Chemical Composition and Sensory Properties of Tofu Coagulated with Grape Juice and exposed to different Heat Treatments

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ABSTRACT

Background: *Tofu is a gelatinous food made from soybean with the potentials to offer high protein and micronutrients content depending on the coagulants used in the production.*

Objective: This study aimed to evaluate the chemical composition and sensory properties of tofu coagulated with grape juice and exposed to various heat treatment.

Methods: *In order to obtain the milk, soybean was sorted, winnowed, soaked in clean water overnight. It was thereafter rinsed, dehulled, milled and filtered. The milk was boiled, coagulated with grape juice, and then subjected to several heat treatments. Nutrient and anti-nutrient properties were analysed using standard methods. Sensory evaluation was also done and the result obtained compared with the control (deep-fried chicken).*

Result: *Processing reduced moisture content from 64.84% in fresh Tofu (FRT) to 21.79% in baked Tofu (BDT). Protein, fiber, ash and carbohydrate increased from 16.46%, 0.32%, 1.17% and 14.45% in fresh tofu to 18.65%, 1.20%, 2.29% and 52.68% in baked tofu respectively. Steamed tofu had the highest mineral composition which ranged from 4.06mg/100g in sodium to 121.85mg/100g in magnesium as well as the highest anti-nutrient levels (0.28-1.33mg/100g). Fried tofu was the most preferred of all the tofu samples.*

Conclusion: *Processing reduced the moisture, mineral and the anti-nutrient properties of tofu but increased the other nutrients including protein which makes it a healthier alternative to combat protein energy malnutrition and curb non-communicable disease risk due to its low sodium content.*

Keywords: *Tofu, nutrient composition, mineral content, anti-nutrient properties, Grape juice.*

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INTRODUCTION

Tofu is a gelatinous food made from soybean seeds that is high in protein, isoflavones, vitamins, minerals, and other elements. It is consumed by people in both developing and developed countries. It has a range of textures from soft to firm and extra-firm which is a healthy, natural, affordable food (1). Tofu has a high nutrient content, and can be produced locally and commercially (2,3).

The nine essential amino acids (4) are all present in tofu, making it a significant source of protein. It also contains a comparatively high amount of lipids, vitamins, minerals, and isoflavones. Research has it that Tofu is extremely low in calories, gluten-free and cholesterol-free. Over 18% and 33% of the daily protein and iron requirements can be met by a single serving of tofu (4). Moreover, it contains soy peptides that have antioxidant and anti-inflammatory characteristics that can help shield blood vessels from oxidative and inflammatory damage (1).

Soybean (Glycine max L.), one of the most widely cultivated plant in the world, is used to make tofu. Food and Agriculture Organisation (5) named it the most significant legume of modern agriculture. Several bioactive substances found in soybean seeds, including oligosaccharides, globulin proteins (glycinin, beta-conglycinin), two antioxidants, isoflavones (genistein, daidzen, glycitein), phytosterols (sitosterol, sitostanol, campesterol), and phyto-estrogen, are of great benefit to humans (6). Soy products have been thoroughly studied for their potential to prevent and treat chronic diseases, they have also been shown to lower the risk of non-communicable diseases (7). Since soybean has a higher caloric density than other beans due to its high fat content (20% of the dry weight), it can more easily help meet dietary needs for both essential fatty acids, including omega-3 alpha-linolenic acid and omega-6 linoleic acid, which together make up about 7.9% and 54.4% of the total fat content, respectively (8). According to Fasiha *et.al* (9), consumption of 25g of soybeans per day can boost high-density lipoprotein and decreased low-density lipoprotein while improving cholesterol levels. This makes the introduction of tofu and other soybean products affordable and a healthier alternative to address the increasing burden of protein energy malnutrition as well as the prevention and management of non -communicable diseases in developing countries (10).

