World Journal of Dairy & Food Sciences 6 (1): 67-70, 2011
ISSN 1817-308X

Coagulants Modulate the Yield and Micronutrient Composition of Tofu

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Abstract: Soymilk processed with six different coagulants ($CaCl_2$, $MgCl_2$, $CaSO_4$, $MgSO_4$, alum and steep water from a local pap producing industry) were investigated for the effects of coagulating agents on the percentage yield, mineral and vitamin composition of tofu produced. The percentage yields (57.13 - 70.10%) across treatments were significantly different ($P<0.05$). Mineral analysis revealed the order Mg>K>Ca>Mn>Cu>Zn>Fe>Na>Al>Se>Co in most of the samples. Heavy metals like Pb, As and Cd were not detected in any of the tofu samples analysed. β-carotene (175.98-278.04 mg/100gDW), Vitamin E (43.69-68.44 mg/100gDW), Vitamin B_1 (1.48-3.02 mg/100gDW) and Vitamin B_2 (0.12-0.31 mg/100gDW) were also obtained in the tofu samples. Results suggested that these coagulants modulate the percentage yield, mineral and vitamin compositions of tofu samples produced. All tofu samples analysed were relatively high in micronutrient content, irrespective of the coagulant. However, $MgSO_4$ seemed to be the best coagulant, in terms of the micronutrient content.

Key words: Tofu · Coagulants · Yield · Mineral · Vitamin

INTRODUCTION

Tofu, also known as soybean curd, is a soft cheese-like food made by curdling fresh hot soymilk with a coagulant [1]. Traditionally, it is produced by curdling fresh hot soymilk with either salt ($CaCl_2$ or $CaSO_4$) or an acid (glucuno-δ-lactone). The coagulant produces a soy protein gel, which traps water, soy lipids and other constituents in the matrix forming curds. The curds are then pressed into solids cubes [2,3]. The coagulation of soymilk relies on the complex interrelationship between type of soybean, soymilk cooking temperature, volume, solid content, pH, coagulant type, amount and time [3]. Tofu is low in calories, rich in essential amino acids, contains beneficial amounts of iron and has no saturated fat or cholesterol [4].

The yield and quality of tofu have been reported to be influenced by soybean varieties, soybean quality, processing conditions and coagulants [2,5,6]. Coagulants have also been reported to modulate hypocholesterolemic effect on experimental rats [7]. Furthermore Bhardwaj *et al*. [8] had reported the effects of genotype and growing location on the mineral composition of tofu. However, there is a paucity of information on the effect of various coagulants on the yield and the micronutrient content of tofu. This study was therefore carried out to determine the effect of six coagulants on the yield, mineral and vitamin 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.

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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°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°C prior to analysis.

Chemical Analysis: Potassium and sodium contents were determined by the modified method [9], using Jenway digital flame photometer (PFP7 Model). Phosphorus was determined by vanado-molybdate spectrophotometric method [10]. Calcium, magnesium, iron, zinc, copper, manganese, aluminum, cobalt, arsenic, cadmium, lead and selenium were determined spectrophotometrically using Buck 200 atomic absorption spectrometer (Buck Scientific, Norwalk) [11] and compared with absorption of standards of these minerals. β-carotene, thiamine, riboflavin and tocopherol concentrations of the tofu samples were determined according to AOAC [12]. Results were expressed on dry-matter basis.

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 of the tofu is presented in Table 1, values ranged from 57.13-70.10 %. Significant differences were observed in the yield, except for those coagulated with $MgSO_4$ and $CaCl_2$. Tofu prepared with $MgCl_2$ gave the highest yield while that of $CaSO_4$ gave the least yield. This suggested that $MgCl_2$ has the highest coagulating property and is the best in terms of percentage yield.

Table 1: Percentage yield of Tofu processed with different coagulants

Coagulants	% Yield
$CaCl_2$	65.47 ± 0.85^b
$CaSO_4$	57.13 ± 0.61^e
$MgCl_2$	70.10 ± 0.30^a
$MgSO_4$	65.87 ± 0.42^b
Alum	63.67 ± 0.83^c
PSW	60.50 ± 0.36^d

Data are expressed as mean ± Standard Deviation, n=3

Values with the same superscript along the same column are not significantly different

Yields obtained for tofu in this study were higher than values (7.6-18.3%) reported by Oboh [7]. Variations may however, be due to differences in the processing procedure.

