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RESEARCH ARTICLE

QUALITY OF COW MILK SET YOGHURT STABILIZED WITH NATIVE SWEET POTATO *(Ipomoea batatas* L.) STARCH EXTRACTED USING DIFFERENT METHODS

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Abstract

Gelatin extracted from animal tissues is widely used to stabilize set yoghurt. However, there is an increased consumer preference for plant-based stabilizers, such as starch, over animal-based gelatin in yoghurt products. The properties of starch depend on the extraction method and affect the quality of the final product. Therefore, this study investigated the quality of cow milk set yoghurt stabilized with sweet potato *(Ipomoea batatas* L.) starch (SPS) extracted using three different methods. Sweet potato tubers (3 kg) were washed, peeled and divided equally into 3 lots. Starch was extracted by blending each lot separately with distilled water (1:1) (SPS1), 1M NaCl (1:1) followed by centrifugation at 2200 rpm/15 min (SPS2), and distilled water (1:1) followed by centrifugation at 2200 rpm/15 min (SPS3). Experimental yoghurts (3% fat, 7% sugar) were prepared using gelatin (Control), SPS1 (T1), SPS2 (T2) and SPS3 (T3) as the stabilizer at the rate of 0.5% (w/w) and arranged according to completely randomized design with 3 replicates. The physicochemical and functional properties of SPS and yoghurt and the sensory attributes of yoghurt were investigated using standard methods. Data were analyzed with SPSS software (ver. 25) employing the analysis of variance (ANOVA) procedure followed by Tukey's test for mean separation, while sensory data using the Friedman non-parametric test. SPS1 had the highest water absorption capacity of 0.780±0.002 mg/g and was significantly ($p<0.05$) different from SPS2 and SPS3, while pH was significantly ($p<0.05$) higher in SPS2. Moisture content in SPS produced with different methods was in the agreeable range (12.73±0.05 to 16.74±0.03%) and significantly ($p<0.05$) different with the starch extraction method. Swelling power and solubility of SPS were increased with the increase of temperature from 50°C to 80°C. Compared to the control, yoghurt manufactured using SPS showed significantly lower ($p<0.05$) water holding capacity except in T2, while spontaneous whey syneresis was not detected in any of the treatments. The colour of the yoghurts was not affected by the stabilizers used except the *b value. Sensory evaluation revealed no differences between the treatments, indicating the possibility of using SPS extracted using the methods mentioned as a stabilizer in the production of set yoghurt, which is comparable to gelatin.**

Keywords: Spontaneous whey syneresis, Solubility, Stabilizer, Swelling power, Water absorption capacity

INTRODUCTION

Yoghurt is one of the most popular and widely consumed fermented dairy products having several nutritional and health benefits. Two main types of bacteria are involved in the fermentation of yoghurt, namely *Streptococcus thermophilus* and *Lactobacillus delbrueckii* sub spp. *bulgaricus* (Tamime and Robinson, 2000). When lactose in milk is used by these microorganisms as the fermentation substrate, lactic acid and a series of other compounds are formed contributing to its flavour. Due to the reduction in pH, calcium and phosphorus present in milk are converted into soluble forms that are better utilized. Apart from that, majority of milk proteins free of calcium are better digested by the proteolytic enzymes (Fisberg and Machado, 2015). Therefore, yoghurt is a highly digestible dairy product with various bioavailable nutrients. It is not only a good source of protein, calcium, potassium, phosphorus, iodine, vit. B2, B12 etc. but also serves as a vehicle for fortification (Moore *et al*., 2018; Fisberg and Machado, 2015). Due to its healthy image, yoghurt has a growing consumer demand throughout the world. It has been reported that

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the global yoghurt market reached a value of over US$ 113.5 billion in 2022 and is forecasted to reach about US$ 164 billion by 2028 (Shahbandeh, 2023). Various yoghurt varieties exist in the market at present, such as natural, flavoured, fruit, nut, probiotic, prebiotic, symbiotic, non-fat, reduced fat, full fat, etc. Further, depending on the consistency and the physical form, different variants such as set, stirred, drinking, strained, frozen etc. are also commonly available in the market. In Sri Lanka, set yoghurt is the most common variant even though the other physical forms also have an emerging market at present.

Maintaining optimum consistency, texture and stability during production, transportation, and storage are the major challenges faced by the yoghurt industry (Saleh *et al*., 2020). Especially in the case of set yoghurts, stability during transportation is a crucial factor to be considered. The major factors influencing the yoghurt consistency are differences in the processing variables, viscosity at high total solids content, texture and characteristics of the starter culture used in the production process (Omer, 2003). Use of an appropriate stabilizer in the production process of yoghurt is an essential need for the final product quality and consistency. Stabilizers can improve the viscosity and sensory properties, and inhibit or decrease whey separation during storage and transportation of yoghurt (Saleh *et al*., 2020). Various stabilizers, including carrageenan, guar gum, locust bean gum, pectin, starch, gelatin, etc. are added to obtain proper stability and the right texture for the yoghurt. Some of them are synthetic, while others are of plant and animal origin. Due to its unique hydrophilic character and exceptional biocompatibility, gelatin is widely used in the food industry (Milanovic *et al*., 2014) and has been considered as one of the most preferable stabilizers that can be used in dairy products (Pang *et al*., 2022). Gelatin is a multi-functional stabilizer commonly used in the production of set yoghurt. It enhances the gel strength, viscosity, and water binding capacity, modifies the texture, increases the emulsion formation of milk, and stabilizes the yoghurt while minimizing whey syneresis. Additionally, it imparts fat-like sensory perception, especially in low-fat yoghurt (Pang *et al*., 2017; Karim and Bhat, 2009; Kalab *et al*., 1975).

Gelatin is an animal protein produce from collagen. It is mainly produced from pig skin (type A) and bovine hides (type B) (Alipal *et al*., 2021). Despite the increasing demand for gelatin in various applications, there is a growing consumer concern about the use of gelatin in the food industry due to its animal origin, high cost, and growing demand for natural and halal products. According to Abdullah *et al*. (2018), the rising demands, health concerns, and religious issues have intensified the need for alternatives to gelatin. As a result, plant-origin stabilizers, especially the starches from potato, sweet potato, cassava tuber, and taro, have been introduced as alternatives for gelatin in various food applications. Starches are the major storage polysaccharides in foods of plant origin. Cereals, tubers, roots, and pulses are the most common botanical and commercial starch sources. Starch is used in the production of yoghurt as a thickener to reduce defects, improve body and texture, as well as reduce cracks in the surface of the curd (Altemimi, 2018).