The processing of nutrient-dense and palatable tofu using frying, steaming, baking, and microwaving techniques was demonstrated by (10), as one of the oldest ways of food preparation. Frying method of food has more organoleptic advantages over other food processing techniques. This is as a result of the high temperature and rapid heat transfer that takes place throughout the procedure moreover it is of high sensory properties (11). Processing or reheating food in a microwave oven uses electromagnetic waves. This involves heating up the water molecules or food particles through friction. Baking method removes moisture from food fast thereby establishing the product's structure and texture (12, 13). Baked items have strong flavour and come in a wide variety, including breads, biscuits, cookies, cakes, and pastries (12). Beyond making food edible for consumption, studies (10 - 12) have confirmed that cooking alters the chemical composition of food. Although, data is available for many foods, there is a dearth of data on the chemical content of tofu when it is coagulated with grape juice and exposed to different heat treatments. The purpose of this study, therefore is to examine the chemical composition and sensory properties of tofu coagulated with grape juice and exposed to different heat treatments.

MATERIALS AND METHODS

Materials

Grape fruits and soybean seeds were purchased from Orie Ugba Market in Umuahia North Local Government Area, Abia State.

Sample preparation

Prior to tofu production, grape juice was expressed from 4kg grapes, after they were sorted, washed, cut into two halves and the juice extracted using a juice extractor. It was filtered to remove seeds and pulp. Thereafter, it was weighed and stored to be used as the coagulant (Figure 1). The method described by Williams (13) was adopted for tofu production. Four kilogrammes of soybean was soaked in 12 liters of cold water overnight (9 hours) at room temperature after the seed was winnowed and sorted to eliminate stones, broken seeds, debris and dust. The next day, the water was drained and the soybean seeds washed and rinsed. It was grounded to create a puree (1:5 soybean to water ratio). The soy milk was extracted from the puree using a muslin cloth and sieved in water using 6 :1 ratio of water to soybean puree. The milk was transferred into a pot and heated on a cooker to 98°C with constant stirring. It was held at the same temperature for two minutes. Two liters of grape juice (coagulant) was gradually poured into the milk and allowed to solidify into tofu. It was transferred to a muslin cloth, compressed to remove water with a 20kg load until all the water were completely drained. (Figure 2 showed the flow chart for tofu production).

