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Effect of coagulants and drying on the physico-chemical characteristics of Tofu

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Abstract

Soymilk obtained from soy dhal was coagulated with citrus juice and calcium sulphate respectively. Tofu was recovered by filtering and pressing the coagulum with the help of a muslin cloth. Tofu samples so obtained were subjected to mechanical dehydration (55, 65 and 75°C) and sun drying. Sun drying required nearly 14-day hours for the product to reach equilibrium moisture content and yielded an inferior quality product. Where as the rate of drying in the Mechanical drier increased with the increase in drying temperature from 55 to 75°C and the equilibrium moisture contents were achieved in 12, 10 and 8 hours at 55, 65 and 75°C respectively. At 75°C the colour of the product was little brown, however, drying at 55 and 65°C, yielded good quality products. The citrus juice precipitated tofu dried at 65°C was adjudged as reasonably acceptable when compared with highly acceptable chemically precipitated tofu by a panel of judges.

Key words: Coagulants, drying, physico-chemical properties, tofu.

Introduction

Among various products made from Soybean, tofu (soy curd) has a potential in the country as it inexpensive and versatile meat or cheese substitute. Through out East Asia, tofu has been the most popular way to serve soybean as a food. It is relished by most of the people and is an excellent source of protein, fat and some valuable nutrients (Wang *et al.*, 1983, Singh et. al. 2007). Although several studies on the utilization of fresh tofu as a nutritive food have been reported in literature, but there is hardly any information available on the dehydration of tofu, and utilization of dehydrated tofu solids as a nutrient supplement in Indian diets. It is assumed that the soy tofu upon dehydration will become much stable and rich source of valuable nutrients with enhanced acceptability due to reduced beany flavour.

Material and Methods

The seeds of "Bragg" variety of Soybean were procured from the seed production unit of CSK HPKV, Palampur. The seeds were dehulled and dehulled kernels (dhal) were soaked in water (1:3) at an ambient temperature for 10 hours followed by draining. Hydrated kernels were used for the preparation of tofu as depicted in Figure-1.

Tofus obtained from different treatments were subjected to dehydration under the sun light sunlight and in the mechanical dehydrator at 55, 65 and 75° C respectively. The decrease in weights of tofu samples subjected to different drying conditions was recorded till the equilibrium was attained in the weight of the samples.

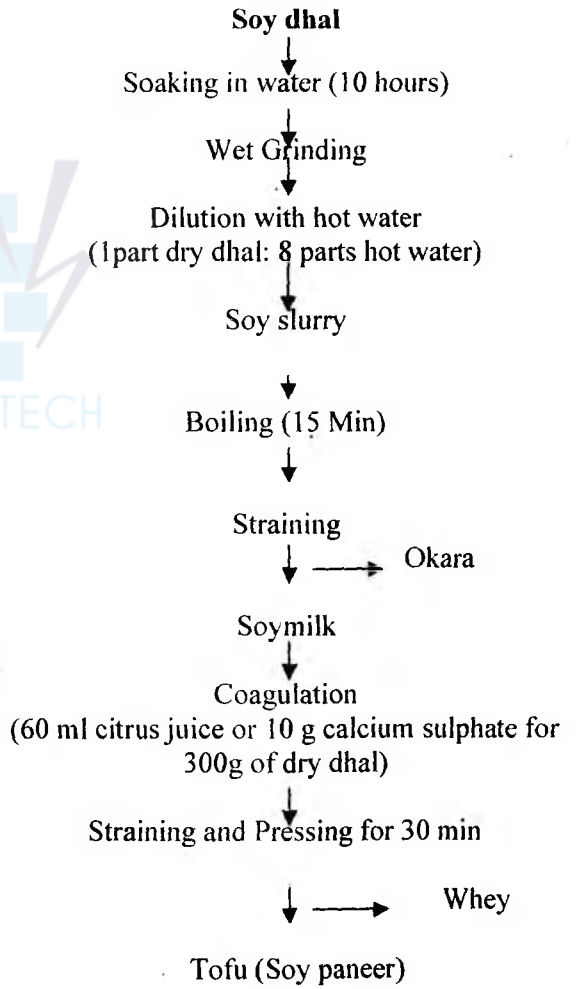


Fig. 1. Sequence of operations followed in the preparation of soy tofu

The yields of dry solids are reported as g of dry solids obtained from 100g dry *dhal*. The dehydrated samples of tofu were ground to pass

through a 20-mesh sieve. The samples were analyzed for their proximate composition (AOAC, 1990). Conversion factor of 6.25 was used to convert nitrogen into protein in soybean. The NDF and ADF content was determined as per method given by Van Soest, 1963. Total carbohydrates were calculated by difference method i.e. by subtracting from 100, the sum of percent values for moisture, protein, fat and ash. Available carbohydrates (%) were calculated by subtracting NDF (%) from total carbohydrates. Total energy was calculated by multiplying the percent protein, fat and total carbohydrates by 4, 9, and 4 and summing up the values. Similarly available energy was calculated by taking in to consideration percent available carbohydrates in the calculation. A completely randomized design was used and the data were statistically analyzed with the help of a computer programme (Gomez and Gomez, 1984).