Sweet potato (*Ipomoea batatas* L.) belongs to the Convolvulaceae family and originated in Central America (Huang and Sun, 2000; Zhang *et al*., 2000). It is one of the important and underutilized crops grown in Sri Lanka which has enormous potential in various food applications. The world's total sweet potato production in the year 2014 was more than 106 million metric tons. In 2014, about three-fourths of the global production was from Asia and Pacific Islands (China is the world leader in sweet potato production with a share of 67%), followed by Africa with about 21%, while the Americas (North, Central, and South) account for about 3.6% (Truong *et al*., 2018). In some parts of the world, such as in Papua New Guinea, sweet potato is consumed as the staple food, and the average annual consumption is around 550 kg per person. Consumption has been greatly increased in the USA due to the availability of frozen 'french-fried' sweet potatoes (Truong *et al*., 2018). Apart from their use in many food applications, such as the production of vermicelli, noodles, jelly sheets, fried chips, alcoholic drinks, jam, cake, and steaming bread etc. (Zhu *et al*., 2011; Avula, 2005), the tubers have shown potential as a source of starch in various industrial applications. It has been reported that sweet potato starch (SPS) is used as a thickener, binder, adhesive, gelling agent, encapsulating agent, film forming, stabilizer, texturizer, and fat-replacer in a variety of foods (Sameen *et al*., 2016). On a dry matter basis, it contains 50-80 per cent starch. Sweet potato starch has an A-type (high swelling) pattern, with medium-sized granules that are smooth, round, or oval in shape. Different methods have been used to extract SPS using chemicals such as sodium metabisulphate and sodium chloride, as well as distilled water. However, it is reported that the properties of SPS can vary depending on the extraction method (Surendra Babu and Parimalavalli, 2014). Hence, it is important to study the influence of the extraction method on the properties of SPS, and the quality of cow milk set yoghurt manufactured using it. Therefore, a study was planned to investigate the possibility of utilizing SPS extracted using different methods as a stabilizer in the production of cow milk set yoghurt.

MATERIALS AND METHODS

Materials

Good quality purple skin sweet potato tubers with white flesh were bought from the local market in Kamburupitiya, Sri Lanka. Fresh cow milk was purchased from the farm of the Faculty of Agriculture, University of Ruhuna. Fermentation of yoghurt was carried out using freeze-dried thermophilic yoghurt starter culture containing *Streptococcus thermophilus* and *Lactobacillus delbruekii* ssp *bulgaricus* (1:1 ratio) (Chr. Hansens Laboratories, Denmark). Skim milk powder (Anchor, Fonterra, Sri Lanka), sugar, gelatin, vanilla flavour and polystyrene yoghurt cups were obtained from the local market, Kamburupitiya, Sri Lanka.

Methods

Preparation of sweet potato tubers and extraction of starch

Mature, good-quality sweet potato tubers (3 kg) were washed with cold water to remove impurities. Then, the peels were removed, and the edible portion was taken. Three alternative procedures were used according to the method outlined by Surendra Babu and Parimalavalli (2014), with slight modifications to extract starches from the edible portions of sweet potato tubers.

1) Distilled water extraction without centrifugation

The edible portion of sweet potato tubers was sliced into small pieces and blended using a kitchen blender for two minutes with distilled water (1:1). The slurry was filtered using three layered cheesecloth, and the filtrate was allowed to settle for three hours at room temperature (26±1 °C). The precipitated starch was washed three times using distilled water and dried at room temperature (26±1 °C) for two days. The extracted starch (SPS1) was kept in an oven at 50±1 °C for three hours before being ground into a fine powder with a mortar and pestle (Surendra Babu and Parimalavalli, 2014).

2) NaCl extraction with centrifugation

The edible portion of sweet potato tubers was sliced into small pieces and blended with 1 M NaCl solution (1:1) in a kitchen blender for two minutes. Triple-layered cheesecloth was used to filter the slurry, and distilled water was used to wash the starch. While allowing the starch granules to settle, water was decanted. The sediments were centrifuged for 15 minutes at 2200 x g. The starch was taken out, dried overnight at room temperature (26±1 °C), and then ground into a fine powder (SPS2) using a mortar and pestle according to the method proposed by Surendra Babu and Parimalavalli (2014).

3) Distilled water extraction with centrifugation

The edible portion of sweet potato tubers was sliced into small pieces and blended with distilled water (1:1) in a kitchen blender for two minutes. A Triple-layered cheesecloth was used to filter the liquid, and distilled water was used to wash the starch. While allowing the granules to settle, water was decanted. Fifteen minutes were spent centrifuging the sediments at 2200 x g. The starch was taken out, dried overnight at room temperature (26±1 °C), and ground into a fine powder (SPS3) using a mortar and pestle, as reported by Surendra Babu and Parimalavalli (2014).

Manufacturing of yoghurt

Raw cow milk (3.67±0.58 % fat and 8.74±1.31 % SNF) was preheated to 40±1°C and cream was separated using a cream separator. Milk was standardized to 3% fat and 12 % SNF by adding the required amount of cream and SMP. The extracted SPS was used separately according to the extraction method at the rate of 0.5% to prepare 3 batches of yoghurt, and gelatin was added as the stabilizer at the rate of 0.5 % to prepare the control yoghurt (Table 1).

Table 1: Treatments used in the study

Treatment	Description
C	Yoghurt stabilized with 0.5 % (w/w) gelatin
T1	Yoghurt stabilized with 0.5 % (w/w) SPS1
T2	Yoghurt stabilized with 0.5 % (w/w) SPS2
T3	Yoghurt stabilized with 0.5 % (w/w) SPS3

C: Control; SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min

The resultant yoghurt mixes were separately pasteurized at 85°C for 30 minutes. Then the yoghurt mixes were cooled to 42°C in a water bath. Direct vat set (DVS) yoghurt starter culture containing *S. thermophilus* and *L. delbruekii* ssp. *bulgaricus* (1:1) was added at the rate of 2 % of the yoghurt mix and mixed well for the proper distribution of the culture microorganisms. The vanilla flavour (0.01 % v/w) was added as the flavouring agent and mixed well, and the yoghurt mix was poured into 80 mL polystyrene cups. They were kept in an incubator maintained at 42±1°C temperature until the desired pH of nearly 4.6 was attained. The resultant yoghurts were immediately kept in a refrigerator maintained at 4±1°C until further analysis.

Proximate composition and pH of SPS

The crude protein percentage of the SPS was determined by using the Kjeldahl method (N × 6.25). Soxhlet procedure was used to determine the fat percentage of the SPS. The oven dry method was used to determine the dry matter and moisture content of SPS. The Ash content of the SPS was determined by the ignition method as mentioned in AOAC (2000). The pH of SPS was measured as follows. Five grams of starch sample was mixed in 25 mL of distilled water for 60 seconds and allowed for settling 15 minutes. After that, the pH of the water phase was measured using a benchtop digital pH meter (Agilent, 3200P) after calibration with fresh pH 4.0 and 7.0 standard buffers at 25°C (ISI 26, 1999).

