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Preservation and processing of soymilk: A review

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Abstract
Soy milk is a plant based drink prepared by soaking dried soybeans and grinding them in water. It is a highly nutritious which contains protein, fat, carbohydrates vitamins and minerals. The greatest problem with soy milk is its very short shelf life due to microbial activity. The combination of different preservation methods is just the solution to the problem of short life. The different preservation techniques which can be applied to soymilk are chemical preservatives, heat processing, high pressure processing, pulse electric field, ohmic heating and drying. All these preservation technique gives best results if stored at refrigerated condition as compare to storage at room temperature.

Keywords: soymilk, preservation, preparation, food safety, shelf life

Introduction

Soymilk is an aqueous, white, creamy extract produced from soybeans which is similar to cow milk in appearance and consistency. It is a highly nutritious which contains protein, fat, carbohydrates vitamins and minerals [1]. It is because of this nutritious value and comparative low cost, that soymilk plays an important role in the dietary pattern of people in most developing countries [2]. The nutrients content in eight ounces of plain soymilk are 140gm calories, 10gm protein, 4gm fat, 14gm carbohydrate, 120mg sodium, 1.8mg iron, 0.1mg riboflavin and 80mg calcium [3]. It has about the same amount of protein as cow's milk, though the amino acid profile differs [4].

The increasing popularity of soymilk as a beverage worldwide is credited to health benefits e.g. low cholesterol and lactose, its ability to reduce bone loss and menopausal symptoms, prevention and reduction of heart diseases and certain cancers [5]. As this drink is cholesterol free and low in energy, it could enhance health benefits in terms of reducing body weight and blood lipids [6]. With its unique nutty flavor and rich nutrition, soymilk can be used as supplementary way of dairy milk. It is available as a plain, unflavored beverage or in a variety of flavored beverage including chocolate, vanilla and almond. Soy-based diets can reduce blood pressure in spontaneously hypertensive rats but apparently not in hypertensive humans [7].

Preparation of Soy Milk

Soybean was sorted and cleaned to remove stones and damaged, deformed seeds. Then the dry soybean was washed and soaked in water (500g in 1 Liter) for 12 hours. It was then rinsed and blanched in 1.25% $NaHCO_3$ for 30 minutes. The rehydrated soybean was washed, manually dehulled and rinsed. The soybean seeds were ground in blender and expressed in the ratio of 3:1 (water to beans on a weight basis) to remove the okra. The obtained milk is then formulated by adding anti-oxidants and preservatives. The milk was then pasteurized at the temperature 71ºC for 15 seconds and subsequently bottled and stored at ambient and refrigeration temperature [8].

Preservation methods of soymilk and milk product

The nutritious nature of soymilk makes it prone to microbial attack as the nutrients it contains are also required for the growth of most spoilage organisms if not properly processed and stored. A large number of microorganisms such as coliforms, mesophilic aerobic bacteria, yeasts and moulds are responsible for the spoilage of soymilk and it can produce undesirable changes in the milk [9]. A large number of preservation techniques exist including ohmic heating, high pressure processing, drying, pulse electric field processing etc. Some of these applications are discussed as below:

Preservation by using preservatives

The preservatives in food preparations inhibit or retard the growth of microorganisms which reduces the deteriorative effects of microorganism on food [10]. The soymilk is stable upto two days at room temperature without addition of any preservatives and by using different types of preservatives in different levels the shelf life can be increased upto 14-17 days at refrigeration temperature. Potassium-meta-bi-sulphite (KMS), Sodium-benzoate and potassium sorbate can be used individually or in a mixture of the three for preservation of soymilk. Sodium benzoate and Potassium meta bi-sulphite are acceptable then potassium sorbate because these two preservatives not only preserve soymilk upto 17 days but also increase the colour, flavor, taste and overall acceptability of soymilk. The mixed preservatives can give shelf life of 17 days but decreases the colour, flavor, taste and overall acceptability of soymilk [11]. The soy milk can be kept for up to 13 days at refrigerated condition without no multiplication of mesophilic aerobes above $3x10^3$ cfu/mL when preserved with 700-800 parts per million (ppm) of sodium benzoate, pasteurization and refrigeration while a combination of 175 ppm of sodium metabisulphite and 400 ppm of sodium benzoate can achieve a preservation of the milk for about 11 days [12]. The effect of levels and types of different preservatives in total viable bacterial count is shown in Table 1.

