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EFFECTS OF DRYING AND STERILIZATION ON THE QUALITY AND SHELF-LIFE OF SEMI-MANUFACTURED SOYBEANS

Running title: Semi-manufactured soybean for instant soymilk

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ABSTRACT

Traditionally, soybeans are soaked in water for a dozen of hours in soymilk processing. To make instant soymilk, soybeans were semi-manufactured (SM) by using different dehydration and sterilization methods, and their effect on the product quality and shelf-life were investigated. Results indicated that the instant soymilk made from the SM soybeans using hot-air drying and combined sterilization method exhibited the highest quality. The shelf life of the SM soybeans was determined to be 80 d at 25 °C and 180 d at 4 °C, based on their rehydration ratio, microbial load and browning index. The SM soybeans only need to be rehydrated for 10 min before being prepared as soymilk, which is very convenient to consume at home and office.

PRACTICAL APPLICATIONS

Soymilk is nourishable and popular to many people worldwide. Besides purchasing processed products from supermarkets, people may choose to make it by themselves using the household soymilk grinder for freshness. However, the preparation is time-consuming and a dozen of hours' soaking process of soybeans is necessary to obtain good quality soymilk. This paper presents an alternative to make instant soymilk, i.e. by using semi-manufactured (SM) soybeans, through pre-soaking, dehydration and sterilization. Experimental results indicated that hot-air drying and combined sterilization had many advantages over the other methods such as longer shelf life of the SM soybeans and better quality of the corresponding soymilk. The SM soybeans may have the potential to be commercialized to for consumers who prefer to make instant soymilk at home or office in a convenient manner.

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KEYWORDS

Semi-manufactured soybean; instant soymilk; hot-air drying; combined sterilization; shelf life

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INTRODUCTION

Soymilk is traditionally processed by soaking soybean grains for about 12 hours, grinding, filtering and heating (Liu 2004). It has been reported that soymilk may have potential health benefits, such as reducing the risks of cancer, cardiovascular disease, bone loss and relieving women's menopause symptoms (Atteritano *et al.* 2009; Ho *et al.* 2007; Chan *et al.* 2007). Compared with animal milk, soymilk does not have lactose intolerance problems. Moreover, soymilk is free of starch and cholesterol, which makes it specifically suitable for patients with diabetes, cardiovascular disease and obesity.

Fresh soymilk is a popular beverage, especially in Asian countries. However, the shelf life of fresh soymilk is less than 1 d at ambient temperature in summer and only 2~3 d even under 4°C. Currently, more and more people prefer instant home-made soymilk, which is fresh, nutritious, and the taste is adjustable depending on personal appetite. However, in the traditional soymilk manufacturing process, soybeans are generally soaked for a dozen of hours to change their texture characteristics and facilitate the extraction of protein (Pan and Tangratanavalee 2003). Although making soymilk directly from dry un-soaked soybeans is a convenient and quick method, the soymilk is low in protein content and not easy to be digested, and the taste is inferior to that made from soaked soybeans. In addition, shorter cooking time is needed for the soaked samples (Molina *et al.* 1975), and the soaking process is recommended to improve the protein digestibility (Silva and Leite 1982). However, soaked soybeans are suffered for a limited shelf life. Therefore, the objective of this study was to develop semi-manufactured (SM) soybeans which had been soaked and dried to some extent that only a few minutes were required to rehydrate for instant soymilk making. The effect of drying and sterilization techniques on the quality and

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shelf life of the soaked soybeans were also investigated.

MATERIALS AND METHODS

Materials and Reagents

Soybean seeds with moisture content less than 13%, produced in Heilongjiang province, China, were kindly provided by Hangzhou Alerle Food Company (Hangzhou, China). The soybeans were washed by 10 mg/L ClO_2 solution to reduce the initial loads of microbes and then soaked in 0.5% $NaHCO_3$ solution at 15°C for 12 h to minimize the beany flavor and increase protein content in the soymilk (Yang *et al.* 2015). The soaked soybeans were then processed by the following procedures. All chemicals and reagents were of analytical grade and were purchased from National Drugs Group, Shanghai, China.