Physical properties of SPS

Water absorption capacity (WAC)

In a centrifuge tube with a defined weight, 1 g of the starch sample was mixed with 10 mL of water. After keeping for 30 minutes, the mixture was centrifuged (2200 × g, 15 minutes), and the supernatant was discarded. The gain in weight of the tube was recorded. The WAC was calculated as follows, according to Surendra Babu and Parimalavalli (2014).

$$\text{Water absorption capacity (\%)} = \frac{\text{Gain in weight (g)}}{\text{Initial weight of the starch (g)}} \times 100$$

Solubility and swelling power

Distilled water (180 mL) was added to a 2 g sample of SPS in a centrifuge tube before being heated in a water bath at 50 to 90°C for 30 minutes with 10°C intervals. The suspension was heated and centrifuged for 15 minutes at 2200 × g. Suction was used to remove the supernatant, which was then dried for 4 hours at 120°C in an oven to determine the amount of soluble starch extracted. Solubility and the swelling power of SPS were calculated following the method mentioned by Surendra Babu and Parimalavalli (2014) as follows.

$$\text{Solubility (\%)} = \frac{\text{Soluble starch weight (g)}}{\text{Initial weight of the starch (g)}} \times 100$$

The weight of the sedimented paste per gram of dried starch was used to calculate the swelling power of SPS.

$$\text{Swelling Power} = \frac{\text{Weight of the sedimented paste (g)}}{\text{Initial weight of the starch (g)}}$$

Physicochemical properties of raw milk, yoghurt mix and finished yoghurt

The pH of raw milk, yoghurt mix and the finished yoghurt were measured using a benchtop digital pH meter (Agilent 3200P, USA) after calibration with fresh pH 4.0 and 7.0 standard buffers at 25°C. Titratable acidity (TA) of raw milk, yoghurt mix and the finished yoghurt was determined by titrating with 0.1 N NaOH using 0.5 % phenolphthalein indicator. Total solids and solid-not-fat contents of milk were determined by the lactometer method, whereas the fat content was using the Gerber method.

Physical properties of yoghurt

Spontaneous whey syneresis (SWS)

Spontaneous whey syneresis was determined in undisturbed set yoghurt samples according to the method proposed by Amatayakul *et al.* (2006) and modified by Narayana and Gupta (2013). A cup of yoghurt (80 mL) was tilted at an angle of 45° to collect the surface whey, immediately after removing it from the refrigerator. Collected whey was siphoned out by using a needle fitted to a graduated syringe. Siphoning was completed within 10 seconds to avoid forced leakage of whey from the yoghurt. Percent SWS was calculated as follows.

$$\text{Spontaneous whey syneresis (\%)} = \frac{\text{Volume of the siphoned whey (mL)}}{\text{Volume of the initial yoghurt sample (mL)}} \times 100$$

Water holding capacity (WHC)

The WHC of yoghurt was measured by a centrifugation method proposed by Narayana and Gupta (2013) with slight modifications. Ten grams of yoghurt sample was centrifuged at 1,500×g for 10 minutes at 10±1°C within 12 hours of the production of set yoghurt. The supernatant was removed within less than 10 minutes and the wet weight of the pellet was recorded. The WHC was calculated by the following equation.

$$\text{Water holding capacity (\%)} = \frac{\text{Weight of the [native yoghurt (g)} - \text{expelled whey (g)]}}{\text{Weight of the native yoghurt (g)}} \times 100$$

Instrumental colour

Instrumental colour analysis of the yoghurt samples was performed by using PCE-CSM 2 colourimeter calibrated with the white calibration plate provided and as specified by the manufacturer. CIELab colour scale was used to get L^*, a^* and b^* values. The L^* value ranges from 0 to 100, indicating the brightness from black to white; the a^* value indicates the variation from red (+a^*) to green (-a^*); the b^* value indicates the variation from yellow (+b^*) to blue (-b^*) in the CIELab colour scale.

Sensory evaluation

Sensory evaluation was carried out by using an untrained panel of thirty judges, following the method proposed by Mason and Nottingham (2002) for the finished yoghurt samples for appearance, flavour, texture, acidity and overall acceptability after one day of refrigerated storage at 4±1°C. Non-smoking, regular yoghurt-consuming healthy adults who were willing to participate in the sensory evaluation test were selected. Individual sensory booths were prepared with the yoghurt samples, drinking water to wash off the mouth and a sensory evaluation sheet. The place was well-ventilated, and ample lighting was provided to eliminate disturbances from nuisance odours and insufficient light conditions, respectively. Each yoghurt sample was labelled with random three digits. Panellists were advised to evaluate the samples in a quick manner but not in a hurry using a 5-point hedonic scale (1 = dislike extremely, 2 = dislike slightly, 3 = neither like nor a dislike, 4 = like slightly and 5 = like extremely).

Statistical Analysis

All the experiments were conducted in triplicates. Data were tabulated and analyzed using SPSS (ver. 25) statistical software package. Differences in the mean values of the parameters tested among the treatments were examined using one way ANOVA procedure followed by Tukey's test. Sensory data were analyzed using Friedman non-parametric test.

RESULTS AND DISCUSSION

Proximate composition of SPS extracted using different methods

Table 2 shows the proximate composition of SPS obtained using three different extraction methods. It was observed that the proximate composition varied significantly ($p<0.05$) among the starches extracted by different methods. The lowest moisture percentage was observed in the starch extracted using distilled water without centrifugation and the highest in the starch extracted using distilled water with centrifugation at 2200 × g/ 15 minutes. Babu and Parimalavalli (2014) extracted starch from sweet potatoes using sodium metabisulphite, sodium chloride and distilled water separately and reported that the starch moisture percentage was in the range of 14.11 -17.76. Further, Tsakama *et al.* (2010) studied the physicochemical and pasting properties of starch extracted from different sweet potato varieties grown in Africa and reported that the moisture percentage of the starches varied significantly with the variety as well as with the extent of drying, from 6.83 to 12.4. In another study, Oswal *et al.* (2019) extracted starch from 3 different sweet potato varieties grown in India and observed that the moisture percentage varied from 14.23 to 14.82. In the current study, even though the same variety of sweet potato was used, 3 different starch extraction methods having slight variations in drying were employed in accordance with the past literature and observed that the moisture percentage was between 12.73±0.05 to 16.74±0.03. Nevertheless, the moisture percentage observed was within the range of 10-20 %, which is recommended for commercial starches (Soni *et al.* 1993). The dry matter percentage of the starches was in the range of 83.26±0.03 to 87.27±0.05, and in their study, Babu and Parimalavalli (2014) reported that the dry matter percentage of SPS extracted was between 82.22 to 85.88. Further, Oswal *et al*. (2019) stated that the dry matter percentage of starches extracted from 3 different Indian sweet potato varieties varied from 82.94 to 83.51. The protein, fat and ash percentages of extracted SPS were observed to be low, indicating the high purity of starch. The ranges of protein, fat and ash percentages were from 0.14±0.01 to 0.22±0.02, 0.08±0.01 to 0.10±0.01, 0.24±0.01 to 0.32±0.03, respectively in extracted starches and significant ($p<0.05$) variations were observed depending on the extraction procedure.