Table 2 shows the mineral composition of the various tofu samples. There was no detection of heavy metals such as As, Cd and Pb in the tofu samples. Calcium salts and $MgCl_2$ seems to limit the Co concentration in their samples. All the tofu samples notably contained Na, K, Ca, P, Fe, Mn, Mg, Zn, Cu, Al and Se (Table 2). The result also shows that the Ca and Mg salts, with the exception $MgSO_4$, did not increase these respective minerals in their samples. Al content of the sample coagulated with Ca salts was significantly lower than other tofu samples. $MgSO_4$ modulated a significantly higher ($P<0.05$) level of virtually all the minerals analyzed, when compared with other coagulants.

The mineral content noted in all the samples were significantly higher than that reported by Bhardwaj *et al.* [8]. This might be due to variation in processing procedures and soybean variety. The values of the mineral content are comparable with that of the fresh sample from the local tofu producing industry, probably also due to similarity in procedures and soybean variety. The samples contain significant amounts of Se, Mn, Zn and Cu. These are antioxidant minerals notable for free radical scavenging activity and could readily boost the antioxidant defense system of people who consume them in appropriate proportions [13].

The β-carotene, vitamin B_1, vitamin B_2 and vitamin E composition of the tofu samples prepared are as presented in Table 3. β-carotene (175.98-278.04 mg/100gDW), vitamin E (43.69-68.44 mg/100gDW), vitamin B_1 (1.48-3.02 mg/100gDW) and vitamin B_2 (0.12-0.31 mg/100gDW) activities were shown for the tofu samples analyzed. $CaSO_4$ and $MgCl_2$ seem to significantly reduce ($P<0.05$) the β-carotene content of the tofu samples. Tofu obtained from $MgSO_4$ coagulation showed highest activities of β-carotene and other vitamins assayed.

Table 2: Mineral composition of tofu samples processed with different coagulants

Coagulants	Na	K	Ca	P	Fe
	(mg/100gDW)				
$CaCl_2$	12.13±0.21^{d}	869.33±14.40^{e}	161.73±7.91^{ab}	965.09±14.33^{f}	15.36±0.08^{d}
$CaSO_4$	11.63±0.15^{e}	828.28±10.14^{f}	150.11±7.90^{b}	1004.30±12.98^{e}	14.68±0.06^{e}
$MgCl_2$	13.19±0.13^{b}	1106.78±6.02^{d}	129.40±6.03^{c}	998.40±13.63^{e}	14.86±0.09^{e}
$MgSO_4$	14.94±0.21^{a}	1351.97±13.38^{a}	169.17±5.01^{a}	1326.33±3.98^{a}	20.37±0.42^{a}
Alum	13.37±0.12^{b}	1306.60±14.97^{b}	165.73±8.26^{a}	1290.71±14.63^{b}	16.19±0.10^{b}
PSW	11.91±0.11^{d}	1247.47±5.05^{c}	152.76±9.08^{b}	1117.96±9.36^{c}	15.71±0.09^{c}
AlumLTPI	12.51±0.14^{c}	1321.8±10.54^{b}	151.09±4.79^{b}	1035.34±6.40^{d}	16.07±0.06^{b}

Coagulants	Mn	Mg	Zn	Cu	Al
	(mg/100gDW)				
$CaCl_2$	61.29±1.73^{d}	1189.60±15.44^{d}	44.27±0.77^{e}	59.69±1.55^{b}	0.57±0.10^{b}
$CaSO_4$	55.61±2.01^{e}	1143.61±14.18^{e}	42.66±1.24^{e}	51.19±1.07^{e}	0.41±0.03^{c}
$MgCl_2$	61.76±0.65^{d}	1088.77±13.43^{f}	38.29±1.71^{f}	51.44±0.52^{e}	0.71±0.13^{b}
$MgSO_4$	86.57±1.19^{a}	1577.33±11.47^{a}	80.07±1.04^{a}	82.33±1.05^{a}	1.01±0.09^{a}
Alum	78.21±0.94^{b}	1457.59±7.52^{b}	57.33±1.28^{b}	56.98±1.37^{c}	0.72±0.11^{b}
PSW	67.79±1.14^{c}	1340.55±6.38^{c}	52.51±1.45^{c}	46.23±0.87^{f}	1.06±0.06^{a}
AlumLTPI	65.97±0.65^{c}	1141.83±7.44^{e}	47.31±1.05^{d}	53.75±0.91^{d}	1.07±0.10^{a}

