Nutrient and Sensory Properties of Tofu Coagulated with Tamarind

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ABSTRACT

Background: *Tofu is an inexpensive, nutritious, healthy meat or cheese substitute with bland taste and porous texture made from soybean. This study was designed to determine the nutrient composition and sensory properties of tofu coagulated with tamarind exposed to different heat treatments.*

Methods: *Soybean was soaked overnight, washed, milled and filtered to obtain the milk, which was boiled, coagulated with tamarind and exposed to following cooking methods. The samples were subjected to chemical analysis as using procedures described mainly by AOAC. The sensory attributes were assessed using a nine point hedonic scale and compared with the control (deep fried chicken).*

Result*: Cooking reduced the moisture content of fresh tofu from 82.47 to 20.49% but increased other nutrient contents - crude protein (8.02% to 10.72%), fat (4.74% to 14.47%), ash (0.97% to 2.76%), crude fiber (0.91% to 1.11%), carbohydrate (3.67% to 59.70%) and energy/calorie (89.39kcal/100g in to 378.50kcal/100g). Mineral contents such as calcium (105.23-101.85mg/100g), iron (8.71 to 6.90mg/100g), magnesium (108.03 to 98.84mg/100g), potassium (69.90 to 60.58 mg/100g) and sodium (3.10 to 2.66mg/100g) decreased upon heating. Baked and fried samples had lower phytate (0.52-0.65mg/100g), oxalate (0.43-0.54mg/100g), tannin (0.71-0.86mg/100g) and saponin (0.32-0.47mg/100g) contents. The sensory evaluation showed that microwaved tofu (ex) was highly rated.*

Conclusion:

Cooking increased the macronutrient but decreased the moisture, mineral and nutrient contents of tofu. Micro-waved products averagely had higher nutrient composition and sensory properties. The low fat/calorie and sodium, and good protein levels of this coagulated tofu makes it a healthier alternative for non-communicable diseases prevention/management.

Keywords: Tofu, Nutrient, anti-nutrient, mineral properties, tamarind.

Received: 28-06-2022
Accepted: 03-02-2023
doi: https://dx.doi.org/10.4314/njns.v44i1.10

INTRODUCTION

Tofu also called bean curd is a product of soybean which is made by coagulating soy milk and pressing the resulting curds into soft white blocks (1). It has a subtle flavor and can be used in sweet and savory dishes. Tofu is an important source of protein which has helped in no small way in combating the challenges of malnutrition in developing countries (2).

Soybean (*Glycine max*) according to the United States Soyfoods Directory (3) is a nutritious legume that has been used as food as far back as the ancient times, it is relatively cheap and readily available most part of the year. It is a specie of legume that is native to East Asia and is widely grown for its edible bean which has numerous uses. Soybean is rich in protein, amino acids and minerals with strong resistance to insect/pest attack (4). It also helps to fix atmospheric nitrogen which reduces the need for farmers to purchase fertilizers (5-7). In Nigerian markets, soybeans cost about one fifth as much as other forms of protein including diary and fish, so it is affordable, easy to store and transport(7). There is need for increased advocacy and awareness on the introduction of soy and soy enhanced products in local diets as it represents an affordable alternative to address the increasing burden of hunger and protein energy malnutrition in developing countries (8-10).

Tofu is consumed daily as high protein food in Western cultures. According to Du et al. (11), different countries have variety of ways of using soy bean and tofu. For example, In Malaysia, tofu variety 'douhua' is usually served warm with white/ dark (palm), sugar syrup or served cold with vegetables (preferably longue). In Japan and Korea, tofu is consumed as 'momen-dofu' and 'dandenhan dubu' respectively and because the firmness of this type of tofu is like that of raw meat, it could be arranged in chop stick and served as a snack or dessert (10). Tamarind salt can be used as a coagulant in tofu preparation (12).

Global evidence have shown that soybean production increased between 2000 and 2006 but decline within 2007/2008 (13). This also affected the soybean consumption in Nigeria which stood at 0.28% in 2006 but decline to 0.26% in 2007 (13).