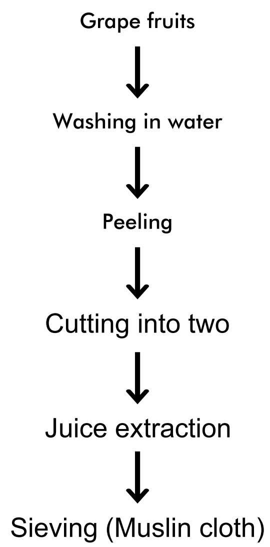

Figure 1: Flow chart for extraction of grape juice

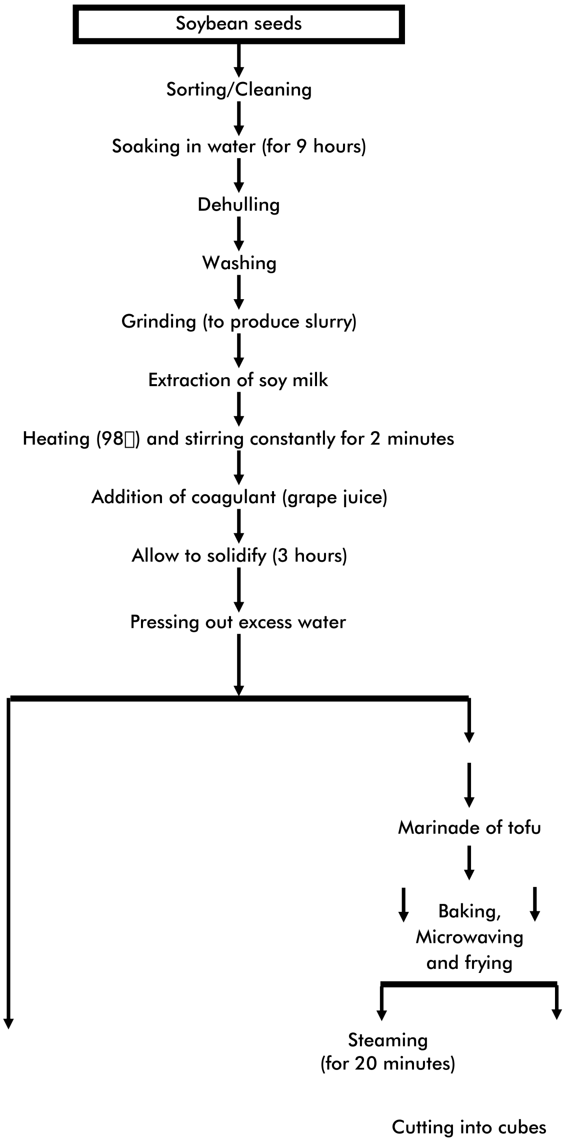

Figure 2: Flow chart for tofu production

The heat treatment was applied using the method described by Ezenwa *et. al* (10). Two hundred grams (200g) of fresh tofu was put in a cellophane bag and stored in the refrigerator for laboratory analysis. Seasoning (20g each of: salt, ground pepper, thyme, ginger and garlic) were mixed in 100ml of water. The remaining tofu was cut into smaller shapes (cubes) and the seasoning was gradually sprinkled on it. The tofu was allowed to marinade in the refrigerator for 3hours. The tofu cubes were steamed for 20 minutes, two hundred grams (200g) was cooled, put in a cellophane bag and stored in the refrigerator for laboratory analysis (STT). The remaining portion was divided into three parts of 400g each. The first portion was baked (BDT) in a preheated moderately warm oven (160°C or gas mark 3) for 20 minutes. The second portion was microwaved (MVT) in a moderately hot microwave oven for 20 minutes, the third portion was deep-fried (FDT) in 150cl of moderately hot soy bean oil for 20 minutes. For laboratory examination, 200g of each sample was wrapped in polyethylene bags and kept chilled. The remaining samples were cooled, labelled, and put on display for sensory evaluation.

Sensory evaluation: A twenty (20-man) trained panelist made up of staff and students from the College of Applied Food Sciences and Tourism at Michael Okpara University of Agriculture, Umudike, participated in the sensory evaluation. The processed tofu (STT, BDT, FDT, MVT) and the control (FCT) were each arranged and labelled in a clean plate. These were evaluated by the trained panelists for colour, flavor, taste and over all acceptability. Water was provided for mouth rinsing in-between evaluations. 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".

Laboratory analysis: The tofu samples were analyzed in triplicates. The method described by AOAC (14) was used to determine the proximate. The carbohydrate content was determined using anthrone method as described by Leitoyi (15). The minerals (calcium, magnesium, potassium, sodium and iron) were determined "using Atomic Absorption Spectrophotometer (AAS) as described by AOAC (14). The anti-nutrient (phytate, tannin, saponin, and oxalate) contents were assessed using the technique outlined by AOAC (14)"

Statistical analysis: The mean of the 20 responses was obtained and the data subjected to analysis of variance (ANOVA) to compare the means using the statistical Package for Social Sciences (SPSS), version 25. Differences were considered significant at $p<0.05$.

RESULTS

Proximate composition of tofu coagulated with grape juice

Table 1 showed the proximate composition of the tofu coagulated with grape juice. Results revealed a moisture content of 64.84% in fresh tofu (FRT) while that of the processed tofu ranged from 21.79% in the baked (BDT) tofu to 37.55% in steamed (STT) tofu. The crude protein content in FRT was 16.46% while it increased when heat was applied. The lowest was recorded in the FRT and highest (18.65%) was recorded in BDT. The fat content of fresh tofu was 2.72% and ranged from 3.45% in STT to 13.66% in FDT. The ash content of the fresh tofu was 1.17%, and increased to between 1.93% in FDT to 2.9% in

BDT. The crude fiber content of FRT was 0.32%, and ranged from 0.94% in MVT to 1.20% in BDT. The carbohydrate content of the FRT was 14.49%, it increased to between 44.02% FDT to 52.68% in BDT. The energy value in the FRT was 148.19kcal, while it increased to between 315.79kcal/100g in BDT to 367kcal/100g in FDT.

