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Effect of coagulants on the yield, nutrient and anti-nutrient composition of Tofu

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ABSTRACT

The effects of six coagulating agents ($CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$, alum and steep water from a local pap producing industry) on the percentage yield, nutrient, and anti-nutrient composition of tofu samples produced was studied. The percentage yield ranged from 58.69% for tofu coagulated with $CaSO_4$ to 68.15% for tofu coagulated with $MgCl_2$; and were significantly different ($p<0.05$). The tofu had 51.90-62.78% protein, 7.87-15.39% fat, 6.67-9.75% fiber, 5.80-8.80% ash and 10.8-20.24% carbohydrate, on dry weight basis. Results indicated that the six coagulants significantly ($p<0.05$) modulated the various proximate parameters evaluated, with tofu coagulated by $MgSO_4$ yielding the highest contents of protein, fiber and ash. Further analysis revealed phytate (0.41-0.84g/100g), oxalate (0.34-0.73g/100g) and trypsin inhibitor (1.45-2.91 TIU/mg protein) levels in the tofu, on wet weight basis. There was a strong correlation ($r = 0.88$, $p<0.05$) between the phytate and the oxalate concentrations, but a slightly weak correlation ($r = 0.65$, $p<0.05$) between phytate and trypsin inhibitor of the tofu. These results suggest that the coagulants modulated the percentage yield, nutrient and anti-nutrient compositions of tofu produced. The tofus analyzed were high in nutrients, irrespective of the coagulants. However, $MgSO_4$ seems to best potentiate nutrients and minimize anti-nutrients in tofu and thus is most recommended.

Key words: Tofu, Coagulants, Nutrients, Anti-nutrients, Yield.

INTRODUCTION

The human consumption of soy products is increasing, not only because of their high nutritional value but also because of their reported health benefits, such as reduction of cardiovascular disease, osteoporosis, and cancer risks [1, 2, 3]. Tofu, also known as soybean curd, is a soft

cheese-like food made by curdling fresh hot soymilk with a coagulant [4]. Traditionally, it is produced by curdling fresh hot soymilk with either salt ($CaCl_2$ or $CaSO_4$) or an acid (glucuno-δ-lactone). Tofu is low in calories, rich in essential amino acids, contains beneficial amounts of iron and has no saturated fat or cholesterol [5]. For most Nigerians, tofu is receiving attention because it is high in protein and its usage as a substitute for meat. Tofu is often sold as a wet block in rural Nigeria and it is generally made and sold on the same day as it is highly perishable [6].

The yield and quality of tofu have been reported to be influenced by soybean varieties, soybean quality, processing conditions and coagulants [6, 7, 8]. Coagulants have been reported to modulate hypocholesterolemic effect on experimental rats [9]. Furthermore, coagulants have been reported to influence the yield and micronutrient contents of tofu [10]. However, there is a dearth of information on the effect of coagulants on the nutrient and anti-nutrient contents of tofu. This study was therefore carried out to determine the effect of six coagulants on the yield, nutrient and anti-nutrient contents of tofu.

MATERIALS AND METHODS

Materials

Soybeans (*Glycine max)* of tax grain variety were obtained from the Institute of Agricultural Research and Training Ibadan, Nigeria. They were stored at room temperature before tofu processing. The calcium and magnesium salts and alum were industrial grade, while the steep water was collected from a local pap processing industry.

Sample Preparation

500g of raw soybeans was handpicked to remove stones and dirt and then soaked for 6 hours at room temperature using de-ionized water. The soaked soybeans was drained, weighed and ground with a Binatone blender, after which it was sieved using cheese cloth and the shaft separated from the milk. 1 litre of the soy milk was put in each of six labelled (A, B, C, D, E and F) stainless steel containers and heated for 30 minutes at 250^{o}C. Then, 100ml each of the coagulants ($CaCl_2$ (50mM), $CaSO_4$ (50mM), $MgCl_2$ (50mM), $MgSO_4$ (50mM), alum (50mM) and pap steep water) were added and allowed to boil for 20 minutes further. The coagulated soymilk was sieved, pressed (with 1kg load for 3 minutes) and the weight recorded. The tofu produced was stored at 4^{o}C prior to analysis.

Chemical Analysis

Tofu samples were analyzed in triplicates for moisture, protein, lipid, fiber and ash using standard methods of analysis. The chemical composition was estimated according to AOAC [11]: Moisture (AOAC, 967.08); Protein by Kjeldahl (AOAC, 988.05); Fat by Soxhlet (AOAC, 2003.06); Fiber (AOAC, 958.06) and Ashes (AOAC, 942.05). Carbohydrate was estimated by difference. Phytate (AOAC 986.11) and oxalate (AOAC 974.24) were determined according to the standard methods of AOAC [11], where as the trypsin inhibitory activity was determined by the method of Kakade *et al*. [12].

Statistical Analysis

Data were analyzed by one way ANOVA with SPSS version 15.0 and differences were considered to be statistically significant at $p<0.05$. LSD test was further carried out to establish the pairs that showed significant differences.