According to United States Soy Center for Excellence(14) , the estimated that protein consumption of Nigerians is equivalent to about one chicken per year and 30 eggs. The gap between supply and demand is forecasted to result in an overall deficit of more than 1.6 million metric tons of soybeans by the year 2030. To close this gap, poultry consumption would need to increase 10-fold, taking demand for soybeans from 1.3 million metric tons to 14 million metric tons. Therefore, the need for increased production, improved access and acceptability of affordable and healthy protein alternatives is strengthened.

Beyond making foods edible for consumption, several studies have confirmed that cooking alters the nutrient and phytochemical composition of foods through an increase in bio-availability or heightened loss of nutrients (15-19). Although, data is available for others foods, there is a dearth of data on the nutrient content of Tofu when exposed to different types of heat treatment. The purpose of this study, therefore is to examine the nutrient, anti-nutrient and sensory properties of tofu coagulated with tamarind exposed to different heat (steaming, baking, frying and microwave) treatments.

MATERIALS AND METHODS

Sample procurement

The soy bean seed and tamarind fruits used for the study was purchased from Ahiaeke market in Umuahia North Local Government Area of Abia State., Nigeria. It was taken to the Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria for identification and there after stored at room temperature before it was processed into tofu.

Methods of tofu preparation

The method used in tofu preparation was as described by Williams (20). The soy bean seeds (4.0 Kg) were winnowed, and washed to remove dirt and dust. It was soaked in cold water (12 liters) overnight or for about (9 hours) at room temperature or between 27°C – 32°C). The water was removed and the soybean was washed. It was ground to obtain the slurry. The soy milk was extracted from the slurry using a muslin cloth (to obtain soybean pulp –indigenously referred to as "Okara"). The water ratio of 6:1 was used for the extraction. The soy bean pulp (okara) was sieved again to extract more of the soy milk remaining. The milk was transferred into a pot and heated on a cooker to about 98°C with constant stirring. It was held at the same temperature for about two minutes. Coagulant (2 liters of water was used to extract the pulp from 500g of tamarind fruit after steeping it in water for six hours prior to scrubbing with hands and sieving as described by 11) was mixed with the milk. This was allowed to solidify to tofu. The tofu was removed from the cooker and put in a muslin cloth, it was further compressed to remove water with a 20kg load for 3 hours until all the water were completely drained.

Two hundred grams (200g) of the fresh tofu was put in a cellophane bag and stored in the refrigerator for laboratory analysis. The remaining tofu was cut into smaller shapes (cubes). Seasonings (20g each of the following: salt, ground pepper, thyme, ginger and garlic) were mixed in 100ml of water to improve the flavor/taste. The mixture was allowed to marinade in the refrigerator for 3hours. The tofu was steamed for 20 minutes, cooled, put in a cellophane bag and stored in the refrigerator for laboratory analysis (ax). The remaining was divided into three parts of 500g each. The first portion was baked (bx) in a preheated moderately warm (160°C or gas mark 3) oven for about 20 minutes until tofu became golden brown. The second part was deep fried (cx) in 150cl moderately hot soy bean oil (for about 20 minutes) until tofu was golden brown while the third part was micro waved (dx) in a moderately hot micro wave oven (ex). Twenty minutes cooking time was adopted for all the samples as reported by Ezenwa et al. (15). Two hundred gram of each sample was packaged in polyethylene bags and stored in the refrigerator for laboratory analysis, while the remaining were cooled, labelled and displayed for sensory evaluation.

Proximate/micronutrient analysis: All chemical analysis were conducted at the National Root Crop Research Institute, Umudike. The tofu samples were analyzed in triplicates for proximate using method described by Association of Official Analytical Chemist (AOAC) (21). The carbohydrate content of the samples was determined using anthrone method (22). The minerals (calcium, magnesium, potassium, sodium and iron) were determined using spectrometric method using Atomic Absorption Spectrophotometer (AAS) as described in AOAC (21).