Mineral components of tofu coagulated with grape juice (mg/100g)

Table 2 shows the mineral composition of the tofu coagulated with grape juice. Processing decreased the calcium and iron content of tofu from 110.49mg/100g to 108.22mg/100g, and 3.86mg/100mg to 2.89mg/100g respectively.However, the iron content of microwaved tofu increased from 3.86mg/100g to 4.03mg/100g.

Fresh tofu had a magnesium content of 122.14mg/100g while the processed samples decreased to 119.95mg/100g in FDT. The potassium (58.58mg/100g) and sodium (4.21mg/100g) content of fresh tofu decreased to 56.85mg/100g and 2.88mg/100g respectively in the processed samples.

Table 1. Proximate composition of tofu coagulated with grape juice.

Samples Code	Moisture content (%)	Crude Protein (%)	Fat (%)	Crude Fiber (%)	Ash (%)	Carbohydrate (%)	Energy value (Kcal/100g)
Fresh (FRT)	64.84	16.46	2.72	0.32	1.17	14.49	148.19
Steamed (STT)	37.55	17.08	3.45	0.89	1.74	39.29	256.44
Baked (BDT)	21.79	18.65	3.39	1.20	2.29	52.68	315.79
Fried (FDT)	22.49	18.36	13.66	1.11	1.93	42.45	367.01
Microwaved (MVT)	31.70	17.65	3.85	0.94	1.83	44.03	281.33

Values represent mean of triplicate readings.

Table 2. Mineral components of (tofu mg/100g) coagulated with grape juice.

Samples Code	Calcium (mg/100g)	Magnesium (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)	Iron (mg/100g)
Fresh Tofu (FRT)	110.49	122.14	58.58	4.21	3.86
Steamed Tofu (STT)	109.70	121.85	57.90	4.06	3.76
Baked Tofu (BDT)	108.93	120.48	56.85	3.40	3.48
Fried Tofu (FDT)	108.22	119.95	55.91	2.88	2.89
Microwaved (MVT)	109.27	121.33	57.49	3.83	4.03

Values represent mean of triplicate readings.

Table 3 Anti-nutrient content of tofu coagulated with grape juice

Samples Code	Tannin (mg/100g)	Saponin (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)
Safe limits (*37)	3 mg/100g	3 mg/100g	2 - 3 mg/100g	3 mg/100g
Fresh Tofu (FDT)	1.56	0.86	0.95	0.35
Steamed Tofu (STT)	1.33	0.74	0.84	0.28
Baked Tofu (BDT)	0.63	0.43	0.72	0.11
Fried Tofu (FDT)	0.54	0.54	0.56	0.17
Microwaved Tofu (MVT)	0.90	0.65	0.73	0.22

Values represent mean of triplicate readings.

Anti-nutrient content of tofu coagulated with grape juice.

Table 3 shows the anti-nutrient content of tofu. Results showed that Fresh tofu had a tannin content of 1.56 mg/100g which after processing reduced to 0.54 mg/100g - 1.33 mg/100g in Fried and Steamed tofu respectively. Fresh tofu had a saponin content of 0.86 mg/100g which reduced to 0.43 mg/100g in Baked and 0.74 mg/100g in Steamed tofu respectively. The phytate content in Fresh tofu was 0.95 mg/100g but it decreased to 0.56 mg/100g in the Fried and 0.84 mg/100g Steamed samples. Fresh tofu had an oxalate content of 0.35 mg/100g while the processed samples decreased to 0.11 mg/100g in Baked tofu

SENSORY EVALUATION OF SAMPLES

The result of the sensory evaluation is summarized in Table 4, the control was preferred to all the processed tofu samples in terms of colour. The MVT was neither liked nor disliked, STT and BDT samples were liked slightly. A significant difference existed between the control and the tofu samples, but there was no difference between the baked, fried, or microwaved tofu samples at $p < 0.05$.

The taste of FDT and BDT were neither liked nor disliked, whereas FCT was greatly preferred over STT and MVT. The STT, BDT, FDT, and MVT samples did not differ significantly at $p < 0.05$, but the control differed significantly from all the processed tofu.