Table 2: Proximate composition* of SPS extracted using different methods

Sweet Potato Starch	Proximate Composition (%)				
	Moisture	Dry Matter	Protein	Fat	Ash
SPS1	12.73±0.05^{a}	87.27±0.05^{c}	0.19±0.01^{b}	0.10±0.01^{b}	0.30±0.01^{b}
SPS2	14.39±0.03^{b}	85.61±0.03^{b}	0.14±0.01^{a}	0.08±0.01^{a}	0.24±0.01^{a}
SPS3	16.74±0.03^{c}	83.26±0.03^{a}	0.22±0.02^{c}	0.09±0.00^{b}	0.32±0.03^{b}

*n=3

$^{a, b, c}$ Mean±SD with different superscripts within each column differ significantly (*p<0.05*)

(SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min)

Ghoshal and Kaur (2023) extracted SPS using the alkali extraction method with NaOH and the protein and ash percentages they observed were 0.14 and 0.21, respectively. Oswal *et al.* (2019) reported that the protein, fat and ash percentages of SPS extracted from 3 different Indian varieties were in the range of 0.11 to 0.12, 0.05 to 0.06 and 0.33 to 0.34, respectively and more or less similar to the values observed in the current study.

Water absorption capacity and pH of SPS extracted using different methods

The results of WAC and pH of SPS extracted using three different methods are shown in the Table 3. Water absorption capacity ranges from 0.598±0.004 mg/g in SPS extracted using NaCl with centrifugation at 2200 × g/15 minutes to 0.780±0.002 mg/g in SPS extracted using distilled water without centrifugation and was observed to be significantly (p<0.05) different. Babu and Parimalavalli (2014), in their study where 3 different extraction methods were used, reported that the WAC of SPS ranged between 0.62 to 0.66 mg/g and no significant differences were observed depending on the extraction method. Oswal *et al*. (2019) reported 0.61 to 0.89 mg/ g of WAC for starches from Indian sweet potato varieties. The WAC of starch is associated with the interactive forces within the starch components, and weak interactive forces result in higher WAC (Oswal *et al*., 2019). Therefore, it can be stated that SPS1, which was obtained by distilled water extraction without centrifugation, has weak interactive forces compared to the SPS extracted using the other two extraction methods. Further, Cavalcanti *et al*. (2019) reported that the WAC can be further improved by modification of sweet potato starches. The starch they obtained from a sweet potato cultivar had 0.76 g/100 g WAC, which is more or less similar to the values observed in the current study. Also, they mentioned that some products which require characteristics such as improved crunchiness need low water absorption as well as low oil absorption capacities. However, in the current study, improved WAC is much more important since the extracted starch was intended to be utilized as a stabilizer for producing set style yoghurt.

Table 3: Water absorption capacity and pH of SPS extracted using different methods

Sweet potato starch	WAC (mg/g)	pH
SPS1	0.780±0.002[b]	4.5±0.01[a]
SPS2	0.598±0.004[a]	4.7±0.01[b]
SPS3	0.643±0.036[a]	4.5±0.02[a]

n=3

[a, b] Mean±SD with different superscripts within each column differ significantly (*p<0.05*)

(SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/ 15 min)

pH of SPS was observed to be not significantly (P>0.05) different between SPS1 and SPS3 (Table 2). However, the pH of SPS2 was significantly (p<0.05) higher when starch was extracted using NaCl with centrifugation at 2200 × g/15 minutes. This finding agrees with the pH reported by Babu and Parimalavalli (2014) for SPS extracted using different extraction media. The reason might be due to the easy absorbance of CO_2 to water, which makes it acidic and not for NaCl. It ultimately resulted in higher pH in the starch extracted using the NaCl extraction medium. Nevertheless, all the starches extracted using different methods had acidic pH value. This low pH of starch ensures its microbial stability during storage. Tsakama *et al*. (2010) reported that the pH of extracted starch from eleven different sweet potato varieties varied from 4.33 to 5.57. Further, they mentioned that the starch pH is related to starch functionality. High pH starches had increased solubility because of the increased hydrophilic characteristics of the starch at these pH values (Adebowale *et al*., 2005).

Swelling power and solubility of SPS extracted using different methods

Figures 1 (a) and (b) show the changes in swelling power and solubility of SPS extracted using different methods within the temperature range from 50 to 80°C, respectively. The swelling power measures the WHC of starch after being heated, cooled, and centrifuged, while the solubility reflects the degree of dissolution during the starch swelling procedure (Zhang *et al*., 2018).

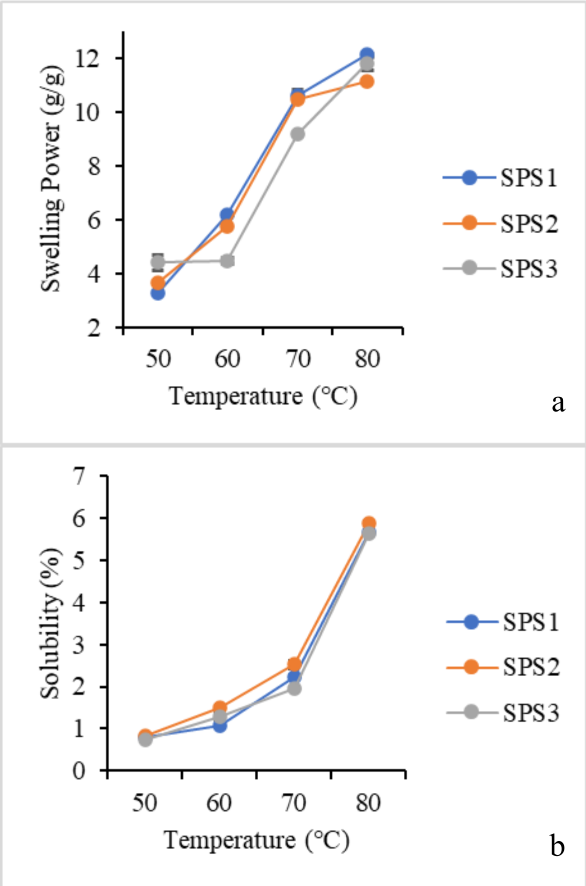

Figure 1: Changes of swelling power (a) and solubility (b) of SPS extracted using different methods with increasing temperature

Values are mean±SD (n=3), SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min

It was observed that the swelling power increased significantly ($p<0.05$) from an initial value of 3.28 - 4.39 to 11.12 - 12.12 g/g with increasing temperature in SPS extracted with different methods, and significant differences were observed with the starch extraction method. This outcome is comparable with the findings of Huang *et al.* (2010), who observed that the swelling power of SPS was found to be 5.23 to 16.38 g/g within the temperature range of 65-95°C. However, Xu *et al*. (2018) reported that the starches extracted from the same sweet potato with different extraction media had similar swelling power and solubility. Further, Babu and Parimalavalli (2014) observed the swelling power of SPS extracted using 3 different methods and reported that it changed from 3.01 to 14.30 g/g. Moreover, they observed that the swelling power increased significantly with the increasing temperature from of 50- 60°C.

