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Original Research

Chemical and sensory evaluation of tofu from soymilk using salting-out methods

Authors:
Chikwendu JN,
Edeh RI and
Okoye EI

Institution:
Department of Home Science, Nutrition and Dietetics, University of Nigeria, Nsukka, Nigeria.

Corresponding author:
Edeh RI

ABSTRACT:

This study assessed the effect of various locally used coagulants on the proximate and micronutrient composition of tofu drink. The result of the study revealed that alum coagulated tofu had significantly higher moisture (3.32%), ash (5.33%), carbohydrates (31.16%), calcium (164.76 mg), potassium (1301.50 mg), zinc (57.29 mg), sodium (13.18 mg), phosphorus (1285.20 mg) and magnesium (1452.10mg) than those of the other coagulants. Whereas *Zamioculcas zamiifolia* coagulated tofu had significantly higher fat (19.35%), crude fiber (2.31%) and vitamin A (38.24 mg RE), calcium chloride coagulated tofu had significantly higher content of protein (44.74%), iron (16.17 mg) and thiamine (2.08 mg). These results suggested that coagulants modulated the nutrient compositions of the tofu produced though the tofu variants were high in macro and micronutrients irrespective of the coagulants. Out of all the locally used coagulants for tofu production, alum appeared to be the most promising in improving the nutrient content, sensory qualities and had similar general acceptability to the other variants. Alum coagulated tofu can therefore be a good vehicle for alleviating malnutrition among the vulnerable groups.

Keywords:

Composition, Sensory, Evaluation, Tofu, Soymilk, Salting-out, Coagulants.

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INTRODUCTION

Soybean is produced extensively in Nigeria which has a very high protein content (Ene-Obong and Carnovale, 1992). Over the time, people have become aware of the potentials of soybean and continued to make efforts to exploit these potentials (Onuoha, 1994). Soybean seeds have a favourable amino acid profile, 15% fibre and 15% sugars (Messina *et al*., 1994). There are also very high sources of complete protein, oil, energy, fat, thiamin, niacin, folic acid and riboflavin (Lui *et al*., 2000). Soy protein and oil make up about 60% of the total composition of soybean while carbohydrates comprise about one-third of the whole soybean composition (Enwere, 1998).

Soybean contains about 32% of carbohydrates which varies with the environment and variety (Enwere, 1998). It occupies an intermediate position between low fat legumes and oil seeds containing more protein than most legumes and less oil than oil seeds (Enwere, 1998). It is widely consumed as a part of main dishes, breakfast foods, weaning and convalescent diets (Enwere, 1998). Soybean contains about 40% protein and 20% oil which is 85% unsaturated, containing 24% oleic, 54% linoleic and 8% linolenic acids (Enwere, 1998; Catherine *et al*., 2005). Soybean oil is high in essential fats and fat soluble vitamin E which it retains at a high level even after processing. It also contains phospholipids and can be refined to produce lecithin (Eitenmiller, 1997). It has about 40% protein content which is considerably higher than that of other legumes and animal products such as fresh meat, milk and eggs (Ikeme, 1990).

It is also a good source of calcium and iron (UNICEF, 1990). Raw soybean seed contains 18.3 mg of calcium, 541 mg of phosphorus and 6.1 mg of iron (FAO, 1995). Soybean has an inherent nutritive value that can fight malnutrition and is used at the household level for the preparation of various dishes (Ihekoronye and Ngoddy, 1985).

The essential amino acids in soybean are equal to or exceed the levels found in egg protein except for the sulphur-containing amino acids (methionine and cysteine) (Ihekoronye and Ngoddy, 1985). Soybean is a low-caloric, low carbohydrate food that possesses the ability to decrease fat storage, increase fat cell metabolism and preserve lean muscle mass. Consumption of plant proteins like soy protein often results in significant lowering of plasma levels of Low Density Lipoproteins (LDL) and total cholesterol levels, thus reducing the risk of cardiovascular diseases (Friedman and Brandon, 2001). This explains the use of soy protein (a lean protein) in weight loss programs and in the treatment of obesity (Friedman and Brandon, 2001; Iwe, 2003). Soybean vitamin may assume a very decisive role in the maintenance of health when the seeds are consumed in the form of protein rich supplements to basal diet that might be deficient in vitamins as well as proteins (Iwe, 2003).