Sample BDT was the most preferred in terms of texture, STT and FDT were neither liked nor disliked. There was a significant difference between FCT and all of the processed tofu samples at $p < 0.05$.

The flavor of FCT was liked very much by the panelists, while BDT and FDT were neither liked nor disliked. There was no significant difference between all the processed samples at $p < 0.05$.

In general acceptability, FDT was liked slightly, STT, BDT, and MVT were neither liked nor disliked. The FCT and all of the processed tofu samples differed significantly $p < 0.05$.

DISCUSSION

Processing decreased the moisture content of tofu. The effect of dry heat may be responsible for the lowest value observed in the baked tofu. This is consistent with the assertion that moisture elimination occurs fast during baking (16). Earlier research (10) reported that the baking process drastically reduced the moisture content of soybean tofu that had been coagulated with Epsom salt from 60.61% to 21.53%.

The fresh tofu contained 16.46% crude protein, which increased to 17.08% and 18.65% in baked and steamed tofu respectively. Protein is essential for enzyme catalysis, molecular transport and cell regeneration, immune system defence and nerve impulse generation and transmission (17). The availability of protein in meals aids in synthesis and maintenance of lean muscle mass and other body tissues (18).

Processing increased the Crude fibre of tofu. Twinomuhweziet.al (19)had opined that plant fibre is made of the cell walls of plants that contain indigestible carbohydrates like cellulose, hemicellulose, pectin, and lignin. The fact that baked tofu has a low moisture content may be the cause of its high fibre content.

The values of ash found in the present study (1.74% in steamed and 2.29% in baked tofu) were greater than the range of 0.50% to 0.70% reported by Oboh and Omotosho (20), but lower than the 5.80% to 8.80%, 3.93% to 5.75%, and 3.30% to 3.60% reported by Shokunbiet,al. Ojhaet,al, Yakubu and Amuzat(21-23) respectively. Ash content serves as a useful tool for evaluation of minerals content of food (24). The reduced mineral content observed when tofu was processed may be associated with the low ash content observed in the present and previous

Table 4. Mean scores for the sensory evaluation of samples

Samples code	Colour	Taste	Texture	Flavour	General acceptability
Deep fried chicken (FCT)	$8.30±0.86^a$	$8.50±0.76^a$	$7.70±1.22^a$	$8.10±1.12^a$	$8.50±0.83^a$
Steamed Tofu (STT)	$6.70±1.53^b$	$4.05±2.44^c$	$5.40±2.11^b$	$4.10±2.45^b$	$5.00±2.50^b$
Baked Tofu (BDT)	$6.85±1.31^b$	$5.50±1.54^b$	$6.00±2.03^b$	$5.20±2.19^b$	$5.65^b±1.93$
Fried Tofu (FDT)	$7.90±0.97^a$	$5.60±1.98^b$	$5.60±1.98^b$	$5.40±1.98^b$	$6.10^b±2.07$
Microwaved Tofu (MVT)	$5.80±1.44^c$	$4.05±1.79^c$	$4.05±1.79^c$	$4.65±1.98^b$	$5.05^c±1.39$

Values with the same superscript along the same row are not significant different at ($p>0.05$).

(25) studies.

The fat content (3.39% to 13.66%) of tofu in the present study were less than 15.81% to 21.15% reported byOjhaet,al (22). The low fat content may make tofu to store better as opined by Ikujenolaet.al (26) in an earlier study stating that low fat products are less susceptible to rancidity. The samples may, however, be less effective at improving, palatability of food and acting as a viable medium for fat-soluble transport (27).

Processing had a significant impact on the carbohydrate and energy content of tofu, which were higher than (10.80% to 20.24% and 22.60% to 28.26%) and (113.19 -250 Kcal/100g and 140.11 – 270.21Kcal/100g) reported by Shokunbiet,al. and Ojhaet,al(21 and 22) respectively. This could be as a result of the high fat content of the fried tofu. Man require energy foods to cover their basal metabolic rate, energy cost of physical activity as well as in the production of new tissue during growth and pregnancy.