The swelling power increased at a decreasing rate from 70-80°C temperature (Figure 1a). Miao *et al*. (2021) mentioned that for the native starches, the swelling power increased as the temperature increased but slightly decreased as the heat treatment was extended. The slight decrease in swelling power might be due to the destruction of starch granules by high temperatures, resulting in restricted swelling, thus decreasing the swelling power (Gul *et al*., 2014). The swelling power of starch is associated with starch and its minor components, such as proteins and lipids, as well as processing conditions (Prinyawiwatkul *et al*., 1997) and amylose and amylopectin present in the starch granules (Tester and Morrison, 1990). The main factor influencing the swelling property is the tightly bound micellar network of the starch polymer (Gujska *et al*., 1994). The low swelling power of starch is due to the extensive and strongly bonded micellar structure (Riley *et al*., 2006) and crystallite formation (Singh *et al*., 2004).

The solubility increased significantly ($p<0.05$) from an initial value of 0.75 - 0.83% to 5.64 - 5.87% in SPS extracted with different methods with increasing temperature, and significant differences were observed with the extraction method (Figure 1b). Solubility values observed in this experiment are comparatively less compared to the values reported by Xu *et al.* (2018) for sweet potatoes. They reported that different sweet potato varieties had different swelling powers and solubilities. It was observed that the solubility of starch increased gradually from 50-70°C and sharply from 70-80°C. Alam and Hasnain (2009) worked with Taro starch and reported that the solubility of starch is a function of temperature between 70-90°C. Moreover, they mentioned that starches are less soluble below their gelatinization temperature. At higher temperatures, an increase in solubility indicates an increase in solubilized amylopectin, and this increase is enormous after granule disruption. The solubility of starches is affected by factors such as inter-associative forces, swelling power, presence of surfactants and associative compounds, starch granule size, amylose content, etc. (Riley *et al.,* 2006; Moorthy, 2002; Sibanda *et al*., 2000; Soni *et al*., 1985). Further to this, SPS2 has comparatively higher solubility values (Figure 1b), and as reported by Adebowale *et al*. (2005) and mentioned elsewhere in this article, SPS2 has high pH and, therefore, high hydrophilic properties, which increase the solubility.

Physicochemical and physical properties of yoghurt stabilized with SPS extracted using different methods

pH and TA of yoghurt mixes during the incubation

It was observed that in all the yoghurt mixes, pH was decreased from an initial value ranging from 6.3-6.4 to a final value ranging from 4.2-4.6 while TA was increased from 0.22-0.25 to 0.68-0.81% lactic acid (LA) during the incubation period of 3 h at 42±1°C (data not shown). It indicates a typical pH lowering and acidity increment trend in all the treatments. It is a well-established fact that the gradual pH reduction of a yoghurt mix during the incubation is as a result of the increment of the lactic acid produced by yoghurt starter bacteria due to the fermentation of milk sugar lactose into lactic acid. The above observations indicated that the addition of gelatin, as well as the SPS extracted using different methods, did not have any negative impact on the metabolic activity of the starter culture microorganisms used, and therefore, SPS can be used as an effective stabilizer in the yoghurt production.

pH and TA after yoghurt gel stabilization

Table 4 shows the physicochemical and physical properties of yoghurt (including pH and TA) stabilized with gelatin (control), and SPS extracted using different methods (T1-T3) after 1 day of storage at 4±1°C.

Table 4: Physicochemical and physical properties of yoghurt stabilized with SPS extracted using different methods

Treatment	pH	TA (% LA)	WHC (%)	SWS (%)
C	4.60 ±0.00^{b}	0.76 ±0.02^{ab}	92.32 ±4.41^{b}	ND
T1	4.30 ±0.10^{a}	0.81 ±0.03^{b}	79.12 ±3.05^{a}	ND
T2	4.40 ±0.00^{a}	0.71 ±0.02^{a}	82.65 ±3.15^{ab}	ND
T3	4.27 ±0.06^{a}	0.80 ±0.02^{b}	78.79 ±3.98^{a}	ND

n=3

[a, b] Mean±SD with different superscripts within each column differ significantly ($p<0.05$)

C: Control (0.5% gelatin); T1: 0.5% SPS1; T2: 0.5% SPS2; T3: 0.5% SPS3 (SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min); TA: titratable acidity; LA: lactic acid; WHC: water holding capacity; SWS: spontaneous whey syneresis; ND: not detected

It was observed that the control yoghurt stabilized with gelatin had significantly ($p<0.05$) higher pH compared to the yoghurt stabilized with SPS extracted using different methods. In contrast, no differences were observed in the yoghurt stabilized with SPS. However, the TA of the yoghurt after gel stabilization did not show a special trend and was above the minimum TA (0.6% LA) prescribed for yoghurt (Codex Alimentarius Commission, 2023).

Water holding capacity and SWS of yoghurt

Water holding capacity, which is the ability of a yoghurt gel to hold all or part of the water (Bierzuńska *et al*., 2019), is an important physical property of yoghurt. It reflects the stability of the coagulum and its ability to hold water in the yoghurt matrix (Narayana *et al*., 2022). This will, in turn, help to avoid whey syneresis, which is considered a major defect, especially in a set style yoghurt that may lead to consumer rejections (Narayana and Gupta, 2013). Water holding capacity of the yoghurt stabilized with gelatin was observed to be 92.32±4.41 and was significantly ($p<0.05$) higher compared to the yoghurt stabilized using SPS extracted either with or without centrifugation except in T2 (Table 4), confirming the effectiveness of gelatin in binding water in the yoghurt matrix. Nevertheless, the absence of SWS indicates the possibility of utilizing SPS extracted using any method as a stabilizer in the production of cow milk set yoghurt at the rate used.

Instrumental colour of the yoghurt

Colour is an important factor that affects the consumer acceptance and commercial value of food (Yilmaz-Ersan and Topcuoglu, 2021), and yoghurt is no exception. Table 5 depicts the instrumental colour of the yoghurt prepared using SPS as the stabilizer extracted using different methods.