Table 1: Total viable bacterial count of five different soymilk samples [11]

Samples	Preservatives			Total viable bacterial count (CFU/ml)	Total viable bacterial count (log CFU/g)
	Potassium meta-bi sulphite (KMS)	Sodium-benzoate	Potassium Sorbate		
1	0	0	0	197000	5.294
2	300	0	0	196667	5.293
3	0	350	0	177000	5.248
4	0	0	350	168667	5.277
5	250	250	200	132000	5.120

The pH values for clove extract-treated soymilk samples on shelf can increase the level of acidity (5.16±0.13) as compare to treated-refrigerated samples (6.62±0.03), while the protein contents decreases more with storage time. The fat contents of the samples treated with a combination of extracts of cloves (Syzygium aromaticum myrtaceae) and guinea-pepper (Xylopia aethiopica annonaceae) are significantly higher than the untreated soymilk samples. There is more pronounced reduction in total microbial count in samples treated with clove extract (1.92 x 10^5) as compare to the samples treated with guinea pepper extract (2.70 x 10^5). The cloves and guinea pepper extract gives the best preservative effect as compare to the single extracts in terms of nutrient content. Cloves used as a preservative increases the shelf life of soymilk by 2 days at room temperature and 8 days in refrigerated condition. Guinea pepper extends the shelf life by 1 day at room temperature and 6 days in refrigerated condition while combination of these extracts maintain longer shelf life of 12 days in the refrigerated condition and 2 days at room temperature [10]. The fresh soybean milk applied with the heat treatment at 100°C for 10 minutes, and nisin 0.004%, nipagin complex esters 0.008%, dehydroacetate 0.002% can be maintained under upper limit of the microbial count (100 CFU/mL) for more than 6 days at 25°C, and 11 days at 4°C [13].

The highest number of aerobic count at the end of storage in the samples without treatment is 1.15x10^6 at ambient temperature. There is a significant difference (P<0.05) in the aerobic count between the $NaHCO_3$ treated soymilk and Na_2CO_3 treated soymilk. Similar comparable trends are there in fungal population in all the samples. Both samples treated with Na_2CO_3 and $NaHCO_3$, have similar counts. Growth of S. typhi and Staph. Aureus is absent in all the samples. At refrigerated temperature, there is no growth in aerobic population from day 0 to 6 days in all the samples. The soymilk can be kept for up to 16 days at refrigeration temperature, during which no reasonable multiplication of mesophilic aerobes above 3x10^4 CFU/ml is observed and total inhibition of yeast and molds is achieved up till 12 day. The use of $Na_2CO_3$and $NaHCO_3$ can therefore be an additional/complementary method of soymilk preservation, since potassium sorbate and sodium benzoate are known to act at lower pH [8].

The shelf life of soy-milk based juice can be increased by adding 0.5-3.0 grams of the Aframomum danielli spice powder to every 200ml of the blend. The differences can be observed in the colour and aroma of treated samples in comparison with the untreated samples. The percentage loss of the ascorbic acids, total soluble solids and total sugars of treated samples is far lesser than those of untreated samples in the same condition and period of storage. The treated samples preserves better than the untreated samples [14].