Dehydration Treatments

The soaked soybeans were dried in a blast drying oven (DHG-9070A, Shanghai Jing Hong Laboratory Instrument Co. Ltd., China) at 60°C, or a vacuum drying oven (DZF-6050, Shanghai Jing Hong Laboratory Instrument Co., Ltd., China) at 60°C and -0.09 Mpa, or a microwave oven (Galanz WP700P21, Galanz group, China) at a power of 2.8 W/g, until the moisture content was (20.0±1.0) %, (25.0±1.0) %, and (30.0±1.0) % respectively.

Sterilization Treatments

The soaked soybeans were air dried to the moisture content (20.0±1.0) % and vacuum packaged in poly(ethylene terephthalate)/ polyethylene (PET/PE) bags. Five different sterilization methods were applied to the dehydrated and vacuum packaged

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soybeans: (i) pasteurized at 70°C for 20 min, 80°C for 15 min and 90°C for 10 min respectively in a water bath (Shanghai Jing Hong Laboratory Instrument Co., Ltd., China); (ii) sterilized in a microwave oven (Galanz WP700P21, Galanz group, China) at a power of 4.67 W/g for 30 s, 40 s, 50 s respectively; (iii) irradiated by ^{60}Co in Zhejiang Irradiation Center with the dose of 4 kGy, 6 kGy, 10 kGy respectively; (iv) four combined chemicals added into the $NaHCO_3$ solution respectively during the soaking process of soybeans, i.e. 0.5‰ sodium ascorbate and 0.15‰ natamycin (A), 1‰ sodium ascorbate and 0.3‰ natamycin (B), 0.5‰ Na_2SO_3 and 0.15‰ natamycin (C), 1‰ Na_2SO_3 and 0.3‰ natamycin (D), before the air drying and vacuum package; (v) a combination of chemicals sterilization (1‰ sodium ascorbate and 0.3‰ natamycin, B) during the soaking process, microwave sterilization at 4.67 W/g for 30 s and irradiation sterilization at the dose of 10 kGy after air drying and vacuum package. The dehydrated and vacuum packaged soaked soybeans without sterilization were used as control.

Soymilk Preparation

Soymilk was obtained by grinding the above sterilized soybeans (SM soybeans) into slurry, filtered and boiled in a soymilk grinder (AD-506, Foshan Aide Industry Co., Ltd., China) at a soybean/water ratio of 0.125 kg/L. The soymilk grinder is able to grind soybeans, filter and boil the soymilk automatically.

Sensory Evaluation of Soymilk

The sensory evaluation was performed by ten trained panelists (25-35 years of age) from the Institute of Food Science, Zhejiang Academy of Agricultural Sciences. Each panelist conducted the evaluation by scoring the soymilk independently according to

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the criteria set in **Table 1**. The sum of the four parameter scores was regarded as the total sensory score, and the results were expressed as the mean of the 10 panelists.

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Chemical and Properties Analysis

The moisture content of soybeans was determined using direct oven drying method (AOAC 1995). Microbial loads in soybeans was determined by plate counting method (National Standard GB 4789.2 2010). Protein content in soymilk was measured using micro-Kjeldahl method (AOAC 1995). Stability of soymilk was determined with the ultraviolet spectrophotometry method (Miao and Ma 2005). Soymilk samples were diluted 40 times with distilled water, then centrifuged at 5000 r/min for 5 min. Absorbance values of the samples both before and after centrifuging were recorded on an 1800 UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan) at 785 nm. The stability of the soymilk was calculated with the formula as follow.

$$R = A_{after}/A_{before}$$

Where R is the stability coefficient, A_{after}, A_{before} are the absorbance value of the supernatant after and before centrifuging respectively. Generally, R is less than 1.0, and a bigger R value represents higher stability.

Soluble solids content in soymilk was determined using a digital refractometer Quick-Brix 90 (Mettler Toledo, Shanghai, China). The results were expressed as degrees Brix at 25°C (Ma *et al.* 2015).

Color of soymilk samples was assessed using a colorimeter (Minolta CR-410, Konica minolta company, Japan). The parameters L^*, a^*, b^* were recorded and total chromatism ΔE^*_{ab} was calculated (Rahmati *et al.* 2014).

$$\Delta E^*_{ab}=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$$

Total chromatism was expressed as ΔE^*_{ab}, $\Delta L^*=L^*_{sample}-L^*_{standard}$, $\Delta a^*=a^*$

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$_{sample}$-$a^*_{standard}$, $\Delta b^*=b^*_{sample}-b^*_{standard}$. The soymilk made from freshly prepared SM soybeans was used as standard and those from stored SM soybeans were used as samples.