Table 5: Instrumental colour of the yoghurt stabilized with SPS extracted using different methods

Treatment	Instrumental Colour		
	*L**	*a**	*b**
C	67.32 ±11.69	-0.23 ±0.34	16.75 ±0.96^{b}
T1	68.79 ±0.31	-0.64 ±0.47	16.01 ±0.29^{ab}
T2	67.31 ±0.31	-0.26 ±0.07	15.19 ±0.05^{a}
T3	73.74 ±2.54	0.77 ±0.22	15.82 ±0.34^{ab}

$^{a, b}$ Mean±SD with different superscripts within each column differ significantly ($p<0.05$)
{C: Control (0.5% gelatin); T1: 0.5% SPS1; T2: 0.5% SPS2; T3: 0.5% SPS3 (SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min); *L** = Lightness; *a** = redness (+) and greenness (-); *b** = yellowness (+) and blueness (-)

It was observed that none of the values recorded for *L** and *a** were having significant differences between the treatments. In fact, the *L** or the lightness value was higher and ranged from 67.31±0.31 in T2 where SPS extracted using NaCl with centrifugation was used to stabilize the yoghurt gel to 73.74±2.54 in T3 where SPS extracted using distilled water with centrifugation was used to stabilize the yoghurt, with no significant ($p>0.05$) difference. Further, *a** value ranged from greenness to redness from -0.64±0.47 in T1 to 0.77±0.22 in T3 with no significant difference. The treatments having minus *a** value confirm the dominating green tone over the red except in T3, where SPS extracted using distilled water with centrifugation was used to stabilize the yoghurt gel. The sweet potato starch used in this study was white in colour, as in normal starches. Therefore, it is obvious that there should not be any difference between the treatments. However, Abegunde *et al.* (2013) studied colour characteristics of commercially used Chinese sweet potato starches and reported significant differences between them with respect to *L**, *a** and *b** values. Further he reported that these differences might be due to the pigmentation on starches that negatively affects the acceptability of starches. Generally, a high lightness value of starches is desired in the industry. With respect to the *b** values in the yoghurt in the current study, some differences were observed and the control yoghurt showed the highest yellowness compared to the other treatments. This might be due to the faint yellow colour of gelatin (Gelatin Manufacturers Institute of America, 2012) over the white colour of SPS used in the other treatments in the current study, even though the added percentage as a stabilizer was considerably lower, i. e. 0.5%. Moreover, *b** values with all the measurements above zero confirm that the yellow colouration dominates over the blue in all the treatments, including the control.

Sensory quality of yoghurt

Satisfactory sensory quality is a critically important factor in consumer acceptance and market success of any food product. Table 6 shows the results of the sensory evaluation of set yoghurt made using SPS as the stabilizer extracted with different methods.

Table 6: Sensory attributes of the yoghurt stabilized with SPS extracted using different methods

Treatment	Sensory Score*				
	Colour & Appearance	Flavour	Body & Texture	Acidity	Overall Acceptability
C	4.18±0.92	3.39±1.24	3.51±1.19	3.45±1.03	3.59±1.22
T1	4.09±0.79	3.64±0.83	3.75±0.90	3.48±1.06	3.89±0.78
T2	4.10±0.89	3.72±0.91	3.67±0.82	3.67±0.82	3.80±0.84
T3	3.84±0.83	3.74±0.94	3.33±1.12	3.55±1.02	3.52±0.99

Values are presented as mean±SD.

5-point hedonic scale was used where 1 = strongly disagree and 5 = strongly agree

{C: Control (0.5% gelatin); T1: 0.5% SPS1; T2: 0.5% SPS2; T3: 0.5% SPS3 (SPS1: Sweet potato starch extracted using distilled water without centrifugation; SPS2: Sweet potato starch extracted using NaCl with centrifugation at 2200 × g/15 min; SPS3: Sweet potato starch extracted using distilled water with centrifugation at 2200 × g/15 min)

Statistical analysis using Friedman test revealed that there was no significant difference ($p>0.05$) between treatments including the control for all the sensory attributes (X^2 = 6.627, p=0.085 for colour & appearance; X^2 = 1.235, p=0.745 for flavour; X^2 = 1.604, p=0.658 for body & texture; X^2 = 0.245, p=0.970 for acidity and X^2 = 1.730, p=0.630 for overall acceptability). Therefore, it can be stated that consumer preference was not significantly affected due to the incorporation of SPS instead of gelatin for the yoghurt gel stabilization. Stabilizers especially improve the texture of the yoghurt. The sensory body and texture of T1 and T2 were better than the control yoghurt stabilized with gelatin, even though the scores are not significantly different (Table 6). Furthermore, the overall acceptability score was also observed to be better in T1 and T2 compared to the control indicating the possibility of using SPS as an effective stabilizer in the production of set yoghurt

CONCLUSIONS

Even though the method of extraction influenced the moisture content, pH, WAC, swelling power, and solubility of SPS, the values were within the acceptable range reported for starch. The added SPS for the yoghurt gel stabilization did not negatively affect the milk fermentation ability of the starter culture microorganisms or the physical, physicochemical, and sensory quality of the resultant yoghurt. Therefore, SPS extracted using any method specified in the present study is recommended at the rate of 0.5% to manufacture good quality cow milk set yoghurt.

AUTHOR CONTRIBUTION

NMNKN conceptualized and designed the study. BSRB performed the experiments. NMNKN and BSRB analyzed the data and interpreted the results. NMNKN drafted and critically revised the manuscript.

REFERENCES

Alam, F. and Hasnain, A. (2009) 'Studies on swelling and solubility of modified starch from Taro (*Colocasia esculenta*): Effect of pH and temperature', *Agriculturae Conspectus Scientificus*, 74(1), p 45-50.

Abdulla, M.S.P., Noordin, M.I., Ismail, S.I.M., Mustapha, N.M., Jasamai, M., Danik, M.F., Ismail, W.A.W. and Shamsuddhin, A.F. (2018) 'Recent advances in the use of animal sourced gelatin as natural polymers for food, cosmetics and pharmaceutical applications', *Sains Malaysiana*, 47 (2), pp. 323-336. DOI: 10.17576/jsm-2018-4702-15.

Abegunde, O.K., Mu, T., Chen, J. and Deng, F. (2013) 'Physicochemical characterization of sweet potao starches popularly used in Chineese starch industry', *Food Hydrocolloids*, 33(2), p 169-177. DOI: 10.1016/j.foodhyd.2013.03.005.

Alipal, J., Mohd Pu'ad, N.A.S., Lee, T.C., Nayan, N.H.M., Sahari, N., Basri, H., Idris, M.I. and Abdullah, H.Z. (2021) 'A review of gelatin: Properties, sources, process, applications, and commercialisation', *Materials Today: Proceedings,* 42(1), p 240–250. DOI: 10.1016/j.matpr.2020.12.922.