Sensory evaluation: Sensory evaluation was carried out with a twenty (20) man trained panelist made up of both 10 staff and 10 students of Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike. These trained panelists checked for colour, flavor, taste and over all acceptability. A nine-point Hedonic scale was used for the evaluation with one (1) representing "Dislike extremely", nine (9) representing "Like extremely" and five (5) the mid- point representing "Neither liked nor disliked".

Statistical analysis:
Data were analyzed in triplicates and subjected to analysis of variance (ANOVA) to compare the means. All analysis were done using IBM SPSS version 25. Differences were considered significant at $p<0.05$.

RESULTS
Table 1 showed the proximate composition of the tofu coagulated with tamarind. Results revealed a high moisture content of ax (82.47%) while that of the cooked tofu ranged from 20.49% in cx to 30.28% in bx` . The crude protein content in ax was 8.02% while it was higher when heat was applied. The lowest (9.71%) was recorded in the ex and highest (10.72%) was recorded in the cx. The fat content in fresh tofu was (4.74%) and ranged from 5.17% (in steamed sample) to 14.47% in the fried sample. The ash content of the fresh tofu was 0.97%, it increased to between 1.61% (microwaved) to 2.76% in the steamed sample. The crude fiber content of ax was 0.91%, and it increased to 0.90% (micro waved sample) to 1.11% in the baked sample. The carbohydrate content of the fresh tofu was 3.67%, it increased to between 51.45% in the fried tofu to 59.70% in the baked tofu. The energy value in the fresh tofu was 89.39, while it increased to between 290.10kcal/100 to 378.50kcal/100 in the baked tofu.

Raw soy bean

↓

Sorting / cleaning

↓

Soak in water (overnight or for about 9 hours)

↓

overnight water

↓

Wash soy bean

↓

Grind (to produce slurry)

↓

Extract soy milk

↓

Heat (98° C) and stir constantly for 2 minutes

↓

Add coagulant (by using 2 liters of water to extract the pulp from 500g of tamarind fruit after steeping it in water for six hours prior to scrubbing with hands and sieving)

↓

Allow milk to solidify

↓

Press out excess water

Figure1. Flow Chart for Coagulated Tofu Production

Table 1. Proximate composition of tofu

Tofu	Moisture %	Crude Protein %	Fat %	Ash %	Crude Fiber %	Carbohydrates %	Energy kcal/100g
Fresh (ax)	82.47	8.02	4.74	0.97	0.91	3.67	89.39
Steamed (bx)	30.28	9.87	5.17	2.76	1.03	50.97	290.10
Baked (cx)	20.49	10.72	5.51	2.50	1.11	59.70	331.30
Fried (dx)	20.51	10.62	14.47	1.82	0.96	51.45	378.50
Microwaved (ex)	26.23	9.71	5.40	1.61	0.90	56.15	311.95

Values represent mean of triplicate readings. Values with the same superscript along the same row are not significant different at ($p>0.05$).

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

Tofu	Calcium	Iron	Magnesium	Potassium	Sodium
Fresh (ax)	105.23	8.71	108.03	69.90	3.10
Steamed (bx)	104.54	8.02	107.34	69.23	3.01
Baked (cx)	104.07	6.90	100.92	65.80	2.80
Fried (dx)	101.85	6.73	98.84	60.58	2.66
Micro-waved (ex)	104.83	7.70	105.75	68.48	2.93

Values represent mean of triplicate readings. Values with the same superscript along the same row are not significant different at ($p>0.05$).

Table 3. Anti-nutrient factors of Tofu

Tofu	Phytate	Oxalate	Tannin	Saponin	Phenol
Fresh (ax)	0.94	0.72	1.47	0.64	1.01
Steamed (bx)	0.70	0.63	1.35	0.64	0.89
Baked (cx)	0.65	0.54	0.86	0.32	1.64
Fried (dx)	0.52	0.43	0.71	0.47	1.52
Micro-waved (ex)	0.81	0.65	1.31	0.54	0.78

Values represent mean of triplicate readings. Values with the same superscript along the same row are not significant different at ($p>0.05$).