Rehydration ratio of soybeans was measured as reported by Nathakaranakule *et al*. (2010). The dried samples were weighed (m_A), placed into a beaker and immersed in distilled water (25°C) for 10 min. The samples were weighed again (m_B) after being took out from the beaker and the surface moisture removed. The rehydration ratio (w) of the dried soybeans was then calculated as $w = m_B / m_A$.

Polyphenol oxidase (PPO) and peroxidase (POD) activities in soybeans were determined using spectrophotometry. About 2 g SM soybean samples were weighed and ground into powder in liquid nitrogen, incubated with 25 mL phosphate buffer (pH 7.0) at 0°C for 20 min and centrifuged under 4000 r/min at 4°C for 10 min. The supernatant was used for enzyme activity determination. The activity of PPO and POD was determined using the method reported by Luo *et al*. (2010) and Zang *et al*. (2015) respectively. The ratio of enzyme activity after and before sterilization was defined as the relative enzyme activity and expressed in percentage.

Anti-browning effect and browning index of the soybeans were determined as follows. The packed SM soybeans were incubated under dark at 40°C, and the time (d) when the sample became perceptible brown was recorded. A shorter time indicated a better anti-browning effect of the sample. Browning index of the samples was measured using the method of Yang *et al*. (2010). About 5 g samples were weighed and ground into powder using 25 mL anhydrous ethanol, centrifuged at 3000 r/min for 10 min and the supernatant was measured on the 1800 UV-Vis spectrophotometer at 420 nm.

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Shelf Life Determination of SM Soybean Products

The SM soybean products prepared within 24 h were stored in an incubator in the dark at 25°C and 4°C, respectively. Indicators of shelf life were determined at intervals of 10 d for 25°C stored samples and 30 d for 4°C. Three indicators, i.e. microbiological, sensory, and chemical index, were used to judge the shelf life. The shelf life was defined to expire when any one of the three indicators reached the standard: 1) the total microbial counts exceeded 750 CFU/g (National Standard GB 2711 2003); 2) the browning index of soybeans exceeded 0.700 or the sensory score of soymilk was less than 65 points according to our experience; 3) the content of main nutrients (i.e. protein and soluble solids) in soybean or its corresponding soymilk was decreased by 50% (Polydera *et al.* 2005).

Statistical Analysis

All the experiments were done in triplicate and duplicate samples were analyzed at each sampling time. Data were expressed as mean ± standard deviation and were analyzed using the SPSS Statistics 20.0 (IBM, USA). The significant difference was evaluated by Duncan multiple test and defined as $P<0.05$.

RESULTS AND DISCUSSION

Effects of Drying Conditions on Rehydration Ratio and Microbial Load of Soaked Soybeans and Quality of the Corresponding Soymilk

Rehydration capability is an important indicator to determine the structural quality of dried product and is expressed as rehydration ratio. As seen in **Table 2**, the rehydration ratios of the soaked soybeans dried to different moisture content were

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significantly different (P<0.05), where the soybeans with higher moisture content had lower rehydration ratio. In addition, different drying methods also had significant effects on the rehydration ratio (P<0.05). The microwave dried soaked soybean had the highest rehydration ratio followed by the hot-air dried and the vacuum dried had the lowest. However, it was observed that the appearance of the vacuum dried soybean was the best, showing a uniform texture and little surface flaw, while this for the microwave dried soybean was the worst with serious surface flaw and even some cracks. Sangkram and Noomhorm (2002) reported that high drying temperature led to high skin cracks of the beans. Dondee *et al*. (2011) also observed that the cracking and breakage of soybean kernels was affected by drying methods.