Results and Discussion

Dehydration of Tofu

Water loss and weight of tofu

Table1 shows the effect of temperature and time of drying on percent weight and water loss from tofu during the course of drying. The tofu weight decreased and water loss from tofu increased with the increase in temperature and duration of drying. Tofu dried under the sun took about 14 hours for attaining equilibrium in the weight of tofu (27.00g/100g) and with a water loss of 73.0 per cent. Whereas the tofu dried at 75°C took about 4 hours for attaining equilibrium in weight of tofu (26.00g/100g) and with a water loss of 74.0 per cent. At 65°C the equilibrium was attained after 6 hours with 26.4g/100 g weight of tofu and water loss of 73.5 per cent. At 55 °C the equilibrium in the product was attained after 10 hours with 26.8g/100g weight of dried tofu and 73.2 per cent water loss. In conclusion, the tofu dehydrated at 75, 65 and 55°C required 4, 10 and 14 hours for attaining a constant weight of solids and maximum loss of water from the tofu during the course of drying. Similar trends were observed for both the samples, but higher contents of dried solids were obtained in case of tofu obtained with calcium sulphate after drying irrespective of drying temperature (Table 2).

Sun drying required about 12 to 14 hours for thorough drying and was weather dependent as the sunlight was not available for this much duration continuously and the samples were dried next day. Ho *et al.* (1997) also recovered an acceptable quantity dehydrated tofu from soymilk slurry using calcium sulphate as a curdling chemical.

Table 1. Effect of temperature and time of dehydration on the percent weight and percent water loss of tofu coagulated with citrus juice

Time of drying (hours)	Temperature of drying							
	Sun drying		55°C		65°C		75°C	
	Wt. of tofu	Water loss	Wt. of tofu	Water loss	Wt. of tofu	Water loss	Wt. of tofu	Water loss
0	100	0	100	0	100	0	100	0
2	61.1	38.9	56.6	43.4	33.3	66.7	29.3	70.7
4	36.7	63.3	34.2	65.4	27.7	72.3	26.0	74.0
6	33.1	66.9	29.2	70.8	26.7	73.1	26.0	74.0
8	30.5	69.5	28.1	71.9	26.4	73.6	26.0	74.0
10	29.3	70.7	26.8	73.2	26.4	73.5	--	--
12	27.3	72.7	26.8	73.2	--	--	--	--
14	27.0	73.0	--	--	--	--	--	--
16	27.0	73.0	--	--	--	--	--	--

Table 2. Effect of temperature and time of dehydration on the percent weight and percent water loss of tofu coagulated with calcium sulphate

Time of drying (hours)	Temperature of drying							
	Sun drying		55°C		65°C		75°C	
	Wt. of tofu	Water loss	Wt. of tofu	Water loss	Wt. of tofu	Water loss	Wt. of tofu	Water loss
0	100	0	100	0	100	0	100	0
2	63.9	36.1	59.1	40.9	35.4	64.6	30.6	69.4
4	38.1	61.88	35.7	64.3	29.6	70.4	28.1	71.9
6	35.1	64.9	30.1	69.9	28.5	71.5	28.0	72.0
8	32.5	67.5	29.5	70.5	28.4	71.6	27.8	72.2
10	30.1	69.9	28.7	71.3	28.0	72.0	--	--
12	28.9	71.1	28.6	71.4	--	--	--	--
14	28.8	71.2	--	--	--	--	--	--
16	28.8	71.2	--	--	--	--	--	--