The total lipid content of soybean is about 18-23% with about 88.1% being new trial lipids while 9.8% and 16% are phospholipids and glycolipids respectively. The lipids are characterized by a relatively high content of unsaturated fatty acids, mainly oleic and linoleic acid (Iwe, 2003). Soybean saponins seem to be of considerable nutritional significance. They were reported to have hypocholesterolaemic effect on the blood and liver cholesterol levels of rats which was attributed to a complexation of the saponin with cholesterol and bile acid, which decreases their absorption from the intestine (Iwe, 2003). Soy protein has proved to be beneficial in lowering blood cholesterol in animals including man (Ene-Obong, 2001).

Defatted soybean flakes contain about 11.6% total soybean sugar made up of 5% sucrose, 1.1% raffinose, 3.8% stachyose, glucose, fructose, galactose, rhamnose arabinos, glucuronic acid and verbascose (pentasaccharide) (Orthoefer, 1978). Apart from its nutritional benefits, soybean is a concentrated source of phytochemicals that reduce the risk of certain diseases like cancer (Martin *et al*., 2010).

Different coagulants play important roles in the production of tofu from soymilk. Each coagulant produces tofu with different textural and flavour properties (Poysa and Woodrow, 2001). There is therefore a need to determine the chemical and sensory attributes of different tofus produced with coagulants inorder to add nutritional and sensory values to the products. This work is an attempt on dietary diversification using the processing of soybean to improve on the nutrient and sensory potentials of the product in order to ensure that it can be used as a reliable vehicle to combat malnutrition especially among vulnerable groups.

MATERIALS AND METHODS

Material procurement

Dry, market grade soybeans (Glycine max) seeds were obtained from the Ogige market, Nsukka, Enugu State. Alum and calcium chloride coagulants were purchased from the Altran International Company, Nsukka while *Zamioculcas zamiifolia* seeds were purchased from Makurdi local market in Benue state, Nigeria. The materials were stored at room temperature before tofu processing.

Sample preparation

The soybean seeds were sorted by hand-picking to remove spoiled seeds, sticks, stones, stalks and other dirts. They were further cleaned to remove dusts, grease and other contaminants that stuck to the seeds. The seeds were soaked in six-times their volume of deionised water for eight hours at room temperature with an intermittent change of the water every two hours. The soaked seeds were boiled for 45 min at 75^{o}C. The seeds were subsequently dehulled by rubbing between the palms and subsequently on the ground with water in the ratio of 3:1 (water : beans). The resultant paste was filtered through a muslin cloth to get the soymilk used for the study.

Preparation of tofu using different coagulants (salting out)

The soy milk was already prepared and boiled for a further 20 min at 95-100^{o}C. Two liters of the soymilk was cooled and kept at 70^{o}C in a water bath was mixed with 250 ml of the *Z. zamiifolia* extract (coagulant) with slow stirring until the soy protein began to curdle. The set up was left to stand for 10 min before the supernatant (whey) was decanted and sieved with a metal sieve lined using cheese cloth. The curd was pressed with a 1 kg weight and placed on the top for 30-45 min until draining gets stopped. The prepared soy and tofu were subjected to chemical analysis. The same process was employed for the production and analysis of alum and calcium chloride coagulated tofus.

Organoleptic evaluation

Twenty panelists were chosen based on a previous experience participated in the sensory evaluation of the samples. The organoleptic evaluation was conducted in the morning to avoid subjective evaluation due to the loss of appetite or hunger. The test samples and control which were presented at a warm temperature were coded appropriately with the panelists blinded to what samples the codes represented. The panelists each had a cup of water to rinse their mouths after each assessment to avoid bias. Their independent assessments were recorded using a validated nine-point hedonic scoring form. The highest level of acceptability on this hedonic scoring form was assigned nine while the least was one.

Chemical analysis

Proximate analysis- Moisture determination: The moisture content of the samples was determined by the hot air oven method (Pearson, 1976).

Crude protein determination: This was done using the microkjeldahl method (Pearson, 1976).

