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Preparation of organic tofu using organic compatible magnesium chloride incorporated with polysaccharide coagulants

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ABSTRACT

Organic tofu using organic compatible coagulants of magnesium chloride and three polysaccharides including carrageenan, guar gum and gum Arabic were generated. For $MgCl_2$ coagulated tofu, carrageenan significantly increased the hardness from 969.5 g to 1210.5 g whereas guar gum (0.6 g) decreased the hardness to 505.5 g. Interestingly, gypsum and guar gum (0.6 g) increased the yield of tofu significantly. These organic compatible coagulants didn't affect most of 7S and 11S protein subunits. Importantly, the overall-acceptability of organic tofu prepared with $MgCl_2$ combined with guar gum or gypsum was almost the same as conventional tofu made with gymsum while having more beany-flavour. Among these organic coagulants, tofu made from 0.6 g guar gum and $MgCl_2$ mixture was the most similar to that coagulated by conventional gypsum. Thus this mixture is promising as coagulant for making organic tofu.

1. Introduction

Organic food is "food guaranteed to have been produced, stored and processed without the addition of synthetically produced fertilisers and chemicals" (Lockie, Lyons, Lawrence, & Mummery, 2002). Recently, consumption of organic food has increased rapidly worldwide, especially in developed countries. For instance, organic sales in the U.K. is more than ten times that of ten years ago (Jiwan, Duane, O'Sullivan, O'Brien, & Aherne, 2010). In the U.S. an increased number of consumers choose to consume organic foods instead of conventional foods. In 2009, approximately 4% of food retail sales in the U.S. were organic foods which accounted for nearly half of organic food sales globally (Nie & Zepeda, 2011). In 2011, worldwide organic food sales was approximately $\$6.3 \times 10^{10}$ while U.S. alone reached $\$2.9 \times 10^{10}$ (Weedsnetwork. Global organic food, 2013).

The current trend shows more and more organic foods are demanded; however, the rigid organic food regulations and the strict certification restrict many products being considered as "organic food". Take the U.S. for instance, the National List of Allowed and Prohibited Substances excludes many popular foods being considered as organic once the foods are made with some additives which are not on the allowed list.

Tofu, originated from China, is gaining increasing popularity throughout the world. Being a valuable protein source compared to meat, fish and cheese, especially important to Asian people and vegetarian people. Furthermore, tofu is cholesterol-free and has a less amount of saturated fat compared to animal source proteins like meat and milk (Liu, 1997). It even has health-promoting functions such as lowering the incidence of many types of cancers (Messina, Persky, Setchell, & Barnes, 1994). Recently, application of $MgCl_2$ as a coagulant in tofu attracted much attention (Hsieh, Yu, & Tsai, 2012; Li, Cheng, Tatsumi, Saito, & Yin, 2014; Nagano & Tokita, 2011; Toda, Nakamura, Takahasi, & Komaki, 2009; Toda et al., 2003). Findings indicate that $MgCl_2$ creates a more natural flavour for tofu and allows the taste of soybean to be retained, which makes $MgCl_2$ one of the most popular tofu coagulants. Moreover, consumers prefer $MgCl_2$ coagulated tofu because it retains the original sweet taste of the soybeans, and maintains the quality of soybean oil (Li et al., 2014). However, $MgCl_2$ is a quick-acting coagulant. Tofu coagulated by $MgCl_2$ solidifies more rapidly and has a lower yield, resulting in a harder and non-uniform tofu (Watanabe, 1997). The National List of Allowed and Prohibited

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Substances (U.S.) contains $MgCl_2$ (derived from sea water) and $CaSO_4$ (mined) as organic compatible components. The use of $MgCl_2$ in generating organic tofu has not been reported due to the above described disadvantages. While $CaSO_4$ has been used in the production of organic tofu in the U.S., tofu coagulated by $CaSO_4$ is smoother and of higher yield. Other potential organic allowed coagulants include polysaccharides like guar gum. In a protein based food system, polysaccharides play an important role in affecting the textural properties. For instance, polysaccharide carrageenan and coagulants including calcium acetate, calcium sulphate and glucono-delta-lactone (GDL) affected the yield and some other physicochemical properties of tofu (Abd Karim, Sulebele, Azhar, & Ping, 1999; Hua, Cui, & Wang, 2003). Moreover, guar gum and gum Arabic impacted on the protein gelling property via segregative interactions and electrostatic attractions (Fitzsimons, Mulvihill, & Morris, 2008; Harrington & Morris, 2009; Yang, Anvari, Pan, & Chung, 2012).

Here we investigated the possibility of producing organic tofu using organic compatible polysaccharides and $MgCl_2$ as coagulants and organic practises. Our goal is to identify a novel organic coagulant including $MgCl_2$ from the National List of Allowed and Prohibited Substances for organic foods suggested by U.S. National Organic Program. Effects of just $MgCl_2$ or $MgCl_2$ combined with three different polysaccharides (carrageenan, guar gum and gum Arabic) as tofu coagulant agents were investigated and compared with gypsum, a traditional tofu coagulant.

