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Effect of soybean aging on the quality of soymilk, firmness of tofu and optimum coagulant concentration

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ABSTRACT

This study investigated the influence of soybean aging (cultivars Coodetec 214 and BRS 267) on the physicochemical properties of soymilk and tofu. Two aging conditions were adopted: accelerated aging (84% relative humidity and 30 °C, up to 9 months) and natural aging (ambient temperature and relative humidity, up to 18 months) and a control condition (47% relative humidity, −20 °C). Tofu was coagulated with $MgSO_4$. Optimum coagulant concentration (OCC) decreased with increasing coagulation temperature and soybean aging time. OCC showed positive correlation with total solids, protein, ash, Ca, Mg and P contents of soymilk. The products showed, in general, reduced color parameters (L^* and h°), proteins, lipids, carbohydrates, ash, Ca, Mg, P and total solids (except in the tofu) and firmness (tofu) with increasing aging time. Tofu yields decreased with accelerated aging time.

1. Introduction

Tofu and soymilk are widely consumed soybean-based foods in eastern countries and are becoming increasingly popular in the West. The quality of these products, besides the manufacturing process, depends on the cultivar and quality of soybean grains, and the latter is related to storage conditions, namely time, temperature and relative humidity (RH) (Hou & Chang, 1998, 2004a, 2004b, 2004c; Kong, Chang, Liu, & Wilson, 2008; Murphy, Chen, Hauck, & Wilson, 1997; Thomas, deMan, & deMan, 1989). In tropical countries, as well as in many Brazilian regions, with mean annual temperatures close to 27 °C and relative humidity at about 80%, storing of soybean for long periods of time, under ambient conditions (uncontrolled), leads to losses in the quality of grains and their products (Kamizake, Varéa, & Prudencio, 2014; Kamizake, Yamashita, & Prudencio, 2014; Kong et al., 2008). Quality deterioration of these products consists mainly in browning, reduced solids, especially proteins, decreased yield and quality of tofu texture (Hou & Chang, 1998, 2004a, 2004b, 2004c; Kong et al., 2008; Saio et al., 1980; Thomas et al., 1989).

The manufacturing process of tofu is complex, involving specific stages. The first step is to obtain soymilk, which is also a product for final consumption. In this case, the preparation is performed with some modifications, such as the thermal inactivation of lipoxygenase enzymes, with or without the addition of sugar and flavorings (Ciabotti, Barcelos, Pinheiro, Clemente, & Lima, 2007). Heat treatment of grains may decrease protein solubility, affecting tofu yield. Therefore, inactivation is not necessary in order to manufacture tofu. Soybean cultivars without lipoxygenases could be a good modification in tofu making, by improving flavor and maintaining hydration of the grains (Benassi, Benassi, & Prudencio, 2011; Sun & Breene, 1991).

Soymilk coagulation is the most critical step for obtaining good tofu texture and yields. The coagulants used can be of slow-action ($CaSO_4$ and GDL or glucono-δ-lactone) and quick-action ($CaCl_2$, $MgCl_2$ and $MgSO_4$) and result in silken or filled and firm (momen) tofu, respectively. Curd formation involves complex interactions between soybean proteins, coagulants and non-protein compounds such as phytates, lipids and carbohydrates (Hou & Chang, 2003).

The amount of coagulant added to soymilk is a critical factor for tofu manufacturing, especially affecting product yield and texture. The addition of a higher amount, instead of an optimal amount, leads to increased whey and lower tofu production (Skurray, Cunich, & Carter, 1980). Moreover, the resulting tofu is harder, and, under extreme situations (in which higher concentrations than the optimum concentration are added), tofu resembles a precipitate rather than a gel (Liu & Chang, 2008). Prior knowledge of the optimum coagulant concentration (OCC) is essential, especially

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for quick-acting coagulants. Studies have been conducted on $CaCl_2$ and $MgCl_2$; however, there are no reports on the use of $MgSO_4$ in firm tofu preparation, which is very common in Brazil. The OCC can be determined by the titrimetric method developed by Liu and Chang (2003).

The OCC depends on the content of total solids, especially from soybean extract proteins, and also on other variables, such as temperature, agitation speed and time elapsing during coagulation (Liu & Chang, 2003, 2004, 2008). The OCC for freshly harvested soybeans may not be suitable for aged soybeans. There are few studies on OCC for soymilk coagulation obtained from aged soybean. Liu and Chang (2008) observed a significant decrease in the optimum concentrations of $CaCl_2$ and $MgCl_2$for soymilk obtained from grains stored under different water activities, for three months, at 30 °C.

The aims of this study were to determine the optimal concentration of $MgSO_4$ coagulant (OCC) to obtain firm tofu and to evaluate the quality of soymilk and tofu made from accelerated and natural aged (AA and NA) soybean. The effect of soymilk coagulation temperature and aging time on the OCC was evaluated.