Table 4. Mean scores for the sensory evaluation of samples

Tofu	Colour	Taste	Aroma	Texture	General Acceptability
Steamed (bx)	$4.50^{c} \pm 2.48$	$3.85^{c} \pm 2.13$	$4.25^{c} \pm 2.17$	$4.95^{c} \pm 2.84$	$3.85^{c} \pm 2.91$
Baked (cx)	$6.50^{b} \pm 1.73$	$6.40^{b} \pm 1.79$	$6.20^{b} \pm 1.82$	$6.50^{b} \pm 1.93$	$6.00^{b} \pm 1.62$
Fried (dx)	$6.95^{b} \pm 1.15$	$6.15^{b} \pm 1.67$	$5.95^{b} \pm 1.79$	$6.60^{b} \pm 1.50$	$6.25^{b} \pm 2.02$
Micro-waved (ex)	$6.40^{b} \pm 1.64$	$5.53^{b} \pm 1.76$	$7.70^{a} \pm 1.17$	$6.65^{b} \pm 1.79$	$6.35^{b} \pm 2.25$
Control (fx)	$8.40^{a} \pm 0.82$	$8.45^{a} \pm 0.76$	$8.25^{a} \pm 1.02$	$8.40^{a} \pm 0.99$	$8.40^{a} \pm 0.68$

Values represent mean of triplicate readings. Values with the same superscript along the same row are not significant different at ($p>0.05$).

Table 2 presents the mineral composition of tofu. Cooking decreased the mineral content of the fresh tofu. Calcium (105.23mg/100g) and Iron (8.71mg/100g) decreased to between 101.85mg/100g – 104.83mg/100g and 6.73mg/100g – 8.71mg/100g in the cooked samples respectively. Fresh tofu had a magnesium content of 108.03mg/100g while the cooked samples ranged from 98.84mg/100g in dx to 107.34mg/100g in bx. The potassium (69.90mg/100g) and sodium (3.10mg/100g) content of fresh tofu decreased to between 60.58mg/100g – 69.23mg/100g and 2.66mg/100g -3.01mg/100g respectively in the cooked samples.

The anti-nutrient composition of tofu is shown in table 3, the phytate and oxalate (0.94mg/100g and 0.72mg/100g) composition in the fresh samples decreased to between 0.65mg/100g – 0.81mg/100g and 0.43mg/100g - 0.65/mg/100g respectively in the cooked samples. Fresh tofu had a tannin content of 1.47mg/100g which decreased to between 0.71mg/100g and 1.35mg/100g in dx and bx respectively. Saponin in ax was 0.64mg/100g, but decreased to between 0.32mg/100g to 0.60mg/100g in the cx and bx respectively. The phenol content in ax was 1.01mg/100g, but it decreased to 0.78mg/100g and 0.89mg/100g in ex and bx respectively and increased slightly to 1.52mg/100g and 1.64mg/100g in dx and cx respectively.

Information on the sensory evaluation of the samples is summarized in table 4. The result on colour showed that the control fx (deep fried chicken) 8.20 was preferred than all the cooked tofu samples. The cx and dx samples were moderately liked while bx was neither liked nor disliked. There is no significant difference at $p \leq 0.05$ between the baked, fried and microwaved tofu samples but a significant difference was observed between the control and the cooked tofu samples.

Results showed that in taste cx and dx were liked slightly and fx was liked extremely while the bx was disliked slightly. There is no significant difference at $p \leq 0.05$ between cx, dx and ex samples but a significant difference was observed between the control (fx) and all the cooked tofu samples.

The result on the panel acceptance of the aroma of tofu showed that microwaved (ex) was the most preferred of the cooked samples. It was liked very much (7.70), while cx and dx were liked slightly but the control (fx) was liked very much. There is no significant difference a $p \leq 0.05$ between the microwaved tofu and the control but a significant difference was observed between the control and the other cooked samples of tofu.