Adebowale, K., Owolabi, B., Olayinka, O. and Lawal, O. (2005) 'Effect of heat-moisture treatment and annealing on physicochemical properties of red sorghum starch', *African Journal of Biotechnology*, 4(9), p 928-933.

Altemimi, A.B. (2018) 'Extraction and Optimization of Potato Starch and Its Application as a Stabilizer in Yogurt Manufacturing', *Foods*, 7(14), p 1-11. DOI:10.3390/ foods7020014.

Amatayakul, T., Halmos, A.L., Sherkat, F. and Shah, N.P. (2006) 'Physical characteristics of yoghurts made using exopolysaccharide-producing starter cultures and varying casein to whey protein ratios', *International Dairy Journal*, 16(1), p 40-51. DOI: 10.1016/j.idairyj.2005.01.004.

AOAC, (2000) Association of Official Analytical Chemists, Official Method of Analysis. 16th ed. Washington DC.

Avula, R.Y. (2005) Rheological and functional properties of potato and sweet potato flour and evaluation of its application in some selected food products. PhD thesis, University of Mysore, Mysore. Available at: https://ir.cftri.res.in/1529/1/ramesh_yadav.pdf (Accessed: 10 February 2024).

Bierzuńska, P., Cais-Sokolińska, D. and Yiğit, A. (2019) 'Storage Stability of Texture and Sensory Properties of Yogurt with the Addition of Polymerized Whey Proteins', *Foods*, 8(11), pp. 548. DOI:10.3390/foods8110548.

Cavalcanti, M.T., de Farias, N.S., Cavalcante, A.N., Goncalves, M.C., Silva, A.S.A. and Candeia, R.A. (2019) 'Morphological structure and crystallinity of 'Rainha' sweet potato starch by heat-moisture treatment', *Polimeros*, 29(2), pp. e 2019016. DOI: 10.1590/0104-1428.03917.

Codex Alimentarius Commission (2023) 'Codex Alimentarius Codex-standard 243-2003: Codex standard for fermented milks', Available at: http://www.fao.org 2003 (Accessed: 10 February 2024).

Fisberg, M, and Machado, R. (2015) 'History of yogurt and current patterns of consumption-Supplement Article', *Nutrition Reviews*, 73(S1), pp. 4-7. DOI: 10.1093/nutrit/ nuv020.

Gelatin Manufacturers Institute of America, (2012) Gelatin Handbook. Available at: https://nitta-gelatin.com/wp-content/uploads/2018/02/GMIA_GelatinHandbook.pdf (Accessed: 11 February 2024).

Ghoshal, G. and Kaur, M. (2023) 'Optimization of etraction of starch from sweet potato and its application in making edible film', *Food Chemistry Advances*, 3 100356, pp. 1-10. DOI: 10.1016/ j.focha.2023.100356.

Gujska, E., Reinhard, W.D. and Khan, K. (1994) 'Physico chemical properties of field pea, pinto and navy bean starches', *Journal of Food Science*, 59 (3), pp. 634–636. DOI: 10.1111/j.1365 -26211994.tb05580.x.

Gul, K., Riar, C.S., Bala, A. and Sibian, M.S. (2014) 'Effect of ionic gums and dry heating on physicochemical, morphological, thermal and pasting properties of water chestnut starch', *LWT-Food Science and Technology*, 59(1), p 348–355. DOI: 10.1016/ j.lwt.2014.04.060.

Huang, J.C. and Sun, M. (2000) 'Genetic diversity and relationships of sweet potato and its wild relatives in *Ipomoea* series *batatas* (Convolvulaceae) as revealed by inter-simple sequence repeat (ISSR) and restriction analysis of chloroplast DNA', *Theoretical Applied Genetics*, 100, p 1050–1060. DOI: 10.1007/ s001220051386.

Huang, C., Lai, P., Chen, I., Liu, Y. and Wang, C. (2010) 'Effect of mucilage on the thermal and pasting properties of yam, taro and sweet potato starches', *LWT-Food Science and Technology*, 43 (6), p 849-855. DOI: 10.1016/ j.lwt.2009.11.009.

ISI 26, (1999) ‘Determination of pH in starch and syrup’, International Starch Institute, Science Park Aarhus, Denmark. Available at: http:// www.starch .dk/isi/methods/ 26ph.htm (Accessed: 12 February 2024).

Kalab, M., Emmons, D.B. and Sargant, A.G. (1975) ‘Milk-gel structure. IV. Microstructure of yoghurts in relation to the presence of thickening agents’, *Journal of Dairy Research*, 42(3), p 453-458. DOI: 10.1017/ S0022029900015491.

Karim, A.A. and Bhat, R. (2009) ‘Fish gelatin: properties, challenges, and prospects as an alternative to mammalian gelatins’, *Food Hydrocolloids*, 23(3), p 563–576. DOI: 10.1016/j.foodhyd.2008.07.002.

Mason, R.L. and Nottingham, S.M. (2002) ‘Sensory Evaluation' Practical workshop manual presented for personnel at Naresuan University, Phitsanulok, Thailand.

Miao, W., Ning, Y., Huang, H., Liu, H., Cai, X. and Wang, X. (2021) ‘Effect of dry heat modification and the addition of Chinese quince seed gum on the physicochemical properties and structure of tigernut tuber starch’, *Arabian Journal of Chemistry*, 14, 103407, p 1-11. DOI: 10.1016/ j.arabjc.2021.103407

Milanovic, J., Petrovic, L., Sovilj, V. and Katona, J. (2014) ‘Complex coacervation in gelatin/sodium caseinate mixtures’, *Food Hydrocolloids*, 37, 196–202. DOI: 10.1016/j.foodhyd.2013.10.016

Moore, J.B., Horti, A., Fielding, B.A. (2018) ‘Evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets’, *BMJ Open*, 8, e021387. DOI: 10.1136/bmjopen-2017-021387.

Moorthy, S.N. (2002) ‘Physiochemical and functional properties of tropical tuber starches: A review’, *Starch/Starke*, 54: 559-592. DOI: 10.1002/1521-379X (200212)54:12<559::AID-STAR2222559>3.0.CO;2-F.

Narayana, N.M.N.K. and Gupta, V.K. (2013) ‘Effect of total milk solid content adjusted by adding ultrafiltered milk retentate on quality of set mango yoghurt’, *International Journal of Dairy Technology*, 66(4), pp. 570-575 DOI: 10.1111/1471-0307.12081.

Narayana, N.M.N.K., Govinda, G., Kumari, A.V. and Palliyaguru, O.G. (2022) ‘Effect of sugar replacement with Stevia on quality of vanilla flavoured cow milk set yoghurt’, *Food Research*, 6(5), pp. 174-182. DOI: 10.26656/ fr.2017.6(5).548.

