nutritional quality of soybeans (American Soybean Association, 2000).

Tofu in Asian cuisines is highly nutritious, protein-rich, cheese analog delicious food made from soybean milk. It is a cheap source of protein which is readily available and affordable for common man as compared to animal protein. The production of tofu from soybean has been reported by several workers (Lim et al., 1990; Murphy et al., 1997; Moizuddin et al., 1999; Kong et al., 2008). To provide the global population with a source of protein other than meat is a worldwide challenge. Sesame seed is deficient in lysine but rich in sulphur amino acids such as methionine and cystine which makes it an appropriate supplement to diets that contain soybean that tends to be deficient in sulphur amino acids (Elkafi et al., 1991). This work is aimed at enhancing the utilization and diversification of underutilized legume. Therefore, the study was planned to prepare tofu from blend of soybean and sesame seeds and study its proximate composition, anti-nutrient constituent and the acceptability of the product.

MATERIALS AND METHODS

The materials used were soybean, sesame seeds, hydrated analytical grade potassium aluminium sulfate (potassium alum) used as coagulant, pepper, refined soybean oil and salt which were purchased from a local market in Akure, Nigeria. All other chemicals used were of analytical grade.

Tofu was produced using the modified method of Kong et al. (2008). Soybeans and sesame seeds of selected quality was blended at various proportions viz. soybean: sesame – 100:0, 70:30, 50:50 and 0:100. Soybean and sesame seeds were soaked overnight and dehulled. The treated beans/seeds were washed and ground with added water to a milky slurry in a steel mill (Chang-Seng Mechanical Co., Taoyuan, Taiwan). The slurry was then heated to boiling temperature and filtered through muslin cloth to separate soymilk. The coagulation of protein was done at 70-80℃ by adding 1.3 g of potash alum dissolved in 10 ml of water. This was poured into soymilk, sesame-milk and soy-sesame milk respectively. After adding the coagulant, the mixture was agitated and then set aside for 10-15 min to complete the coagulation. The precipitate was collected in a muslin cloth and subsequently pressed using iron blocks (improvised mechanized press) for about an hour and the final moisture content was 70-76%. Finally, a soft, cake-like tofu resulted which was then cut into desired sizes (rectangular pieces), approximately 3.2 × 3.2 × 1.6 cm. Samples were divided in two parts; one portion was subjected to frying in deep oil while the other was left unfried. Refined soybean oil purchased from the local market was heated at 180 ± 5°C and used for frying until tofu attained brownish colour. They were then stored in an air tight container in the freezer for further studies.

Proximate composition

The tofu samples (fried and unfried) were analyzed for moisture, protein, fat, carbohydrate, fibre and ash in triplicate using standard methods (AOAC, 2000).

Firmness determination

The unfried samples were analyzed for their firmness by filling a tin of 200 ml with each of the sample to the brim and the firmness determined using the penetrometer (Tech Mech Scientific Instrument Corroration, India).

Microbiological analysis

Fried and unfried samples of tofu were examined for viable counts of bacteria, yeast and mould and *Escherichia coli* using Plate count agar, Potato Dextrose agar and Eosin Methylene Blue agar respectively using pour plate technique. Serial dilutions were performed using saline solution (0.85% NaCl) and 0.1 ml of 10^2 and 10^3 dilutions was added to each agar plates. The plates were incubated at 37 and 28℃ for bacteria and fungi resp ectively. The number of colonies counted on plates was calculated considering the dilution factor (American Public Health Association, 1984).

Anti-nutrients

Determination of phytate

The phytate content was determined following modified method of Chitravadivu et al. (2009). Four grams of the blended samples were soaked in 100 ml of 2% HCl for 3 h and then filtered. A sample size of 25 ml of the filtrate was placed in a 100 ml conical flask and 5 ml of 0.03% NH_4SCN solution was added as indicator. A volume of 50 ml of distilled water was added to provide proper acidity. This was titrated with ferric chloride solution which contained about 0.005 mg of Fe per ml of $FeCl_3$, the equivalent was obtained and from this, the phytate content was calculated and expressed in mg/100 g.