In texture, results showed that ex was the most preferred by the panelist, ex, dx and ex were all liked moderately while the control (fx) was liked very much bx was neither liked nor disliked. There is a significant difference at $p \leq 0.05$ between fx and all the cooked tofu samples

In general acceptability, the most preferred ex. The cx, dx and ex were all liked slightly. The bx was disliked slightly while fx was liked very much. There is a significant difference at $p \leq 0,05$ between the fx and all the cooked tofu samples but no significant difference between cx, dx and ex.

DISCUSSION

Fresh tofu had the highest (82.47%) moisture content whereas the lowest value (20.49%) was obtained in baked tofu. The high moisture content was greater than 68.6% and 62% reported in previous studies (15,23). This could be as a result of the different coagulant (Epsom salt) or variety of soybean (flour) used in those studies. The lowest moisture content obtained in baked tofu corroborate with the report of Arepally et al.(24) which revealed that moisture removal takes place first during baking in order for the structure and texture of the product to be formed. The moisture content range of 20.49 % – 30.28% observed in the present study was higher than the moisture content range of 13.6% - 14.58% obtained in tofu processed from fluted pumpkin seeds (25). Ayo-Omogie and Odekunle, (26) opined that food products with moisture less than 13% are stable from moisture-dependent deterioration.

The crude protein content of the tofu sample ranged from 8.02% in the fresh tofu to 10.73% in the baked tofu. The range was higher than 4.57% - 7.18% obtained in fresh undried, fried, fried air dried and sun dried soybean tofu (27) but lower than the crude protein content (32.10% - 39.00%) of soybean produced using various types of coagulant (28) in other studies. The disparity in crude protein of these tofu samples could be because they were exposed to different types of heat treatment and different types of coagulants were also used in processing them respectively. The high value of crude protein obtained in baked tofu could be attributed to the report of Onyeike et al. (29) that dry heating causes a significant increase in crude protein.

The fat content of tofu in the present study ranged from 4.74% in the fresh sample to 14.47% in the fried sample. The range was higher than 1.80% - 2.20% reported in (23) which may have been as a result of the different treatments given to the products. This suggested that cooking particularly frying caused increase in the fat content of the product. Ezeama and Dobson, (15) previously attributed it to the soybean oil used in the frying. Fats are source of essential fatty acids required for the body fat synthesis, and serve as vehicles for the absorption of fat soluble vitamins and other precursors (25). However the range of 4.74% - 14.74% is lower than ≤ 25% upheld by Talabi et al. (30) that might lead to food rancidity.

The ash content of the fresh tofu was 0.97% which increased to between 1.61% in the microwaved to 2.76% in the steamed tofu. This compares well with the range of 1.55% - 2.41% reported by Ezenwa et al. (15). This could be attributed to the similarity in the treatment and cooking methods employed in the two studies. Ash content is a reflection of important mineral component of a food which confers numerous nutritive benefits (31).

The crude fiber (0.91%) increased to 0.96%, 1.03% and 1.11% in the cooked (fried, steamed and baked) tofu respectively. This is higher than the range (6.93% - 6.95%) reported by previous studies (24, 32). This may be as a result of the disparity in ingredients used in the studies. Crude fiber not only adds bulk to stool but also aids in bowel movement and contributes to prevention of metabolic and digestive disorders (33).

The carbohydrate content of the fresh tofu was 3.67%, this increased to between 50.97% in the steamed to 59.70% in the baked tofu. It was higher than the range of 1.81% - 2.34% and 17.00% - 26.00%) reported in previous studies (23, 32). The differences observed could be because of the different treatments used in the production. The highest value obtained in baked tofu could probably be that baking process resulted to change in the chemical structure of tofu which enhanced its carbohydrate content as opined by Arepally et al. (24). This makes tofu a veritable tool in combating Protein-Energy Malnutrition (PEM), because the abundant carbohydrate in it will provide energy and help to spare protein.

The energy value of tofu samples ranged from 89.39kcal/100g in the fresh to 378.50kcal/100g in the fried samples. This was however lower than the highest energy value of 4104.00kcal/100g reported by Adeyeye et al. (34). This could be as a result of the different methods used in preparing the samples. The highest energy value observed in the fried tofu could be as a result of the high fat content in line with the assertion by previous studies that foods with high fat and carbohydrate content has high energy value (35, 36).