Calcium and iron content of tofu decreased after processing but the values were lower than the range of 101.85mg/100g to 104.83 reported in Ezenwaet.al(28)This could be as a result of the different coagulants (tamarind in the former and grape juice in the present) used in the studies, including the dissolution and leaching of the calcium into the frying medium as reported by Crudwell (29). The iron content (2.89 mg/100g) in fried tofu observed in the present study was lower than the values (6.94mg/100g to 8.41 mg/100g) found in fermented soy-tofu observed in Crudwell (29) and the 13.54 mg/100g found in soy-tofu coagulated with sodium chloride reported in Adeyeye(30) . The different processing methods used in the studies may have been responsible for the variation.

The magnesium content observed in the present study was higher than the 21.02mg/100g to 24.83 mg/100g reported by Crudwell (29). In an earlier study Akpomieet.al (31) had observed that heating can breakdown magnesium more quickly. This may be the reason why fried tofu had a lower (55.91mg/100g) magnesium content. In addition, the decreased potassium content also observed indicated that heating resulted in the degradation of potassium. This is in agreement with the claim by Onwuka (32) that minerals like potassium are heat-liable.

Processing decreased the sodium content of tofu which was lower than the range of 8.31 mg/100g to 9.42 mg/100g reported by Adeyeye (30). The low sodium (2.88 mg/100g) content in fried tofu may be because frying cause sodium to break down and leach into the frying medium as earlier observed by Crudwell (29). The low sodium content observed in this study is good. Given that very high salt level in food products has been found to contribute to hypertension in vulnerable persons and increase calcium loss in urine (33).

Oxalate concentration in tofu decreased during processing with baked tofu having the lowest (0.11 mg/100g) value, which could be attributed to the heat created during baking. This agrees with the findings of Ifesan and Oguntoyinbo (34) that heat generated during processing cause the oxalate content of soybean tofu to decrease. The phytate content also decreased but the results were within the range of 0.4 mg/100 g to 0.84 mg/100 g and 0.57 mg/100 g to 1.75 mg/100 g reported by Shokunbiet,al and Ojhaet,al (21, 22).

Tannins are phenolic compound that have the ability to precipitate proteins (35). The heat produced during the processing procedure may have contributed to the reduced tannin levels in the processed tofu. This is consistent with the assertion made by Abbas and Ahmad (36) that heat processing is a successful technique that is frequently employed to de-activate anti-nutritional components. The tannin content of the tofu processed in this study was lower than the range of 43.26 mg/100g to 125.16 mg/100g reported by Crudwell (29). Moreover, the tannin levels in the heat-treated tofu samples were less than the 3mg/100g recognised fatal dose and within the permissible level for humans (37).

In nature, saponins are widely distributed but are mostly found in oilseeds like soybeans. They are typically thought of as non-volatile, surface active secondary metabolites (38). The high temperature created during baking processes may be the cause of baked tofu's reduced saponin concentration. This supports the idea put forth by Jaichand (39) that the use of heat procedures minimizes the presence of anti-nutrient properties in food. Bloating, poor nutrient absorption, lower liver cholesterol, slowed overall growth, and impaired intestinal absorption of several nutrients are all side effects of consuming foods with high saponins levels (40). This is because saponins adhere to the cells in the small intestine. The saponin level of the processed tofu were within the permissible level for humans as recommended by FAO (37).

Fried tofu had better sensory properties (in terms of colour, texture and general acceptability), fried and baked tofu were preferred in taste and flavor while the steamed and microwaved tofu were the least preferred by the panelists. There was however no significant difference between the baked, fried and micro waved tofu in terms of flavour but a significant difference existed between the processed tofu and the control (deep fried chicken) at $p. > 0.05$

CONCLUSION:

Tofu can be produced by coagulating soymilk with grape juice which is a cheap, local and readily available commodity. Consumption of tofu should be encouraged as it is rich in nutrients and minerals, also, the anti-nutrient contents are within the safe levels making it safe for human consumption. Steamed, fried, baked and microwaved tofu can also serve as a healthy and nutrient-dense snack and it can also be used as a mid-day meal alternative.

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