RESULTS AND DISCUSSION

The percentage yield as modulated by the coagulants is presented in table 1. It varied from 58.69% (for tofu coagulated with $CaSO_4$) to 68.15% (for tofu coagulated with $MgCl_2$). This trend is similar to the report of Shokunbi *et al.* [10]. However, this tofu yield is higher than 7.6–18.3% reported by Oboh [9]. The processing procedure and or the soybean varieties processed might have resulted in this obvious difference.

Table 1: Percentage yield of tofu processed with different coagulants

Coagulants	% Yield
$CaCl_2$	66.25 ± 0.48^{b}
$MgCl_2$	68.15 ± 0.11^{a}
$CaSO_4$	58.69 ± 0.89^{d}
$MgSO_4$	65.95 ± 0.73^{b}
Alum	64.18 ± 0.69^{c}
PSW	60.72 ± 0.94^{d}

Data are expressed as mean ±Standard Deviation (SD), n = 3
Values with different superscript along the same column are significantly different (p<0.05).

The proximate composition of the processed tofu is presented in table 2. The tofu samples had 51.90–62.78% protein, 7.87 –15.39% fat, 6.67–9.75% fiber, 5.80–8.80% ash and 10.80–20.24% carbohydrate, on dry weight basis. The result showed that the various coagulants used tend to modulate the proximate composition of the tofu obtained. $MgSO_4$ significantly increased all the proximate parameters determined, relative to all other coagulants, except for the fat and carbohydrate contents.

Table 2: Proximate composition (g/100g dry weight) of tofu processed with different coagulants

Coagulants	Protein	Fat	Fibre	Ash	Carbohydrate	Moisture#
$CaCl_2$	56.89 ± 0.45^{c}	11.93 ± 0.15^{c}	7.70 ± 0.09^{c}	7.10 ± 0.06^{cd}	16.39 ± 0.09^{b}	68.67 ± 0.03^{d}
$MgCl_2$	58.28 ± 0.68^{c}	8.22 ± 0.07^{b}	7.78 ± 0.10^{c}	7.12 ± 0.12^{bc}	15.12 ± 0.14^{c}	68.32 ± 0.71^{e}
$CaSO_4$	57.22 ± 0.51^{c}	12.28 ± 0.10^{b}	7.60 ± 0.13^{c}	6.88 ± 0.08^{e}	16.03 ± 0.41^{b}	69.13 ± 0.06^{c}
$MgSO_4$	67.31 ± 1.70^{a}	7.87 ± 0.10^{e}	9.75 ± 0.20^{a}	8.80 ± 0.16^{a}	10.80 ± 0.47^{e}	77.93 ± 0.49^{a}
Alum	59.98 ± 0.43^{b}	11.31 ± 0.19^{d}	8.40 ± 0.09^{b}	7.31 ± 0.07^{b}	13.00 ± 0.62^{d}	70.63 ± 0.61^{b}
PSW	56.98 ± 0.56^{c}	11.97 ± 0.08^{c}	7.70 ± 0.08^{c}	6.93 ± 0.09^{de}	16.42 ± 0.43^{b}	67.05 ± 0.04^{f}
AlumLTPI	51.90 ± 0.45^{d}	15.39 ± 0.05^{a}	6.67 ± 0.10^{d}	5.80 ± 0.04^{f}	20.24 ± 0.49^{a}	59.63 ± 0.07^{g}

Data are expressed as mean ±Standard Deviation, n=3
Values with different superscript along the same column are significantly different (p<0.05)
 # - On wet weight basis
PSW - Pap steep water
AlumLTPI- Alum as applied by a Local Tofu Producing Industry

The moisture content of tofu samples varied from 59.63% to 77.93%. The variation in the moisture content of tofu prepared with different coagulants is probably due to the differences in gel network within the tofu particles that is influenced by different anions and its ionic strengths

towards the water holding capacity of soy protein gels [6]. It may also be due to the unique coagulating properties of the coagulants used.

The ash content reported in this work (5.80–8.80%) is slightly higher than the 5.64–5.76%, 3.57–4.24% and 5.2–7.9% reported by Shih *et al.* [13], Bhadwaj *et al*. [14] and Obatolu [6] respectively. These differences may be due to difference in processing procedure as well as soybean varieties processed. This trend will likely be noticed, if the mineral analysis of the samples is evaluated. Tofu coagulated with $MgSO_4$ had the highest ash content, thus might be richest in micronutrients. The various modulating effects notable in the values of the proximate parameters is a reflection of the different coagulants used.

The values reported for protein (51.90–62.71%) reflects the high protein content of soybeans, which makes it useful in combating protein-energy malnutrition, especially in the rural communities of developing countries. This is expected as soybean is notable to contain significant amount of protein that is of high biological value with excellent essential amino acid composition comparable to animal protein except for methionine. The quality of protein in tofu has made it to be incorporated as animal-protein substitute in vegetarian diets. This is the practice at Babcock University, Nigeria, a Seventh-day Adventist Institution of higher learning that strictly presents lacto-ovo vegetarian diets to her resident student population. Students to be admitted are usually pre-informed of this dietary pattern as it is based on the globally practiced Seventh-day Adventist philosophy of education and health principle.