Crude fibre determination: The Weende method was

Table 1. Proximate composition of soymilk and tofu samples (%)

S. No	Sample	Moisture	Protein	Fat	Fibre	Ash	CHO
1	Soymilk	89.19±2.10	2.09±0.00	1.17±0.00	Trace	0.44±0.00	6.41±0.00
2	Tofu A	3.30±0.05^{b}	41.65±0.50^{b}	19.35±0.01^{a}	2.31±0.03^{a}	5.05±0.05^{b}	28.33±0.00^{b}
3	Tofu B	3.32±0.01^{a}	39.54±0.35^{c}	12.33±0.47^{c}	2.10±0.01^{b}	5.33±0.02^{a}	31.16±1.03^{a}
4	Tofu C	2.84±0.06^{c}	44.74±0.71^{a}	15.60±0.60^{b}	1.25±0.07^{c}	4.87±0.06^{c}	29.58±1.37^{b}

Mean ± SEM of 3 determinations; Values with different superscripts in the same column are significantly different (P<0.05); Tofu A: *Z. zamiifolia* coagulated tofu; Tofu B: Alum coagulated tofu; Tofu C: Calcium Chloride coagulated tofu; CHO: Carbohydrates.

used for the determination of crude fiber (Pearson, 1976).

Carbohydrate determination: This was done by the difference method (Pearson, 1976).

Fat determination: This was done using the soxhlet extraction method (AOAC, 2005).

Ash determination: The ash content of the samples were determined using the method of AOAC (2005).

Mineral determination - Determination of calcium, magnesium and sodium: Calcium, magnesium and sodium contents of the samples were determined using the methods described by AOAC (2005).

Determination of zinc and iron: The iron and zinc content of the samples were determined using atomic absorption spectrophotometry described by AOAC (2005).

Statistical Analysis

The data were analyzed using mean and standard deviation. Means were separated and compared using one way analysis of variance and Duncan's studentised multiple range tests respectively to establish if there were significant differences between the samples.

RESULTS

The results of the proximate analysis shown in Table 1 indicated that tofu C had the highest protein content (44.74%) significantly higher than the other samples while tofu B had the lowest protein content (39.54%). Tofu A had the highest fat content which is significantly higher when compared to the other samples while tofu B had the lowest fat content.

Tofu B had the highest Ash content which is significantly higher than the other samples while tofu C had the lowest ash content. Tofu B had the highest carbohydrate composition which is significantly higher than the other samples. Tofu C had the lowest carbohydrates there was no significant difference.

Tofu A has the highest content of fiber which is significantly higher when compared to the other samples. Tofu C had the lowest fiber content. The results of the mineral composition of tofu shown in Table 2 indicated a significant difference in the Na content of the tofus. Tofu B had the highest sodium content and is significantly higher than in sodium content than the other samples. Tofu C differed significantly in its sodium content when compared to tofu A which had the lowest sodium content.

Tofu B had the highest potassium content which is significantly higher when compared to the other samples. Tofu A differed significantly in its potassium content when compared to tofu B which had the lowest

Table 2. Mineral composition (mg/100g) of tofu samples

S. No	Sample	N	K	Ca	P	Fe	Zn	Mg
2	Tofu A	11.19±0.01^{c}	1120.50±0.71^{b}	160.50±0.71^{b}	74.24±0.36^{b}	14.27±0.01^{c}	28.00±0.00^{c}	856.35±0.21^{c}
3	Tofu B	13.18±0.25^{a}	1301.50±0.71^{a}	164.76±1.41^{a}	1285.20±0.01^{a}	15.37±0.01^{b}	57.29±0.02^{a}	1452.10±0.01^{a}
4	Tofu C	12.88±0.23^{b}	864.50±0.71^{c}	160.36±0.52^{b}	959.54±0.08^{c}	16.17±0.06^{a}	44.21±0.01^{b}	1183.60±0.64^{b}

Mean ± SEM of 3 determinations; Values with different superscripts in the same column are significantly different (P<0.05); Tofu A: *Z. zamiifolia* coagulated tofu; Tofu B: Alum coagulated tofu; Tofu C: Calcium Chloride coagulated tofu.