Coagulants	Co	As	Cd	Pb	Se
	(mg/100gDW)				
$CaCl_2$	0.00	0.00^{a}	0.00^{a}	0.00^{a}	0.35±0.06^{cd}
$CaSO_4$	0.00	0.00^{a}	0.00^{a}	0.00^{a}	0.27±0.04^{d}
$MgCl_2$	0.00	0.00^{a}	0.00^{a}	0.00^{a}	0.41±0.06^{c}
$MgSO_4$	0.41±0.05^{ab}	0.00^{a}	0.00^{a}	0.00^{a}	0.73±0.07^{a}
Alum	0.44±0.07^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.56±0.05^{b}
PSW	0.11±0.02^{c}	0.00^{a}	0.00^{a}	0.00^{a}	0.35±0.07^{cd}
AlumLTPI	0.37±0.05^{b}	0.00^{a}	0.00^{a}	0.00^{a}	0.42±0.10^{c}

Data are expressed as mean ± Standard Deviation, n=3 Values with the same superscript along the same column are not significantly different

DW- On dry weight

PSW: Pap steep water

AlumLTPI- Alum as applied by a Local Tofu Producing Industry

Table 3: Vitamin composition of tofu processed with different coagulants

Coagulants	Nutrient (mg/100gDW)			
	β-Carotene	Vitamin E	Vitamin B_1	Vitamin B_2
$CaCl_2$	233.13±0.14^{c}	52.67±0.61^{bc}	2.06±0.04^{c}	0.20±0.05^{cd}
$CaSO_4$	175.98±0.25^{f}	51.19±1.21^{c}	2.43±0.06^{b}	0.12±0.02^{e}
$MgCl_2$	189.04±0.31^{d}	54.18±1.00^{b}	1.92±0.06^{cd}	0.28±0.05^{ab}
$MgSO_4$	278.04±6.11^{a}	68.44±0.94^{b}	3.02±0.10^{a}	0.31±0.05^{a}
Alum	277.19±0.41^{a}	52.67±0.78^{bc}	1.82±0.05^{d}	0.25±0.04^{abc}
PSW	242.83±0.88^{b}	53.01±0.69^{b}	1.48±0.11^{e}	0.17±0.04^{de}
AlumLTPI	182.67±1.63^{e}	43.69±0.70^{d}	1.83±0.16^{d}	0.27±0.05^{ac}

Data are expressed as mean ± Standard Deviation, n=3 Values with the same superscript along the same column are not significantly different

DW- On dry weight

PSW - Pap steep water

AlumLTPI- Alum as applied by a Local Tofu Producing Industry

Coagulants tend to modulate the β-carotene, vitamins B_1, B_2 and E contents of the tofu samples as reflected in Table 3. Generally, our result showed that tofu samples obtained through this process will readily potentiate the antioxidant status of individuals consuming them due to the β-carotene and the vitamin E content. Tofu obtained from $MgSO_4$ coagulation will likely better improve the antioxidant status of consumers, thereby alleviating complications of oxidative stress-related diseases. Furthermore, consumption of any of these tofu samples can help to prevent or alleviate thiamine, riboflavin and vitamin A deficiency diseases as commonly found in malnourished populace.

CONCLUSION AND RECOMMENDATIONS

The yield, mineral and vitamin contents of tofu are greatly affected by the coagulant used. Generally in this study, $MgSO_4$ coagulated tofu was highest in terms of micronutrients analyzed. Therefore $MgSO_4$ is most recommended in coagulating soymilk for tofu production. It is also recommended that further studies be carried out on the safety of the tofu produced as well as the bioavailability of these nutrients in tofu consumers.

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