Microbial load of the soaked soybeans was 4.71 log10 CFU/g in this experiment. After dehydrated, the microbial load was decreased to the range of 1.73~3.96 log10 CFU/g (Table 2). **Table 2** also shows that, using the same drying method, the soybeans with lower moisture content had lower microbial load. Moreover, at the same moisture content, the hot-air dried soybeans had the highest microbial load while the microwave dried had the lowest. The lowest microbial load in the microwave dried soybean was probably because the fast heat up process as well as the non-thermal lethal effect of the microwave (Decareau 1985). Lower microbial load was observed in the vacuum dried samples than those of hot air dried ones (Table 2), mainly because limited oxygen was available under vacuum conditions which inhibited the growth of aerobic microorganisms. The effect of different drying conditions for the soaked soybeans on the quality of the corresponding soymilk are also presented in **Table 2**. The protein contents in soymilk made from hot-air and vacuum dried soybeans were not significantly different (P>0.05), but were higher

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than those from microwave dried samples. In the microwave drying process, the temperature was relatively high and this could have led to protein denaturation, which then reduced the protein solubility and protein content in the soymilk. **Table 2** also shows that, using the same drying method, the stability of soymilk was better from the soybeans with higher moisture content, probably because the higher moisture content having contributed to the hydration of protein (Hansen 2002). In addition, at the same moisture content, the soluble solid content and sensory score of soymilk made from hot-air dried soybean were the highest. Both the vacuum dried soybeans and the soymilk made from them showed a slight tapinoma-odor, and the soymilk made from microwave dried soybeans had lots of residuals and a sense of particles. Taking the protein and soluble solid contents and sensory score into consideration, the quality of soymilk made from hot-air dried soybeans was the best.

Effects of Sterilization Conditions on Browning and Microbial Load of Dehydrated Soaked Soybeans and Quality of the Corresponding Soymilk

Most plants contain PPO and POD, the enzymes causing and promoting browning reaction, which should be deactivated in food processing (Badiani *et al.* 1990). The PPO and POD activity of the sterilized soybeans all declined to varying degrees, although the irradiation sterilization method showed the least effect (**Table 3**). The PPO and POD activity of the soybeans declined significantly with the increase of pasteurization temperature and microwave sterilization time ($P<0.05$). Microwave might have deactivated the PPO and POD activity efficiently with the double effects of temperature and electromagnetic field (Decareau 1985). The PPO activity in the combined sterilized soybean was the lowest among all the samples and the POD activity was as low as 16.3%, which suggested that this was the best sterilization

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method to inhibit the enzyme activities and potential browning of the soymilk.

As shown in **Table 3**, the microbial load of dehydrated soaked soybeans sterilized by pasteurization, microwave and chemicals was in the range of 2.7~3.2 log10 CFU/g (3.41 log10 CFU/g for the control as shown in Table 2). The sterilization by irradiation or the combined method was better than others and the microbial load was decreased significantly (P<0.05) with the increase of irradiation dose. No microorganism was detected in the soybeans sterilized by irradiation at 10 kGy and by the combined method. However, the anti-browning effect of irradiation sterilized soybeans was not as good as other samples (**Table 3**). It was probably because the relatively higher PPO and POD activities in the irradiation treated soybeans have caused the lower anti-browning effect. Nevertheless, the highest anti-browning effect was observed in the combined sterilized sample. This was mainly because the ascorbate and Na_2SO_3 used in the soaking solution had retarded the enzymatic browning by inhibiting PPO and POD activity (Oms-Oliu *et al.* 2010).

Table 3 also shows that the protein and soluble solid contents of soymilk made from the soybeans sterilized by pasteurization were lower than that of other sterilization methods. The denaturation of soybean protein during the pasteurization process may have reduced the protein solubility and thus resulted in lower protein content in the soymilk. It was noted that the protein and soluble solid contents were the highest in the soymilk made from the combined sterilized soybeans (P<0.05). The results also indicated that soymilk made from combined sterilized soybeans had the highest stability (0.764), while that from pasteurized had the lowest (0.600). In addition, the sensory quality of the soymilk made from combined sterilized soybeans was also significantly higher than that from other samples (P<0.05). These results indicated that the soymilk made from the combined sterilized soybeans had the

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highest product quality.