Fibres are plant based food components made of lignins, cellulose, hemicellulose, pectin, gum and mucilage; which remain undigested on entering the human large intestine [15]. They are useful in the management of diseases such as obesity, diabetes, cancer and gastrointestinal disorders [16]. The fiber content of these tofu (6.67–9.75%) is viable enough to support the management of the afore-listed diseases.

Table 3: Anti-nutrient composition of tofu processed with different coagulants

Coagulants	Phytate (g/100gWW)	Oxalate (g/100gWW)	Trypsin Inhibitor (TIU/mg protein WW)
$CaCl_2$	0.70 ± 0.02^{abc}	0.52 ± 0.01^{c}	2.24 ± 0.04^{b}
$MgCl_2$	0.72 ± 0.01^{abc}	0.55 ± 0.04^{c}	1.61 ± 0.03^{d}
$CaSO_4$	0.66 ± 0.03^{abc}	0.44 ± 0.03^{d}	1.86 ± 0.02^{c}
$MgSO_4$	0.41 ± 0.02^{d}	0.34 ± 0.02^{e}	1.45 ± 0.04^{e}
Alum	0.73 ± 0.05^{abc}	0.72 ± 0.01^{ab}	1.91 ± 0.13^{c}
PSW	0.81 ± 0.03^{ab}	0.66 ± 0.03^{b}	1.83 ± 0.02^{c}
AlumLTPI	0.84 ± 0.03^{a}	0.73 ± 0.04^{a}	2.91 ± 0.04^{a}

Data are expressed as mean ± Standard Deviation, n= 3
Values with different superscript along the same column are significantly different ($p<0.05$)
WW- Wet weight
PSW: Pap steep water
AlumLTPI- Alum as applied by a Local Tofu Producing Industry

Oils from plants are of important interest in various food and application industries. They provide characteristics flavours and textures to foods as integral diet components [17] and can also serve as a source of oleochemicals [18]. Being of plant origin, the oil present in this tofu will be freed cholesterol and thus helpful in the management of cardiovascular related diseases. The

values of fat from this study (7.8-15.3%DW) are slightly lower than 11.3-24.0% reported by Bhadwaj *et* al. [14].

The levels of anti-nutrients: phytate, oxalate and trypsin inhibitor are as presented in table 3. The levels of the phytate, oxalate and trypsin inhibitors reflect the leguminous nature of soy bean and help to indicate that the high levels of minerals found in tofu may not necessarily reflect the amount that will be bioavailable. There was a strong correlation (r = 0.88, $p<0.05$) between the phytate and the oxalate concentrations, indicating that oxalate-rich tofu are also rich in phytate. This pattern has been previously reported by Al-Wahsh *et al*. [19].

Phytate has long been considered as an anti-nutrient because it reduces the bioavailability of mineral in humans. However, studies suggest that phytate exhibits effective anticarcinogenic action against many types of cancers [20]. In addition, to its anticarcinogenic activity, phytate is also a potential inhibitor of calcium kidney stone formation, related to both its antioxidant activity [21] and its ability to inhibit crystal formation [22, 23]. Soy foods containing small concentrations of oxalate and moderate concentrations of phytate may be advantageous for kidney stone patients or persons with a high risk of kidney stones [19]. The levels of phytate in these samples (410-840mg/100g) are somewhat higher than the values (89.0-621mg/100g) reported in tofu by Al-Wahsh *et al*. [19] but lower than values (80.0-1879mg/100g) reported in soy food by the same authors. On the other hand, the levels of oxalate detected in the tofu from this study (340-730mg/100g) is greatly higher than 2-13mg/100g detected in tofu analyzed by Al-Wahsh *et al*. [19] as well as 2-206 mg/100g reported by the same authors in soy foods. This makes it necessary for our processing technique to be reviewed to further minimize the oxalate content of tofu as well as other anti-nutrients, for the safety of consumers.

Trypsin inhibitor is an anti-nutritional factor that affects the protein digestibility [24]. Though it is heat-labile, the heat treatment insolubilizes the much-valued proteins [25] and, more importantly, excessive heat treatment can cause loss of amino acids in soy proteins [26]. There are limited data on the effect of coagulants on the level of trypsin inhibitors in tofu. The trypsin inhibitor levels in this tofu ranges from 1.45 TIU/mg protein in tofu coagulated with $MgSO_4$ to 2.91 TIU/mg protein in tofu coagulated with alum as produced by a local tofu producing industry. There was a slightly weak correlation (r = 0.65, $p<0.05$) between phytate and trypsin inhibitor of the tofu.

CONCLUSION

The yield, nutrient and anti-nutrient contents of tofu are greatly affected by the type of coagulant used. Generally, $MgSO_4$ coagulated tofu has the highest concentration of most proximate parameters and lowest anti-nutrient contents. Thus, $MgSO_4$ is most recommended in coagulating soymilk for tofu production. Further studies on bioavailability of these nutrients can be helpful for most appropriate choice by producers.

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