The calcium content of the fresh tofu was 105.23mg/100g which decreased from 104.83mg/100g in ex to 101.85mg/100g in dx. The range was higher than 4.22mg/100 to 11.03mg/100g reported in (23). This could be because of the coagulants (tamarind) used in the present study and (lime, Epsom salt and tamarind used in the previously reported study. The high calcium content obtained in the study makes tofu coagulated with tamarind a veritable ingredient necessary for bone and teeth health, nerve function as well as in contracting of the muscles and encouraging blood clotting (30).

The Iron content of fresh tofu (8.71mg/100g) decreased to the range of 7.7mg/100g in micro waved to 6.73mg/100g in fried tofu. The range was lower than 11.50mg/100g to 13.07mg/100g reported in Ifesan and Oguntoyinbo (25) but higher than 0.49mg/100g to 1.70mg/100g reported in Yakubu and Amuzat (21). The differences could be attributed to the different coagulants and treatments given to the tofu used in the different studies. The presence of iron in tofu will help it play an essential role in haemoglobin formation, central nervous system functioning and macronutrient oxidation (37).

The magnesium value in fresh tofu was 108.03mg/100g. It also decreased from 107.34mg/100g in steamed tofu to 98.84mg/100mg in the fried tofu. Etiosa et al. (38), had earlier reported that soya bean contain a substantial amount (258.24mg/100g) of magnesium. However the decrease observed conforms to the WHO (39) assertion that the nutritive value of food altered by heat treatment.

Potassium content (69.90mg/100g) of the fresh tofu decreased to 69.23mg/100g when steamed and further to 60.58mg/100 when fried. The range was higher than 1.75mg/100g to 3.42mg/100g reported in Ezeama and Dobson, (2019). The high potassium content of tofu coagulated with tamarind will make it beneficial when consumed as it is essential for the normal functioning of the heart and skeletal muscles as well as for enzyme reactions (38).

The sodium content of fresh tofu was 3.10mg/100g, which also decreased to 3.01mg/100g when steamed and further to 2.66mg/100g when fried. WHO (39) recommends that adults should consume less than 5g or preferably 2g (2000mg) of salt daily and the United States Dietary Guideline Committee (40) advised a much lower intake of 1500mg (1.5g) per day. They also opined that any food or food products that contain 140mg/100g of sodium or less are considered as low sodium foods and are suitable for individuals with conditions that required reduced sodium intake (41).

The presence of anti-nutrients in this study corroborates with Grases et al. (42) that oil seeds possess anti nutrients. Phytate, oxalate, tannins binds and interfers with nutrient absorption/bio-availability (36, 37, 43, 44). However, it was observed that cooking led to the decrease in most of the anti-nutrient properties of the tofu samples. Similarly, Ifesan and Oguntoyinbo (32) affirmed that cooking and other forms of heat treatment decrease anti-nutrient properties of foods. Also, the anti-nutrients were within the standard safe levels (45).

Micro waved tofu had better sensory properties (in terms of aroma, texture and general acceptability) while the fried tofu was preferred in colour and the baked tofu was preferred in taste. This compares well with an earlier study (13, 15).

CONCLUSION

The moisture, micro-nutrient and anti-nutrient content of fresh coagulated tofu decreased during cooking, while the energy and macro-nutrient contents increased significantly. Steamed and microwaved products had overall higher nutrient and also anti-nutrient composition. Microwaved products recorded the highest sensory attributes amongst the test samples.

RECOMMENDATIONS

The consumption of tofu should be encouraged because of its high nutrient composition and several health benefits associated with it. Food industries should find ways of processing and packaging tofu in order to make them more convenient and appealing comparable with the control.

The low fat/calorie, low sodium and optimum protein levels of this coagulated tofu makes it a healthier and affordable alternative for the prevention and management of non-communicable diseases.

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