Determination of SM Soybeans' Shelf Life by Browning Index, Microbial Load and Soymilk Quality

The SM soybeans showed PPO and POD activities (**Table 3**) which resulted in enzymatic browning during storage. Moreover, the soybeans are rich in protein and sugar, which may also cause Maillard reaction (Huma *et al.* 2008). The browning index of the SM soybeans increased significantly with the extension of storage time at 25°C and 4°C (P<0.05) (**Figure 1**). When stored at 25°C, the browning index (0.648±0.021) was close to the unacceptable value of 0.700 at day 80, but exceeded this value at day 90 (0.779±0.023, **Fig. 1**). In contrast, when stored at 4°C, the browning index was 0.642±0.016 at day 180, and 0.722±0.022 at day 210. Therefore, the shelf life of the SM soybeans was 80 d and 180 d when stored at 25°C and 4°C respectively, determined by the browning index. The rehydration ratio of the SM soybeans decreased with the extension of storage (**Fig. 1**). However, only 11.1% decline was detected in the samples at day 90 when stored at 25°C, and 10.2% at day 210 when stored at 4°C.

The growth of microorganisms is one of the most important factors contributing to food spoilage. As shown in **Figure 2**, the microbial load in the SM soybeans increased with the extension of storage both at 25°C and 4°C. When stored at 25°C, the microbial load in the soybeans was 596 CFU/g at day 90, which met the criteria as set in the national standard of GB 2711(2003), but not on day 100 where the microbial quantity was 873 CFU/g. When stored at 4°C, the microbial load (682 CFU/g) in the soybeans met the national standard of GB 2711(2003) on day 240, but not on day 270 where the microbial quantity was 913 CFU/g. Therefore, the shelf life of the SM

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soybeans were 90 d and 240 d respectively when stored at 25°C and 4°C, determined by microbial load.

Color is another important index to evaluate soymilk quality, because it affects the consumer acceptability (Ma *et al.* 2015). Generally, white and glossy color indicates good quality while dark or yellow color suggests poor quality of soymilk (Kwok *et al.*, 1999). The L^* value of the soymilk was declined with the extension of SM soybeans' storage at 25°C and 4°C (**Table 4**), suggesting the color of soymilk became darker. However, the color of soymilk was still acceptable after the soybeans had been stored for 90 d at 25°C and 210 d at 4°C, according to the above set criteria. When compared with **Fig.1**, it was noted that the browning index of soybean was increased when the L^* value of soymilk was declined, which suggested that it might be the soybean browning that had caused the dark color of soymilk. The total chromatism ΔE^*_{ab} value was increased with the extension of the soybeans' storage time, indicating the differences of soymilk color became bigger.

Protein is the major nutrient in soymilk and it is the most important index to reflect its quality. The protein and soluble solid contents of soymilk made from the SM soybeans were decreased with the passage of storage time. According to the above criteria, the soymilk quality was acceptable when the soybeans' storage time was 90 d at 25°C and 210 d at 4°C. During storage, the protein of SM soybeans may have been degraded (Giri and Mangaraj 2012) and the rehydration ratio of the soybeans declined, which resulted in a harder structure and thus difficult to be ground and nutritional components not easily be extracted (Pan and Tangratanavalee 2003). The stability and sensory score of the soymilk were also decreased with the extension of storage time (**Table 4**). It was observed that the soymilk was acceptable when the SM soybeans were stored for 80 days at 25°C and 180 days at 4°C, but was unacceptable

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at 90 days and 210 days respectively, determined by the sensory quality of the corresponding soymilk.

CONCLUSIONS

In the present study, the SM soybeans were manufactured by soaking, dehydration and sterilization, which could be used to make instant soymilk at home or office in 10 min. After a comparison study, the optimum processing technologies for the SM soybeans were obtained. In the pre-treatment stage, soybeans were washed 10 min in the 10 mg/L ClO_2 solution; in the soaking stage, the soybeans were immersed in a mixed solution of 0.5% $NaHCO_3$, 1‰ sodium D-isoascorbate and 0.3‰ natamycin at 15°C for 12 h; in the dehydration stage, the soaked soybeans were air dried at 60°C to the moisture content of 20.0±1.0%; in the sterilization stage, the dried soybeans were vacuum packaged and microwave heated at 4.67 W/g for 30 s, and then irradiated with a dose of 10 kGy. The shelf life of the SM soybean products was 80 d when stored at 25°C and 180 d at 4°C, determined by the qualities of the SM soybean and its corresponding soymilk.