2. Materials and methods

2.1. Materials

Organic soybean was obtained from Beidahuang Yikang Organic Foods Co., Ltd. (Beian, Heilongjiang, China). Carrageenan was bought from Hainan Mengyuan Food Co., Ltd. (Qionghai, Hainan, China). Guar gum was obtained from Qingdao Liuhe Chemical Co., Ltd. (Qingdao, Shandong, China), and gum Arabic was from Tianjin Arthurbranwell Co., Ltd. (Tianjin, China). Magnesium chloride was from Tianjin Jinlun Salt Industry Co., Ltd. (Tianjin, China) and gypsum was from a local market (Zhengzhou, Henan, China). All these reagents were food grade or approved food grade additives in China.

2.2. Preparation of tofu

Tofu was prepared following previous methods with some modifications (Chang, Lin, & Chen, 2003; Lee & Kuo, 2011). Soybeans (100 g) were soaked in distilled water at a soybean water ratio of 1:3 (w/w) for 12 h at 25 °C. The swollen soybeans were drained and then ground with distilled water (1:8, w/w) in a soymilk grinder (Tangshan Tieshi grinder Co., Ltd., Tangshan, Hebei, China), and later filtered through 120 mesh (125 μm) gauze to collect raw soymilk (approximately 800 ml). The raw soymilk in a beaker was incubated in water bath at 95 °C for 5 min, then cooled to 80 °C, added with respective coagulant (2.93 g $MgCl_2$ only, 2.93 g $MgCl_2$ combined with one of the above-mentioned three polysaccharides (0.2 g or 0.6 g) or 2.75 g gypsum), stirred and incubated for 20 min in an 80 °C water bath. The curd was transferred to a cheesecloth placed in a 7 cm × 7 cm × 7 cm mold. The whey in the curd was removed via sequentially pressing at 10 g/cm^2 for 10 min and then 20 g/cm^2 for 40 min. The resulting tofu was stored in a refrigerator at 4 °C until the next day for analysis.

2.3. Proximate composition analyses

Proximate composition analyses were conducted using standard methods (AOAC, 2000). Total protein was assayed by the microKjeldahl method and crude fat by the Soxhlet method. Moisture of tofu was obtained by drying a certain amount of tofu sample to a constant weight at 105 °C for 24 h in an oven. Ash was assayed by AOAC method 14.006. The results were reported on a wet basis.

2.4. Yield and syneresis

Yield of tofu was recorded and expressed as weight of tofu obtained from 100 g dry soybeans. The syneresis of tofu was measured according to a previous method (Lee & Kuo, 2011). Specifically, tofu was cut into slices 15 mm each in length and width, while 5 mm in thickness. Slices (6 pieces) were weighed and placed on a stainless steel mesh which was placed in a plastic box. Small sticks were applied to lift the mesh so that the exuded liquid could be separated from the tofu samples. The box was sealed with parafilm to minimise the loss of moisture content. The sample was then stored in the box at 4 °C for 24 h. The total liquid exuded during this 24 h time period was measured. Syneresis was calculated as the weight of exuded liquid as a percentage of weight of sliced tofu sample.

2.5. Texture measurement

Texture of tofu were analysed with a TA. XT. Plus Texture Analyser (Stable Micro Systems, Goldaming, Surrey, U.K.) using a probe P35. Cylindrical samples, 2.0 cm in diameter and 2.0 cm in height were prepared and compressed to 50% deformation. The test settings were set as Pretest speed: 5.0 mm/s; Test speed: 1 mm/s; Posttest speed: 1 mm/s. Hardness was expressed as the height of the peak force on first bite, which was the force used for achieving a certain deformation. Hardness, springiness, cohesiveness and gumminess of each tofu sample was determined from the texture profile analysis (TPA) curve as described previously (Bourne, 2002; Yang et al., 2007).

2.6. Colour measurement

The colour of tofu, expressed in Hunter *L* (lightness), red–green (+a or −a) and yellow–blue (+b or −b) values according to the CIE definition, was measured using a CR-400 chromametre (KonikaMinolta, Tokyo, Japan). A standard white plate with $L = 88.33$, $a = 3.95$, $b = 0.67$ was applied for calibration. The colour differences among the samples were calculated as $\Delta E = [(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{0.5}$ (Rufián-Henares, Guerra-Hernandez, & García-Villanova, 2006).

2.7. Protein subunit analysis with sodium dodecyl suphate-polyacrylamide gel electrophoresis (SDS–PAGE)

Extraction of crude protein from tofu was performed according to a previous method (Cai & Chang, 1999). After protein content was analysed using the Bradford method (Bradford, 1976), protein extract was modified to 2 mg/mL using distilled water. SDS–PAGE was carried out in a vertical electrophoresis unit (DYY-6D, Beijing Liuyi Instrument Factory, Beijing, China). Concentrations of stacking gel and separating gel were 4% (w/v) and 12% (w/v), respectively. A broad range standard molecular weight marker was applied in the gel which included rabbit phosphorylase B (97.4 kDa), bovine serum albumin (66.2 kDa), rabbit actin (43 kDa), bovine carbonic anhydrase (31 kDa), human growth hormone (22 kDa) and hen egg white lysozyme (14.4 kDa). Protein bands in the gel were stained using coomassie brilliant blue G-250 and were recorded by UNIS scanner (UNIS A688, Beijing, China). Bandscan 5.0 (Glyko, Hayward, CA, USA) was applied to quantitatively analyse the relative ratio of protein ingredients in the protein samples.