Table 3. Vitamin composition of tofu samples

S. No	Samples	Vitamin A (mgRE)	Vitamin B_1 (mg)
1	Tofu A	38.24±0.06^a	1.96±0.04^b
2	Tofu B	35.28±0.04^b	1.83±0.01^c
3	Tofu C	34.79±0.01^c	2.08±0.02^a

Mean ± SEM of 3 determinations; Values with different superscripts in the same column are significantly different (P<0.05); Tofu A: *Z. zamiifolia* coagulated tofu; Tofu B: Alum coagulated tofu; Tofu C: Calcium Chloride coagulated tofu.

potassium content. Tofu B had the highest calcium content which is significantly higher than those of the other samples. Tofu B had the highest amount of phosphorus and is significantly higher in phosphorus content when compared to the other samples. Tofu A differed significantly in phosphorus content when compared to tofu B which had the lowest phosphorus content.

Tofu C has the highest amount of iron and is significantly higher when compared to the other samples. Tofu A differed significantly in its Potassium content when compared to tofu B which has the lowest potassium content.

Tofu B has the highest amount of zinc and is significantly higher when compared to the other samples. Tofu C differed significantly in its zinc content when compared to tofu A which has the lowest zinc content. Tofu B has the highest level of Magnesium which is significantly higher when compared to the other samples. Tofu A had the lowest Magnesium content. The results of vitamin analysis were shown in Table 3. From the results, there are significant differences in the vitamin A content of the sample. Tofu A has the highest content and is significantly higher when compared to the other tofu samples. Tofu B differed significantly in its vitamin A content when compared to tofu C which has the lowest vitamin A content. The significant differences in their vitamin content could be as a result of the different coagulant used in its preparation.

In Tofu C, there was a significant difference in the sense that it has the highest amount of vitamin B1 content when compared to other tofu samples. Tofu A differed significantly in its vitamin B1 when compared to tofu B which has the lowest vitamin B1 content. The results of the sensory evaluation of tofus shown in Table 4 indicates significant differences in the sensory qualities of the samples. Tofu B had a significantly better taste and flavour when compared to the other tofu samples. Tofu B had a significantly better colour than others while tofu A had significantly better texture.

DISCUSSION

The Moisture content of tofu samples ranged between 2.84% and 3.32%. The difference in the moisture of tofu prepared with various coagulants was likely because of the varieties in gel network inside the tofu particles which is known to be impacted by various anions and its ionic strength towards the water holding capacity of soy gel (Obatolu, 2008). It might likewise be because of the remarkable coagulating properties of the coagulants utilized. The low moisture content of samples B and C is important as it would increase the shelf life of the products and enhance their storability since spoilage is favored by water activity.

The values reported for protein (39.54-44.74%) reflect the high protein content of soybeans, which makes it useful in combating protein energy malnutrition, especially in the rural communities of the

Table 4. Sensory evaluation of tofu samples

S. No	Samples	Taste	Colour	Texture	Flavour	General acceptability
1	Tofu A	4.35±0.07^b	4.49±0.02^a	5.25±0.07^a	3.26±0.08^a	4.50±0.28^a
2	Tofu B	5.15±0.07^a	6.25±0.07^b	3.27±0.09^b	3.35±0.07^a	4.30±0.30^b
3	Tofu C	4.46±0.08^b	4.80±0.01^a	3.18±0.04^b	2.49±0.02^b	4.21±0.16^a

Mean ± SEM of 3 determinations; Values with different superscripts in the same column are significantly different (P<0.05); Tofu A: *Z. zamiifolia* coagulated tofu; Tofu B: Alum coagulated tofu; Tofu C: Calcium Chloride coagulated tofu.

developing countries. This is expected as soybean is notable to contain significant amount of protein which has a high biological value with excellent amino acid composition comparable to the animal protein except for its lack of methionine.

From the study, there were significant differences in the protein content of the three samples. This could be as a result of the different coagulants used in their preparation. The high quality of protein in tofu explains its incorporation as animal-protein substitute in vegetarian diets. The high protein content of *Z. zamiifolia* coagulated tofu could possibly be attributed to the likelihood that the protein content of the *Z. zamiifolia* extract might have been transferred into the tofu unlike alum coagulated tofu. Alum is a pure salt, without any protein content. It could also be speculated that the acidic medium created by the *Z. zamiifolia* coagulated tofu created a better coagulating environment for the protein present in the soymilk than the salts. Furthermore, the protein content of all the tofu was higher than that of some commonly consumed tropical plant foods and vegetables in Nigeria (Akindahunsi and Oboh, 1999).