Omer, S. (2003) ‘Chemical and Physical Properties of Yoghurt from Khartoum Dairy Product Company (KDPC)’, Master’s Thesis, Faculty of Animal Production, University Khartoum, Khartoum, Sudan. Available at: https:// core.ac.uk/download/ pdf/71669111.pdf (Accessed: 11 February 2024).

Oswal, M., Tilekar, R., Surendra Babu, A. and Jagan Mohan, R. (2019) ‘Functional characteristics of starches from Indian sweet potato cultivars’, *International Journal of Pure & Applied Bioscience*, 7(3), p 80-85. DOI: 10.18782/2320-7051.7452.

Pang, Z., Deeth, H., Yang, H., Prakash, S. and Bansal, N. (2017) ‘Evaluation of tilapia skin gelatin as a mammalian gelatin replacer in acid milk gels and low-fat stirred yogurt’, *Journal of Dairy Science*, 100(5), p 3436–3447. DOI: 10.3168/jds.2016-11881.

Pang, Z., Luo, Y., Ma, P., Chen, C. and Liu, X. (2022) ‘Fundamental understanding of the role of gelatin in stabilizing milk protein systems during acidification’, *LWT - Food Science and Technology*, 172, 114187. DOI: 10.1016/ j.lwt.2022.114187.

Prinyawiwatkul, W., McWatters, K.H., Beuchat, L.R. and Phillips, R.D. (1997) ‘Functional characteristics of cowpea (*Vigna unguiculata*) flour and starch as affected by soaking, boiling and fungal fermentation before milling’, *Food Chemistry*, 58(4), pp. 361-372. DOI: 10.1016/S0308-8146(96)00259-2.

Riley, C., Wheatley, A. and Asemota, H. (2006) ‘Isolation and characterization of starches from eight *Dioscorea alata* cultivars grown in Jamaica', *African Journal of Biotechnology*, 5(17), p 1528-1536.

Saleh, A., Mohamed, A.A., Alamri, M.S., Hussain, S., Qasem, A.A., Ibraheem, M.A. and Shahzad, S.A. (2020) 'Nonfat set yogurt: effect of okra gum and various starches on the rheological, sensory, and storage qualities and wheying-off', *Journal of Chemistry*, DOI: 10.1155/2020/5091970.

Sameen, A., Khan, M.I., Sattar, M.U., Javid, A. and Ayub, A. (2016) 'Quality evaluation of yoghurt stabilized with sweet potato (*Ipomoea batatas*) and taro (*Colocassia esculenta*) starch', *International Journal of Food and Allied Sciences*, 2(1), pp. 23-29. DOI: 10.21620/ijfaas.2016123-29.

Shahbandeh, M. (2023) 'Global yoghurt market value forecast', Available at: https://www.statista.com/ statistics/870893/global-yogurt-market-value-forecast/ (Accessed: 30 August 2023).

Sibanda, S. and Sychawska, B. (2000) 'A comparative study of wild yam starch from *Dioscorea schimperiana*', *Journal of Applied Science of South Africa*, 6, p 79-86. DOI: 10.4314/ jassa.v6i2.16841.

Singh, N., Sandhu, K.S. and Kaur, M. (2004) 'Characterization of starches from Indian chickpea *Cicer arietinum* L cultivars', *Journal of Food Engineering*, 63(4), p 441–449. 10.1016/j.jfoodeng.2003.09.003.

Soni, P.L., Sharma, H.W., Dobhal, N.P., Bisen, S.S., Srivastava, H.C. and Gharia, M.M. (1985) 'The starches of *Dioscorea ballophylla* and *Amorphaphalus.* Comparison with tapioca starch', *Starch/Starke*, 37, p 6-9. DOI: 10.1002/star.19850370103.

Soni, P.L., Sharma, H., Dun, D. and Gharia, M.M. (1993) 'Physicochemical properties of *Quercus leucotrichophora* (Oak) starch', *Starch/Starke*, 45, p 127-130. DOI: 10.1002/star.19930450403.

Surendra Babu, A. and Parimalavalli, R. (2014) 'Effect of Starch Isolation Method on Properties of Sweet Potato Starch', *Annals of the University Dunarea de Jos of Galati, Fascicle VI: Food Technology*, 38(1), p 48–63.

Tamime, A.Y. and Robinson, R.K. (2000) *Yoghurt Science and Technology*. 2nd ed. Cambridge: Woodhead Publishing Limited.

Tester, R.F. and Morrison, W.R. (1990) 'Swelling gelatinization of cereal starches I. Effect of amylopectin, amylase and lipids', *Cereal Chemistry*, 67, p 551-557.

Truong, V.D., Avula, R.Y., Pecota, K.V. and Yencho, G.C. (2018) 'Sweet potato Production, Processing, and Nutritional Quality', in M Siddiq and MA Uebersax (eds), *Handbook of Vegetables and Vegetable Processing, Volume II*, 2nd ed., USA: John Wiley & Sons Ltd. p 811-838.

Tsakama, M., Mwangwela, A.M., Manani, T.A. and Mahungu, N.M. (2010) 'Physicochemical and pasting properties of starch extracted from eleven sweetpotato varieties', *African Journal of Food Science and Technology*, 1(4), p 090-098.

Xu, A., Guo, K., Liu, T., Bian, X., Zhang, L. and Wei, C. (2018) 'Effects of different isolation media on structural and functional properties of starches from root tubers of purple, yellow and white sweet potatoes', *Molecules*, 23, 2135. DOI: 10.3390/molecules23092135. 1-17.

Zhang, D., Cervantes, J., Huaman, Z., Carey, E. and Ghislain, M. (2000) 'Assessing genetic diversity of sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars from tropical America using AFLP', *Genetic Resources and Crop Evolution*, 47, p 659–665. DOI: 10.1023/A:1026520507223.

Zhang, L., Zhao, L., Bian, X., Guo, K., Zhou, L. and Wei, C. (2018) 'Characterization and comparative study of starches from seven purple sweet potatoes', *Food Hydrocolloids*, 80, p 168–176. DOI: 10.1016/j.foodhyd.2018.02.006.

Zhu, F., Yang, X., Cai, Y., Bertoft, E. and Corke, H. (2011) 'Physicochemical properties of sweet potato starch', *Starch/Starke*, 63, p 249–259. DOI: 10.1002/star.201000134.

Yilmaz-Ersan, L. and Topcuoglu, E. (2021) 'Evaluation of instrumental and sensory measurements using multivariate analysis in probiotic yogurt enriched with almond milk', *Journal of Food Science and Technology*, 59, p 133-143. DOI: 10.1007/s13197-021-04994-w.