Determination of oxalate content

1 g of the blended samples was weighed into a 100 ml conical flask. An aliquot of 75 ml of 1.5 N H_2SO_4 was added and the solution was carefully stirred intermittently with magnetic stirrer for about 1 h and filtered through Whatman No. 1 filter paper. A volume of 25 ml of sample filtrate was collected and titrated hot (80-90℃) against 0.1 N $KMnO_4$ solution (Day and Underwood, 1986).

Mineral content

Macro and micro-minerals were analyzed from solutions obtained by first ashing the samples at 525℃ and dissolving in volumetric flasks using distilled, de-ionized water with a few drops of concentrated hydrochloric acid. Sodium and potassium were

Table 1. Proximate composition of tofu based on soybean, sesame and its blend (%).

Samples	Moisture	Fat	Protein	Carbohydrate	Ash	Fibre
USO	43.56±3.88^{e}	34.33±4.04^{a}	15.75 ±1.05^{c}	1.92±0.46^{cd}	3.40±0.77^{bc}	1.03±0.11^{de}
FSO	28.95±5.07^{cd}	30.56±5.09^{ab}	20.89±0.26^{f}	1.98±0.01^{cd}	1.75±0.26^{a}	0.86±0.20^{cd}
USE	31.66±5.31^{a}	63.03±5.13^{e}	8.52±0.10^{a}	1.42±0.08^{ab}	2.25±0.13^{ab}	0.37±0.57^{a}
FSE	21.20±2.71^{bc}	75.67±2.74^{d}	10.85±0.00^{b}	1.38±0.19^{a}	3.23±0.10a^{bc}	0.27±0.51^{a}
USS(70:30)	29.07±4.90^{cd}	45.20±5.01^{c}	17.94±0.26^{d}	2.28±0.25^{d}	4.77±1.54^{d}	0.73±0.57^{bc}
FSS(70:30)	18.76±6.37^{ab}	43.33±5.77^{bc}	30.33±1.45^{f}	1.81±0.20^{bc}	4.60±0.36^{cd}	1.17±0.30^{e}
USS(50:50)	31.21±2.11^{d}	47.33±2.51^{c}	16.69±0.52^{c}	2.34±0.24^{d}	1.85±0.71^{a}	0.57±0.51^{ab}
FSS(50:50)	18.38±5.62^{ab}	56.67±5.77^{d}	20.49±0.17^{e}	1.91±0.43^{cd}	2.02±1.16^{ab}	0.50±0.17^{ab}

Values in each column with different superscript are significantly different ($p<0.05$),100%USO = unfried 100% soybean tofu, 100%FSO = fried 100% soybean tofu, 100%USE = unfried 100% sesame tofu, 100%FSE = fried 100% sesame tofu, 70:30USS = unfried 70% soybean+30% sesame tofu, 70:30FSS = fried 70% soybean + 30% sesame tofu, 50:50USS = unfried 50% soybean + 50% sesame tofu, 50:50FSS = fried 50% soybean + 50% sesame tofu.

determined using a flame photometer (Corning, UK, Model 405), phosphorus was determined colorimetrically using a Spectronic 20 (Model 372 Gallen Kamp, UK) as described by Pearson (1976). All other minerals were determined using atomic absorption spectrophotometer (PYE Unicom, UK, Model SP9).

Sensory evaluation

Sensory evaluation of tofu (both fried and unfried, of varying ratios of blending soybean and sesame seed) was carried out using 9-point hedonic scales (where 9 = extremely desirable, 5 = averagely desirable, and 1 = extremely undesirable). The unfried sample was brought out from the refrigerator and warm in microwave before serving and both fried and unfried samples were served warm. Twenty one panelists were drawn from the community of Federal University of Technology Akure to cut across social and economic groups. Samples were rated for mouth feel, taste, aroma, colour and overall acceptability (Ifesan et al., 2009).

Statistical analysis

Data were subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan's multiple range test (Steel and Torrie, 1980). Statistical analysis was performed using the Statistical Package for Social Sciences package. All experiments were determined in triplicates and means ± SD were calculated from triplicate determinations.