The fat content of *Z. zamiifolia* coagulated tofu (19.35%), was significantly higher than that of alum (12.33%) and calcium chloride (15.60%) coagulated tofu. This could be as a result of the binding of some of the fat in the heterogeneous solution of *Z. zamiifolia* coagulated tofu by the coagulated milk protein. The fat content of the tofu produced by the various coagulants were generally high when compared with some commonly consumed plant foods in Nigeria (Akindahunsi and Oboh, 1999).

The ash content of the different tofu samples in this research (4.87-5.53%) was lower than 5.64-5.76% and 5.2-7.9% as recorded in prior investigations (Obatolu, 2008; Shih *et al*., 2002). These variations might be because of contrasts in the processing techniques and additionally soybean varities utilized. Tofu coagulated with alum had the most elevated ash content and might be richest in micronutrients. The different modulating impacts notable in the values of the proximate parameters is an impression of the distinctive coagulants utilized.

The carbohydrates content of the tofu samples was very high ranging between 28.33 and 31.16%. This high carbohydrate content of the finished products may be as a result of an equally high carbohydrates value of the sweeteners (starch and sugar) used.

Fibres are plant based food components made of lignins, cellulose, hemicelluloses, pectin, gum and mucilage; which remain undigested on entering the human large intestine. They are useful in the management of diseases such as obesity, diabetes, cancer and gastrointestinal disorders (Ene-Obong, 2001). The fibre content of the tofu samples (1.25-2.31 %) is also good, similar to the value of 1.8% reported for cassava by the Institute for Medicine but lower than 4.0% and 5.3% reported by the U.S. Department of Agriculture for raw sweet potatoes and raw yam respectively (Trumbo *et al*., 2002; ARS, 2005).

Mineral composition of tofu samples produced using three different coagulants

The mineral composition of all the tofus were generally high when compared with some commonly consumed plant foods in Nigeria. Potassium, calcium, phosphorus, zinc and sodium content of the tofu produced using alum coagulant was significantly higher ($P<0.05$) than the one produced using the other two coagulants. Nonetheless, calcium chloride coagulated tofu had elevated magnesium content. The minerals were commonly higher than those of some ordinarily devoured plant foods in Nigeria, for example, edible wild seeds, cassava items, cultivated and wild yams and green leafy vegetables (Akindahunsi, and Oboh, 1999). The high mineral substance in the tofus could be credited to the conceivable solubility of a portion of the salt of those minerals in the whey amid tofu production, in this way keeping the trapping of the mineral in the protein grid of the tofu. The significant differences in mineral content between the tofu samples could be because of the diverse coagulant utilized.

Organoleptic evaluation of tofu samples

The result of the sensory evaluation shown in Table 4 revealed that all the tofus were generally well accepted. The texture was significantly not different (P<0.05) from those of the other coagulants used except tofu B which has a lower textural quality (3.32%). This can be explained by the fact that people especially the eastern part of Nigeria are not used to the product. Relative to colour, the tofu B made from Alum was liked-slightly (6.25%) compared to other products that were disliked- slightly. The preference in the colour was probably because of the whiteness of the alum. The general acceptability of the tofu samples was influenced by the organoleptic attributes of the taste, texture and colour. It was not surprising that the whole sample was poorly accepted, this could be because the panelists were not familiar with the organoleptic properties of the products.

CONCLUSION

Based on the results, the tofus had a better nutrient content than soymilk especially the alum coagulated tofu which had better nutrient and sensory attributes than the other coagulants and was also well accepted by people. Therefore, it could serve as a ready vehicle in addressing malnutrition in the population.

RECOMMENDATION

Further studies are recommended to ascertain the safety of the tofus produced as well as the bioavailability of their nutrient content to consumers. There is also a need to improve the sensory quality of the tofu produced using this locally source coagulant without compromising nutritional quality.

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