Chemical composition

The results presented in Table 3 depict the proximate composition of solar dried tofu and tofus dehydrated at 55, 65 and 75°C prepared by using citrus juice and calcium sulphate as protein coagulants. The tofu dehydrated in the mechanical drier contained lower content of moisture (2.02 to 4.20%) as compare to the tofu dehydrated under solar drying conditions (7.83-8.53 %). The dry matter contents of tofu dried under different conditions of drying ranged from 91.46 to 97.97 per cent. It is seen from the data that the drying temperature had little or no effect on the protein content of the tofu, however the coagulant used in the preparation of tofu seems to have a significant effect on the protein content as well as on the fat and ash content of tofu. The protein, fat, ash, fibre and total carbohydrate contents of tofu dehydrated at different temperatures and coagulated with citrus juice and calcium sulphate varied from 50.89 to 57.73, 23.08 to 32.35, 1.15 to 5.86, 0.57 to 0.68, and 6.22 to 24.88 per cent respectively. The magnitude of variation in the values of proximate constituents of tofu dehydrated at different temperatures seems to be negligible. However, from the physical appearance of tofus it was observed that tofu samples dehydrated at higher temperature (75°C) were darker in colour than the tofu samples dehydrated at lower temperature in mechanical dehydrator. The tofu dehydrated at 65 °C was superior in colour as well as the drying was also achieved satisfactory. Sun drying was slow, required very long duration for drying and some tofu samples also started smelling indicating the growth of putrefactive bacteria in the proteinaceous tofu. This may be dangerous from microbiological quality as well as eating quality viewpoints and a great deal of care is required against contamination and spoilage while drying in the sun.

Carbohydrate and Energy contents

Date presented in Table 4 reveal significant ($P \leq 0.05$) effect of milk coagulants, drying temperature and their interactions on the indigestible carbohydrate and energy contents of tofu. The NDF and ADF contents among different samples varied from 2.92 to 4.85 and 1.56 to 2.93 per cent respectively. Whereas, the total energy and available energy contents varied from 510.8 to 552.09 and 495.4 to 540.13 Kcal/100g, respectively. Drying temperatures, however, had a very little but significant effect on these chemical constituents on dry weight basis. From the data it was concluded that drying temperature and method of drying did not affect the chemical constituents to greater extent accept the colour, which was observed to be darker in case of tofu dried at 75°C. This may be due to occurrence of Millard reaction during the course of drying at high temperature leading to the formation of brown pigments . Ho *et al.* (1997) analyzed dehydrated tofu dried at 94.4°C for various chemical constituents. The values reported for proteins, fats, ash and calories by these workers are in close agreement with those obtained in this investigation. However a little lower values for fat and protein were reported by Rahardjo *et al.* (1994) for spray-dried soymilk.

Table 3. Effect of milk coagulants and drying temperatures on the proximate composition (%) of tofu

Drying temp	Coagulants	Moisture	Dry matter	Crude Protein	Crude Fat	Ash	Crude Fibre	Total carbohydrates
55°C	Citrus juice	4.20	95.80	52.40	26.55	1.29	0.612	19.79
	Calcium Sulphate	3.50	96.49	56.51	32.03	5.24	0.601	6.22
65°C	Citrus juice	3.92	96.08	51.41	25.92	1.19	0.598	21.48
	Calcium Sulphate	3.69	96.31	55.24	31.21	4.85	0.586	8.70
75°C	Citrus juice	2.02	97.97	50.89	23.08	1.15	0.570	24.88
	Calcium Sulphate	2.05	97.94	53.64	30.70	4.0	0.559	11.60
Sun drying	Citrus juice	7.83	92.16	53.71	27.92	1.67	0.675	12.49
	Calcium Sulphate	8.53	91.46	57.73	32.35	5.86	0.643	8.23
CD (P≤0.05)								
Source of Paneer		0.20	0.20	1.03	0.50	0.20	0.09	--
Coagulants		0.14	0.14	0.72	0.35	0.14	0.06	--
Interactions		0.28	0.29	1.45	0.71	0.29	0.13	--

Table 4. Effect of milk coagulants and drying temperatures on carbohydrate and energy contents of tofu

Drying temp.	Coagulants	NDF %	ADF %	Total energy kcal/100g	Available energy Kcal/100g
55°C	Citrus juice	4.62	2.67	527.71	509.23
	Calcium Sulphate	3.35	1.74	539.19	525.79
65°C	Citrus juice	4.51	2.27	524.84	506.8
	Calcium Sulphate	3.40	1.63	536.65	523.05
75°C	Citrus juice	3.85	2.15	510.8	495.4
	Calcium Sulphate	2.92	1.56	537.5	525.82
Sun dry	Citrus juice	4.85	2.93	516.28	496.74
	Calcium Sulphate	3.74	1.89	552.09	540.13
CD (P≤0.05)					
Source of Paneer		0.34	0.21	--	--
Coagulants		0.24	0.15	--	--
Interactions		0.48	0.30	--	--

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