RESULTS AND DISCUSSION

The yield from 900 g of each raw material (soybean, sesame or soy-sesame) include: 100% soybean (428.6 g of tofu), 70% soybean:30% sesame blend (468.7 g of tofu blend), 50% soybean:50% sesame blend (458.1 g of tofu blend) and 100% sesame (320.8 g of tofu).

Table 1 shows the proximate composition of tofu obtained from soybean, sesame or their blend. The highest protein content associated with fried soybean tofu (FSO) (30.89%) was at par with the protein content (30.33%) of tofu made from soybean:sesame (70:30) blend (USS70:30). The protein content of tofu made from soybean is higher than that made from sesame due to greater protein content of soybean. Amongst the tofu, fried sesame tofu (FSE) had the highest fat content (75.67%), followed by unfried sesame tofu (USE – 63.03% fat) and fried soybean tofu (34.33% fat). It has been reported that coagulation conditions, including mixing speed and time, and coagulant concentration, greatly influence tofu yield and quality (Shih et al., 1997; Cai and Chang, 1998). A proper combination of propeller blade size, mixing time, and coagulant concentration was needed to produce tofu with optimal protein recovery and yield (Cai and Chang, 1998). The fat content of tofu was found to increase as the proportion of sesame increased in the blend with soybean (Godin and Spensley, 1971). The moisture content (18.38%) was least for fried 50% soybean+50% sesame (50:50FSS) sesame tofu sesame tofu and highest for soybean tofu (43.56%). However, moisture content of fried tofu made using soybean:sesame (70:30) blend that is (18.76% moisture) and soybean:sesame (50:50) blend that is (18.35%) were found to be at par with each other. Previous research reported moisture content ranged from 5.7-13.3% for freeze dried tofu prepared from soybean (Kong et al., 2008). The low moisture content of tofu prepared from bean-seed blends may provide them superior shelf life as compared to exclusively soybean tofu. The fibre (1.17%) and ash (4.77%) content of the tofu made from bean-seed blend (70:30) was higher than those of soybean and sesame tofu.

There was significant difference in the firmness of the tofu made from soybean, sesame or their blends (Table 2). Sesame tofu was the softest (32.74 mm); the firmness was greater for soybean:sesame (70:30) tofu sample (15.72 mm), followed by soybean:sesame (50:50) tofu (8.70 unit). Higher fat content of tofu makes the protein link weaker, entrapping more water making them softer (Poysa and Woodrow, 2002). Large coagulates formed in the coagulating process were positively correlated with hard tofu; that is, the larger the protein granules in the network, the harder the tofu that would be obtained (Saio,

Table 2. Degree of softness soybean, sesame and soy-sesame tofu.

Tofu obtained from	Hardness (mm)
Soybean	13.39^{b}
Soybean:Sesame (70:30)	15.72^{c}
Soybean:Sesame (50:50)	8.70^{a}
Sesame	32.74^{d}

Values with different superscript are significantly different ($p<0.05$).

Table 3. Microbial quality of tofu obtained from soybean, sesame and their blend (cfu/g).

Samples	Total plate count	Fungi	*Escherichia coli*
Unfried Soybean tofu	1.0×10^3	2.0×10^3	NG
Fried Soybean tofu	1.2×10^2	NG	NG
Unfried Sesame tofu	3.4×10^3	1104	NG
Fried Sesame tofu	2.0×10^2	NG	NG
Unfried tofu (soybean:sesame; 70:30)	1.5×10^3	NG	NG
Fried tofu (soybean:sesame; 70:30)	4.0×10^2	NG	NG
Unfried tofu (soybean:sesame; 50:60)	8.0×10^3	1.0×10^4	NG
Fried tofu (soybean:sesame; 50:50)	1.9×10^2	NG	NG

NG - No growth.

1979). The texture of soft tofu preferred is coherent, smooth, and firm; hard and rubbery is not desirable (Poysa and Woodrow, 2002) (Table 3).