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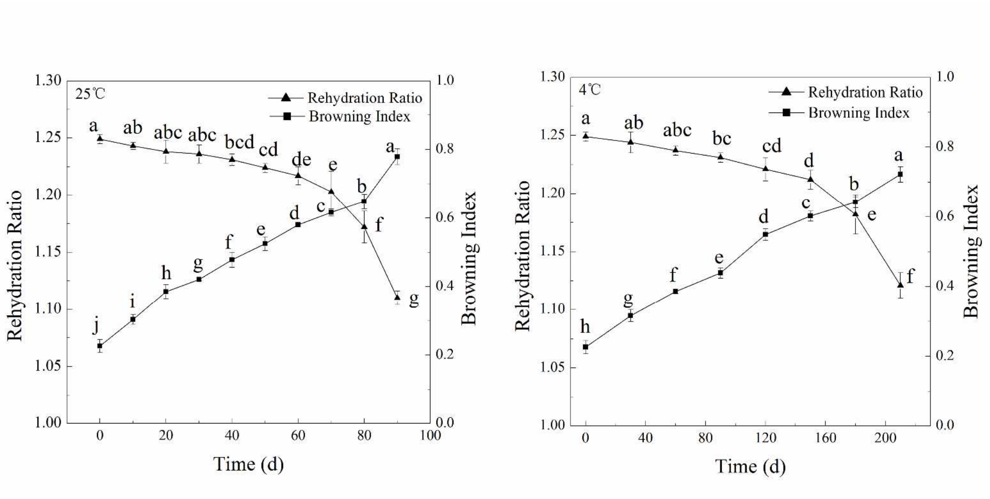

FIG. 1. CHANGES OF BROWNING INDEX AND REHYDRATION RATIO OF THE SM SOYBEANS STORED AT 25°C AND 4°C

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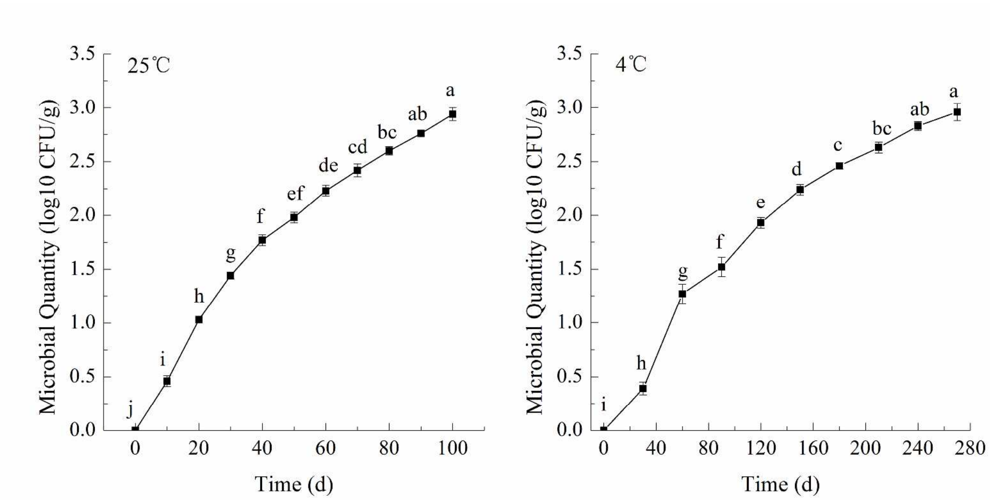

FIG. 2. CHANGES OF MICROBIAL QUANTITY IN THE SM SOYBEANS STORED AT 25°C AND 4°C

401x201mm (300 x 300 DPI)

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TABLE 1. SENSORY EVALUATION CRITERIA FOR SOYMILK

Index	Criteria	Score
Mouthfeel	Full-bodied and smooth, no sense of particles	20~25
	Thin, slight sense of particles	11~20
	Very thin, obvious sense of particles	1~10
Smell	Full-bodied fragrance, no beany flavor	20~25
	Slight fragrance, little smell of burnt and beany flavor	11~20
	Strong smell of burnt and beany flavor	1~10
Color	Homogeneous milkiness or light yellow	20~25
	White, slight gloss	11~20
	Dark, no gloss	1~10
Appearance	Homogeneous emulsion, no sedimentation and no condensation	20~25
	Inhomogeneous, little floc and condensation	11~20

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Much floc, serious condensation	1~10

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TABLE 2. EFFECT OF DIFFERENT DRYING METHODS ON THE QUALITY OF SOAKED SOYBEAN AND THE CORRESPONDING SOYMILK