Preservation by heat treatment

Heating soymilk at 143 °C for 60 s, it can be possible to produce commercially sterile soy milk with satisfactory trypsin inhibitor activity (TIA) inactivation. It can also be possible to produce milk with highly acceptable color, flavor, and thiamin retention between 90 and 93% [15]. On the basis of the quality attributes like viscosity, TSS, titrable acidity, pH, standard plate count, yeast and mold count, the sterilized soymilk samples at 121°C for 15 min after bottling is acceptable up to 170 days in refrigerated condition (4°C) while same samples is acceptable up to 90 days in ambient temperature condition from the day of preparation [16].

Preservation by ohmic heating

Ohmic heating is an advanced thermal processing method which prolongs the shelf -life of a number of food products by killing spoilage organisms. In this process, the electric current is passed through the food materials, which cause heat generation within the food product because of resistance of food against the applied electrical current [17]. The urease activity of the sample which is ohmically heated is significantly lower than that of the sample conventionally heated (P < 0.01) at the same temperature. Electric field not effects the inactivation of the thermostable isoenzyme of the urease [18]. The electrical conductivity of soya milk is proportional to the heating time. The temperature rising rate increased from 1.46˚C to 3.82˚C/min results increased voltage. Hence ohmic heating can be an efficient, convenient heating measure in tofu making [19].

Trypsin inhibitor activity (TIA) and chymotrypsin inhibitor activity (CIA) inactivation in ohmic heated smaple is slower from 0 to 3 min, and faster after 3 min as compared to induction cooker and electric stove heated sample. The thiol (SH) loss rate is slower from 0 to 3 min, and similar to induction cooker and electric stove after 3 min. Ohmic heating slightly increase the protein aggregate formation Ohmic heating is more energy-efficient for TIA and CIA inactivation. TIA and CIA inactivation is accelerated with increase in electric voltage (110, 165, and 220 V) of ohmic heating. The enhanced inactivation of TIA by ohmic heating is due to its combined electrochemical and thermal effects [20].

Preservation by high pressure processing

High pressure processing (HPP) is a "non-thermal" method for food preservation to efficiently inactivate the vegetative microorganisms which are most commonly related to deterioration of food and for food-borne diseases [21, 22]. It is a method for killing of microorganism high pressure (HP) is applied to preserve the foods from microorganisms without the use of heat [23]. Ultra high pressure homogenization (UHPH) at 200 and 300 MPa reduces the initial counts, spores and enterobacteria counts. There is colour difference between UHPH and soymilk base product (BP) or ultra high temperature (UHT) treated soymilks. Treated soymilk at 300 MPa shows the lowest value of L^*, a^* and b^* coordinates. UHPH processed samples are more stable than BP and UHT soymilks and these differences are also observed at days 30 and 60 of storage at 4 °C. The soymilk proteins are partially denatured by 200 MPa, whereas UHPH treatment at 300 MPa shows the same extent of denaturation as UHT soymilk [24]. To achieve a 5 log reduction in natural flora in the enriched soymilk, the high pressure treatment (HPP) or heat treatments needed are 552 MPa for 4 min at 30°C or for 120 s at 78.2°C, respectively. At equivalent levels for a 5 log reduction in E. coli, HPP and heat treatment causes 25% and no detectable loss in bovine IgG activity, respectively. However, at equivalent levels for a 5 log reduction in natural flora, HPP and heat results in 65 and 85% loss of bovine IgG activity, respectively [25].