Escherichia coli was not observed in any of the tofu samples indicative of adherence of strict hygienic practices in the production process. The total viable count of the tofu samples ranged from 10^2-10^3 cfu/g. However, yeast and mould were observed only in unfried samples of tofu. The result revealed that the fried tofu samples had lower microbial count compared to the unfried tofu. It was observed that the phytate content (32.52 mg/100 g) of and oxalate content (5.53 mg/100 g) of unfried sesame tofu was higher than that of unfried soybean tofu. Hence, as the proportion of sesame in the soybean-sesame blend increased, the concentration of these two anti-nutrients also increased (Table 4). The phytate of soybean used for tofu production is reported to get hydrolyzed when stored for 10 months at relative humidity of 55% and temperature of 50℃ thus contributing to the increased titratable acidity (Hou and Chang, 2003). The phytate content of the tofu made from bean-seed blends were much lower than those reported for some underutilized legumes such as pigeon pea (Oboh, 2006). The least values of the two anti-nutrients associated with the fried tofu samples confirmed that heat treatment reduced the content of such anti-nutrients (Brandon et al., 1991; Ene-Obong and Obizoba, 1996).

Comparing the control tofu samples (tofu exclusively from soybean or sesame), soybean tofu had higher calcium (270.66 mg/kg), iron (14.56 mg/kg) and potassium (200.66 mg/kg) than those of sesame tofu that is, (260.33, 7.70 and 81.66 mg/kg respectively) (Table 5). However, sesame tofu had higher magnesium, phosphorus and sodium than soybean tofu. The mineral content of blends produced a good combination as the mineral contents of the blends were average values of the mineral content of sesame-tofu and soy-tofu. The calcium content for the sesame based tofu was lower than that reported by Obiajunwa et al. (2005) whereas the values for calcium of soybean tofu were greater than that reported by Preeti et al. (2008). The observed differences in values may be due to the difference in the purity and concentration of the coagulant used, and the variety of soybean or sesame seed used in the experimentation.

The result of the sensory evaluation of the tofu from soy-sesame blend revealed that there was no significant difference in the colour of fried or unfried soybean tofu and the fried soybean:sesame (50:50) tofu (Table 6). Furthermore, there was no significant difference between the color of fried and unfried tofu from soybean:seame (70:30) and the unfried tofu from soybean:sesame (50:50) which suggests that tofu colour is not affected by the inclusion of sesame solids. The result showed that there was a significant difference with regard to taste for all the samples. All the fried samples scored significantly higher than the unfried counterparts implying that frying enhanced the acceptability of the products. Responses of the panelist to aroma and mouth feel of the tofu followed the same pattern. With regard to aroma, soy tofu (score

Table 4. Anti-nutrient content of Tofu obtained from soybean, sesame and its blend (mg/100 g).

Samples	Phytate content	Oxalate content
Uunfried Soybean tofu	14.01[a]	0.99[a]
Fried Soybean tofu	12.91[b]	0.84[b]
Unfried Sesame tofu	32.52[f]	5.53[g]
Fried Sesame tofu	31.31[h]	3.69[f]
Unfried tofu (Soybean:Sesame; 70:30)	32.93[g]	0.59[c]
Fried tofu (Soybean:Sesame; 70:30)	18.13[c]	0.50[h]
Unfried tofu (Soybean:Sesame; 50:50)	26.92[e]	3.36[e]
Fried tofu (Soybean:Sesame; 50:50)	25.54[d]	2.12[d]

Figures in each column with different superscripts are significantly different (P<0.05).

Table 5. Mineral composition of soybean, sesame and soy-sesame blend tofu (mg/kg).

Samples	Ca	Fe	Mg	P	K	Na
100%USO	270.66±0.58[g]	14.56±0.01[g]	279.66±0.58[b]	701.00±0.00[c]	200.66±0.58[g]	2.33±0.58[a]
100%FSO	267.66±1.53[f]	14.00±0.01[f]	278.00±0.00[a]	700.33±0.58[c]	189.66±0.58[f]	3.03±0.01[b]
100%USE	267±0.00[f]	7.81±0.00[b]	345.33±0.58[g]	768.00±0.00[g]	84.33±1.15[b]	32.01±0.01[e]
100%FSE	260.33±0.58[e]	7.70±0.01[a]	340.33±0.58[f]	764.66±0.58[f]	81.66±0.58[a]	33.01±0.01[f]
70:30USS	185.00±0.00[b]	11.50±0.01[c]	296.00±0.00[e]	687.66±0.58[b]	101.00±0.00[c]	26.03±0.01[c]
70:30FSS	181.66±1.54[a]	11.51±0.00[c]	295.33±0.58[e]	684.33±1.15[a]	100.33±0.58[c]	26.26±0.01[c]
50:50USS	203.66±0.58[d]	12.88±0.02[d]	287.66±0.58[d]	705.66±0.58[e]	108.33±0.58[d]	28.06±0.01[d]
50:50FSS	200.66±0.58[c]	13.07±0.06[e]	285.33±1.15[a]	703.66±0.58[d]	110.33±0.58[e]	28.00±0.00[d]