Drying method	Moisture content (%)	Rehydration ratio	Microbial load log10 CFU/g	Protein content (g/100 mL)	Soluble solids (%)	Stability	Sensory score
	20.0±1.0	1.224±0.013aA	3.41±0.19cA	2.66±0.02aA	6.5±0.1bA	0.647±0.008aB	84±3aA
Hot-air	25.0±1.0	1.203±0.012bA	3.77±0.15bA	2.67±0.04aA	6.5±0.1bA	0.650±0.011aB	78±2bA
	30.0±1.0	1.182±0.010cA	3.96±0.22aA	2.70±0.04aA	6.7±0.1aA	0.663±0.007aC	81±2abA
	20.0±1.0	1.175±0.005aB	2.49±0.13cB	2.67±0.04aA	6.4±0.1aA	0.597±0.002cC	67±3bB
Vacuum	25.0±1.0	1.151±0.010bB	2.82±0.14bB	2.70±0.06aA	6.4±0aA	0.644±0.012bB	72±1abB
	30.0±1.0	1.136±0.009cB	3.15±0.19aB	2.71±0.02aA	6.4±0.1aB	0.682±0.010aB	77±3aAB
	20.0±1.0	1.346±0.012aC	1.73±0.15cC	2.38±0.04aB	6.5±0.1aA	0.753±0.006bA	81±4aA
Microwave	25.0±1.0	1.298±0.005bC	1.92±0.06bC	2.31±0.05bB	6.0±0.1bB	0.767±0.012bA	75±2abAB
	30.0±1.0	1.257±0.008cC	2.08±0.15aC	2.24±0.02cB	5.4±0.1cC	0.795±0.015aA	74±3bB

Note: Different lower case letters in the same column represent significant different ($p<0.05$) within the same drying method; different capital letters in the same column represent significant different ($p<0.05$) within the same moisture content.

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TABLE 3. EFFECT OF DIFFERENT STERILIZATION METHODS ON THE QUALITY OF DEHYDRATED SOAKED SOYBEAN AND THE CORRESPONDING SOYMILK

Sterilization method		PPO activity(%)	POD activity(%)	Anti-browning effect (d)	Microbial load (log 10 CFU/g)	Protein content (g/100ml)	Soluble solids(%)	Stability	Sensory score
Pasteurization	70°C	62.1±3.4d	76.4±2.6c	8±1efg	3.21±0.03b	2.05±0.03g	5.1±0h	0.583±0.010g	65±3f
	80°C	38.9±1.1g	57.3±1.8de	10±1cde	3.13±0.09bcd	2.20±0.04f	4.9±0.1i	0.582±0.013g	74±3cde
	90°C	28.3±1.7i	45.9±3.1f	10±2def	3.02±0.05cd	2.29±0.05e	5.1±0.1h	0.604±0.015f	72±2e
Microwave Sterilization	30s	57.8±4.2e	58.8±3.1d	12±1c	3.15±0.11bc	2.45±0.03d	5.7±0.1d	0.685±0.019b	81±2ab
	40s	34.4±2.4h	35.4±3.5g	14±2b	2.96±0.04d	2.41±0.03d	5.3±0.1fg	0.653±0.016cd	78±3bc
	50s	11.9±1.3j	13.7±2.6h	15±1b	2.74±0.12e	2.32±0.08e	5.3±0f	0.644±0.005de	76±4bcde
Irradiation Sterilization	4KGy	93.9±2.6a	95.8±2.0a	7±2g	2.45±0.07f	2.27±0.04e	5.3±0f	0.629±0.010e	74±3cde
	6KGy	90.1±3.2a	92.5±2.2a	7±1g	1.94±0.11g	2.29±0.05e	5.2±0g	0.611±0.003f	74±2cde
	10KGy	82.5±3.1ba	85.1±0.9b	8±1fg	—	2.47±0.03cd	5.5±0.1e	0.605±0.008f	79±3ab
Chemical sterilization	A	80.4±0.9b	78.8±3.2c	10±2cd	3.50±0.05a	2.53±0.04bc	5.8±0.1c	0.652±0.009cd	80±3ab
	B	56.9±2.5e	53.8±2.3e	15±1b	3.02±0.11cd	2.58±0.06b	6.0±0.1b	0.665±0.006c	78±3bc
	C	75.7±2.3c	80.6±3.0c	8±1fg	3.28±0.18b	2.47±0.06cd	5.9±0.1bc	0.647±0.005cd	78±1bcd
	D	49.2±1.9f	56.8±1.4de	11±2cd	3.16±0.08bc	2.53±0.06bc	5.7±0.1d	0.655±0.006cd	73±3de
Combined sterilization		11.1±2.4j	16.3±3.2h	21±2a	—	2.69±0.02a	6.2±0a	0.764±0.002a	84±2a

Note: "—"means not detected; different letters in the same column represent significant different (*p*<0.05).