After high pressure processing and during storage, there is significant differences in total bacterial count (TBC), *Enterobacteriaceae* (ENT) and numbers of psychrotrophs (PSY), and protein stability between untreated and pressurized samples ($P < 0.05$). Pressure applied at an initial temperature of 75 °C results in a greater suppression in growth of PSY compared to TBC. No ENT is detected in pressurized samples throughout the storage period test. Dwell time have no significant effect on log reduction of TBC at 25 or 75 °C ($P > 0.05$). Treatment at pressure 400 MPa for 5 min, 500 and 600 MPa for 1 and 5 min produces 100% sub-lethal injuries in surviving of bacterial populations irrespective of temperature. After 28 days of refrigeration storage, both aerobic and anaerobic pressurized samples have better or similar stability as the control on day one of storage. Soymilk control samples are spoiled after 7 days whereas pressurization increases the soymilk shelf-life by at least 2 weeks. Pressure (600 MPa) at 75 °C for 1 min not only significantly reduces the initial microbial populations and increases the microbial shelf-life but also extends the protein stability of soymilk ($P < 0.05$) [26]. The pressure treatment of soy milk at 207 and 276 MPa pressure, 121 and 145ºC exit temperatures, and 0.75 and 1.25 L/min flow rates remains stable for 28 days. There is a significant reduction in the particle size of soybean solids which did not change during storage. The pH of the treated soy milk is significantly lower than the untreated soy milk and it reduces further upon storage. The soy milk is pasteurized with high pressure processing coupled with preheating. No lipoxygenase activity is detected. Compared to commercial samples, there is no significant difference in the astringency, bitterness, or chalkiness of prepared soy milk [27].

Preservation by pulsed electric field

Pulsed electric field (PEF) is one of the non-thermal methods of food preservation. The basic principle of the PEF technology is the application of short pulses of high electric fields for micro-seconds to milliseconds. The food is then packaged aseptically and stored in refrigerated condition [28, 29]. It uses short pulses of electricity for microbial inactivation and causes minimal effect on food quality [30]. The PEF treatment at electric field intensity of 18, 20 and 22 kV cm^{-1} and number of pulses of 25, 50, 75 and 100 affects the rheological properties of soy milk. Apparent viscosity of soy milk increases from 6.62 to 7.46 (10^{-3} Pa s) with increase in electric field intensity from 18 to 22 kV cm^{-1} and increase in the number of pulses from 0 to 100. The consistency index (K) of soy milk also changes with PEF treatments. Lightness (L*), red/greenness (a*) and yellowness/blueness (b*) of soy milk are affected by PEF treatments [31]. The highest level of inactivation (84.5%) is obtained using a combination of preheating to 50 °C, and a PEF treatment time of 100 µs at 40 kV/cm. The calculated D values following pre-heating to 50 °C are 172.9, 141.6 and 126.1 µs at 20, 30 and 40 kV/cm, respectively [32]. Residual activity of soybean lipoxygenase decreases with the increase of treatment time, pulse strength, pulse frequency and pulse width. The maximum inactivation of soybean lipoxygenase by PEF achieve 88% at 42 kV/cm for 1036 µs with 400 Hz of pulse frequency and 2 µs of pulse width at 25 °C [33].

Preservation by drying

Drying or dehydration helps to increase shelf life and easier transportation and storage, enabling wider distribution of the product [34]. Residual moisture content is low at higher inlet air temperature, higher atomization pressure, lower feed flow rate, and higher air flow rate in spray drying. Porosity reduces with increase atomization pressure. Higher product yield is obtained at low feed flow rate and high air flow rate. The increase in the atomization pressure increases the cohesiveness between particles and results in reduced flowability. Protein denaturation during the process reduces the product solubility [35]. The vacuum freeze dried (VFD) at 0.6 and 1.2 mmHg product kept the spherical shape, although spheres are fragile. Several Atmospheric freeze dried (AFD) particles collapses. Both VFD and AFD conditions produces a notorious increase in the yellowness of the final product. This effect is more significant in AFD-dried particles. The effective diffusivity (D_{eff}) values obtained are in the expected range for porous particles in freeze drying process, and are in the order of 10^{-10} to 10^{-13} m^2/s [36].

Conclusion

Present review concludes that soymilk is highly nutritious which contains protein, fat, carbohydrates vitamins and minerals similar to cow milk. The shelf life of soymilk can be increased by different techniques of preservation. The non-thermal methods like high pressure processing and pulse electric field processing shows better result in terms of quality of soymilk as compare to the thermal methods of preservation like heating and drying. There is minimum change in color after non thermal methods of preservation. The self life can be increased with best results in quality if stored at refrigerated condition.

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