Values in each column with different superscript are significantly different (p<0.05), 100%USO= unfried 100% soybean tofu, 100%FSO = fried 100% soybean tofu, 100%USE = unfried 100% sesame tofu, 100%FSE = fried 100% sesame tofu, 70:30USS = unfried 70% soybean + 30% sesame tofu, 70:30FSS = fried 70% soybean + 30% sesame tofu, 50:50USS = unfried 50% soybean + 50% sesame tofu, 50:50FSS = fried 50% soybean + 50% sesame tofu.

Table 6. Sensory quality of soybean, sesame and soy-sesame tofu.

Samples	Colour	Taste	Aroma	Mouthfeel	Overall acceptability
100%USO	6.33±1.72[ab]	5.93±1.83[bcd]	6.26±1.33[b]	6.60±1.84[c]	6.13±1.80[bc]
100%FSO	6.53±1.96[ab]	6.80±1.95[d]	6.46±0.91[b]	6.40±1.54[c]	6.86±1.12[c]
100%USE	5.26±1.83[a]	3.60±2.06[a]	3.86±2.28[a]	3.66±2.28[a]	3.93±2.28[a]
100%FSE	5.26±1.90[a]	4.53±2.09[ab]	5.20±2.36[ab]	4.40±2.47[ab]	4.86±2.38[ab]
70:30USS	6.86±1.30[b]	5.00±1.96[abc]	5.00±2.07[ab]	5.26±1.70[bc]	5.33±1.58[b]
70:30FSS	6.66±1.39[b]	5.33±1.67[bc]	6.13±1.55[b]	5.53±1.76[bc]	5.73±1.33[bc]
50:50USS	6.86±1.45[b]	5.13±2.19[bc]	5.73±2.01[b]	5.33±1.83[bc]	5.73±1.79[bc]
50:50FSS	6.20±1.30[ab]	6.13±1.82[cd]	6.13±2.03[b]	6.33±1.44[c]	6.13±1.88[bc]

Values in each column with different superscript are significantly different (p<0.05),100%USO = unfried 100% soybean tofu, 100%FSO = fried 100% soybean tofu, 100%USE = unfried 100% sesame tofu100%FSE = fried 100% sesame tofu, 70:30USS = unfried 70% soybean + 30% sesame tofu, 70:30FSS = fried 70% soybean + 30% sesame tofu, 50:50USS = unfried 50% soybean + 50% sesame tofu, 50:50FSS = fried 50% soybean + 50% sesame tofu.

of 6.46 to 6.26) were preferred over sesame tofu (score of 5.2 to 3.86), however, the tofu made from blends (score of 5.0 to 6.13) had intermediate values. The fried and unfried soybean tofu had the highest score for overall acceptability, followed by the fried tofu obtained from blends, while the fried and unfried sesame tofu had the least overall acceptability. This may be due to the greater softness of sesame tofu compared to soybean tofu and the superior flavor profile for soybean tofu. Amongst the tofu made from soybean:sesame blends, the sensory qualities was highest for the fried tofu from 50:50 blend, followed by sensory score for tofu made from 70:30

blend (Table 6).

Conclusions

Producing tofu from blend of soybean and sesame seeds can be a novel means of creating awareness for food crops that are being underutilized. The high protein content in the resultant tofu can help in providing cheaper source of nutrient for tiding over protein malnutrition. Fried tofu blend 50:50 (sesame:soybean) and 70:30 (soybean:sesame) blend would be preferred considering the response of the taste panel. Improvement in taste, flavour and product quality can be attempted by incorporating spices in order to make soy-sesame based tofu more acceptable.

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