2. Materials and methods

2.1. Material

Two soybean cultivars with contrasting characteristics were studied: Coodetec 214 (small, light and less-protein grains) and BRS 267 (large, dark and high-protein grains) (Kamizake, Yamashita et al., 2014; Kamizake, Varéa et al., 2014). The soybean cultivars were produced in the 2008/2009 harvest, in the northern region of Paraná, Brazil. The commercial antifoam was donated by Prosabor (São Paulo – Brazil). The coagulant used was $MgSO_4{\cdot}7H_2O$ (Sigma).

2.2. Soybeans storage

Three soybean storage conditions were adopted according to the procedures described by Kamizake, Yamashita et al. (2014): accelerated aging (AA): 30 °C (incubator, FREEZETC, model D 1004, Brazil) and 84% RH (saturated KCl solution) up to nine months, natural aging (NA): ambient temperature and RH (range = 17.3–24.5 °C and 59–93% RH) up to 18 months, and a control: −20 °C and 47% RH. Soybean samples stored under AA and NA were taken at intervals of one month and three months, respectively, and stored under the same conditions as the control samples until analyses were performed.

2.3. Soymilk preparation

Soymilks were prepared according to Sun and Breene (1991). The grains were washed and hydrated in distilled water (1/5, w/v) for 8 h at room temperature. They were then drained, rinsed and ground with distilled water (1/7 w/v) in a blender (Philips Walita, RI2034/01), at medium speed for 3 min. 0.1% (v/v) of antifoam agent was added to the mass, which was then heated in a stainless steel pot, under constant stirring until boiling, and kept for 5 more minutes under gentle heating and stirring. To separate the extract from the residue it was filtered through a muslin cloth (100 mesh).

2.4. Determination of optimum coagulant concentration (OCC) at different temperatures

The OCC of the soymilk at different temperatures (20, 30, 40, 50, 60, 70 and 80 °C) was determined by titration with $MgSO_4{\cdot}7H_2O$ solution at 20%, according to the methodology described by Liu and Chang (2003) with some modifications. The titration step employed a burette with a capacity of 10 ml and 0.05 ml exact graduation (Pyrex brand) connected to a peristaltic pump (model brand Biotech Pump P-1) (Pharmacia Biotech model pump P-1). The coagulant solution was then added to the extract at a constant speed of 1.0 ml/min. During titration, 60 ml of soymilk (in a 100 ml beaker) were kept at the study temperature (using a water bath) under constant stirring at 300 rpm, to create the swirl with a magnetic stirrer (Biomixer model 78HW-1) and a Teflon-coated magnetic stirrer (10 mm diameter and 30 mm length). When the swirl disappeared, the pump was turned off and the reading was taken of the coagulant solution volume (ml) consumed (Y). The OCC was calculated by substituting the values of Y in Eq. (1):

$$\text{OCC(mM)} = 1000 \times (Y \div 60 + Y) \times \text{Molar concentration of coagulating solution} \quad (1)$$

To study the soymilk coagulation temperature effect on the OCC, the soybeans stored under control conditions, AA of 9 months, and NA of 18 months were used.

2.5. Preparation of firm tofu

The OCC of $MgSO_4{\cdot}7H_2O$ was determined by the same methodology as described in Section 2.4; however, soymilk temperature was kept at 75 °C (average denaturation temperature of globulins 7S and 11S, according to Saio and Watanabe, 1973). This measurement was performed on soymilk from soybean cultivars stored at all AA and NA experimental times, and also the control.

A sample (550 ml) of each soymilk at 75 °C was coagulated with the solution of $MgSO_4{\cdot}7H_2O$ at 20%, whose volume is determined by the OCC value. The soymilk and coagulant solution mixture was produced under manual shaking for 10 s, and, to complete the coagulation, the temperature was kept at 75 °C in the water bath, for 20 min. The coagulated material was transferred to a plastic form (8.0 × 8.0 × 10.0 cm) lined with muslin cloth and drained for one hour under the pressure of 20 g/cm^2. The tofu was then immersed in water and kept at 4 °C overnight for subsequent analysis.

2.6. Determination of tofu yield

Tofu yield was calculated by Eq. (2) and expressed as tofu g/100 g of whole soybean (Hou & Chang, 2004c).

$$\text{Yield } (\%) = (M1 \times V1 \div M2 \times V2) \times 100 \quad (2)$$

where $M1$ = tofu mass, $M2$ = soybean grains mass, $V1$ = total volume of soymilk, and $V2$ = partial volume of soymilk.

2.7. Determination of chemical composition of soymilk and tofu

Total solid content was determined by drying a sample of 30 g under lyophilization (Edwards, Pirani 501, England). Methods recommended by the Association of Official Analytical Chemists (AOAC, 2000) were adopted to determine moisture, protein, lipid, ash and mineral levels. Carbohydrate content was calculated by difference. Measurements were made in duplicate for each experiment replication. Results for the present composition were expressed as grammes per 100 g of sample. Mineral contents were expressed as grammes per 100 g of samples, in soymilk and tofu.

2.8. Color determination of soymilk and tofu

Color parameters were determined by a colorimeter (Konica Minolta, CR 400/410, Japan). The soymilk was placed in a glass cuvette and reading was performed directly over its surface (CR