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TABLE 4. EFFECTS OF STORAGE TEMPERATURE AND TIME OF SM SOYBEANS ON THE QUALITY OF SOYMILK

Storage Temperature/ °C	Storage Time/d	Protein content (g/100mL)	Soluble solids /%	L^*	a^*	$b*$	$\Delta E*$	Stability	Sensory score
25	0	2.69±0.02a	6.2±0a	74.07±0.05a	-0.85±0.03g	15.62±0.05a	0±0f	0.764±0.020a	84±2a
	10	2.60±0.05ab	6.1±0.1a	73.46±0.29b	-0.77±0.04f	15.42±0.18ab	0.68±0.23e	0.757±0.019ab	83±2a
	20	2.53±0.10bc	5.9±0.1b	73.10±0.30c	-0.66±0.03e	15.13±0.30c	1.17±0.37d	0.749±0.009abc	80±1b
	30	2.48±0.06c	5.7±0.1c	72.93±0.22c	-0.65±0.04e	15.16±0.03c	1.25±0.15d	0.737±0.008bc	78±1bc
	40	2.43±0.03c	5.7±0.1c	71.98±0.15d	-0.65±0.04e	15.56±0.21a	2.11±0.20c	0.725±0.012cd	77±2bcd
	50	2.33±0.06d	5.6±0.1d	71.76±0.28d	-0.63±0.01e	15.45±0.04ab	2.33±0.25c	0.724±0.005cd	75±2cd
	60	2.31±0.03d	5.5±0e	71.86±0.04d	-0.55±0.03d	15.41±0.06ab	2.24±0.03c	0.711±0.005de	74±2d
	70	2.27±0.05d	5.4±0.1f	71.90±0.02d	-0.47±0.05c	15.67±0.01a	2.20±0.06c	0.696±0.014ef	71±2e
	80	2.23±0.09de	5.2±0.1g	71.33±0.07e	-0.33±0.03b	15.46±0.05ab	2.79±0.05b	0.675±0.024f	65±3f
	90	2.16±0.03e	4.9±0.1h	70.39±0.08f	-0.24±0.06a	15.24±0.07cd	3.75±0.13a	0.630±0.009g	61±2g
4	0	2.69±0.02a	6.2±0a	74.07±0.05a	-0.85±0.03e	15.62±0.05a	0±0d	0.764±0.020a	84±2a
	30	2.59±0.06bc	6.1±0.1b	74.13±0.08a	-0.98±0.01f	15.50±0.02a	0.17±0.07d	0.755±0.010ab	82±2ab
	60	2.54±0.05cd	6.0±0.1c	72.77±0.49b	-0.86±0.03e	15.35±0.08a	0.75±0.19c	0.742±0.009b	79±2bc
	90	2.44±0.05de	5.8±0.1d	72.38±0.21bc	-0.78±0.04d	15.37±0.05a	0.74±0.17c	0.733±0.019b	76±2cd
	120	2.36±0.05d	5.7±0.1e	72.25±0.41bc	-0.66±0.02c	15.47±0.11a	2.12±0.26b	0.701±0.003c	76±3d
	150	2.25±0.10e	5.7±0.1e	72.18±0.04bc	-0.63±0.02bc	15.52±0.06a	2.02±0.10b	0.692±0.010c	73±2d
	180	2.19±0.08e	5.5±0f	71.91±0.15c	-0.61±0.00b	15.51±0.05a	2.18±0.19b	0.664±0.012d	67±2e
	210	2.14±0.06e	5.2±0.1g	71.04±0.61	-0.55±0.04	14.83±0.12	3.15±0.35a	0.650±0.008d	62±1f

Note: Different letters in the same column represent significant different (p<0.05).

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