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Supplementary effects of higher levels of various disaccharides on processing yield, quality properties and sensory attributes of Chinese - style pork jerky

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Objective: This study evaluated the supplementary effect of higher concentrations of various disaccharides on processing yield, major physicochemical properties, and sensory attributes of Chinese-style pork jerky (CSPJ).
Methods: CSPJ samples were prepared by marinating sliced ham (4 mm) with three disaccharides, including sucrose, lactose, and maltose, at 0%, 15%, 18%, 21%, and 24%. Subsequently, the CSPJ samples were dried and roasted. The moisture content, water activity, crude protein, moisture-to-protein ratio, pH, processing yield, shear force, color, and sensory attributes of the CSPJ samples were evaluated.
Results: The quality characteristics of CSPJ samples prepared with sucrose were more acceptable. By contrast, CSPJ samples prepared with lactose showed the lowest scores. However, the processing yield and moisture content were the highest for CSPJ samples prepared with lactose, which may be associated with improved benefits for cost reduction. Furthermore, sucrose and lactose supplementation resulted in contrasting quality characteristics; for example, CSPJ samples with sucrose and maltose supplementation had higher sensory scores for color than samples with lactose supplementation. Additionally, most quality characteristics of CSPJ samples with sucrose supplementation contrasted with those of the samples with lactose supplementation; for example, the samples with sucrose supplementation had higher scores for sensory attributes than those with lactose supplementation.
Conclusion: Sucrose supplementation up to 21% to 24% was associated with the highest overall acceptability scores (5.19 to 5.80), enhanced quality characteristics, increased processing yield, and reduced production cost.

Keywords: Chinese-style Pork Jerky; Lactose; Maltose; Quality Characteristics; Sucrose

INTRODUCTION

Jerky or dried, cured meat is a popular and highly required snack that can be conveniently purchased from retail stores worldwide [1,2]. Moreover, this type of meat product has a glossy appearance, light brown color, specific desirable flavor, sweet palatable flavor (due to high sugar concentrations), and chewy texture that imparts a chewing feeling [1-4], particularly for Chinese consumers. Asian consumers prefer sweet-flavored jerky, such as sweet Chinese-style pork jerky (CSPJ), with traditional properties. As popular traditional meat-type leisure snack in Taiwan, CSPJ has high market potential.

Sugar is a very important ingredient in Thailand-style sweet-dried chicken meat (TSDCM) products and is often added in a very large amount, because consumers in Thailand prefer the heavier sweet taste of TSDCM products [5]. Moreover, has two different effects of sugar on muscle protein are to produce a brown color through the Maillard reaction and caramelization and to generate heat denaturation by stabilizing proteins [6]. Supplementation of TSDCM with different sugar types has been resulted in different colors and textures and overall acceptability [5,7]. The Maillard reaction is nonenzymatic browning due to spontaneous interactions of reducing sugars, such as fructose and glucose, with amines or the amino groups of proteins, such as ε-NH2 groups of lysine residues and α-NH2 groups of protein. This reaction is an important cause of functional loss in stored proteins [8]. The rate of nonenzymatic browning reactions is strongly dependent on pH values [8,9], time, temperature [8,10], reactant concentration, and reactant type [8,11]. Different sugar types significantly affect the nonenzymatic browning reaction.

Consumers in Southeastern Asia (e.g., Thailand) favor palatable sweeter flavors. To reduce the cost, sugar supplementation is applied for jerk preparation. Sucrose, lactose, and maltose are common disaccharides in the market. Sucrose is a nonreducing sugar, and lactose and maltose, which have a hydroxyl (-OH) bond on C-1, are reducing sugars [5,12]. Sucrose and maltose are frequently used in cured meat and processed meat products, and lactose is used in nonfat milk powder and calcium-free and nonfat milk powder (both containing 50% lactose). These sugars can act as extenders for meat products. Although sucrose does not lead to nonenzymatic browning, sucrose may be hydrolyzed to glucose and fructose during freezing, dehydration, and storage, and then induce nonenzymatic browning in meat jerky products [12,13]. On the contrary, both maltose and lactose easily induce the nonenzymatic browning reaction and thus influence the color of foods. No systematic study has evaluated the effects of higher concentrations of various sugar types on the quality characteristics of processed CSPJ.

Generally, two types of manufacturing methods to prepare jerky are the sliced ham type and the restructured type. Some researchers have prepared pork jerky, beef jerky, and CSPJ using sliced ham obtained from whole muscle and stored the jerky at ambient temperature [2,4,14]. Other scholars have utilized ground meat to prepare restructured jerky, such as restructured pork jerky [15], restructured chicken meat (e.g., TSDCM) [5], and restructured duck jerky [1]. Furthermore, color is an important attribute of jerky. The formed and/or degraded compounds can contribute to specific coloration. Thus, color can indicate the quality of meat products and is critical to consumers' purchase decisions.

In the meat industry, the sugars added to meat products include sucrose and lactose (disaccharides) [4,5], honey and rice syrup [1], and glycerol and sorbitol [16]. Wongwiwat and Wattanachant reported that TSDCM samples prepared with various sugar types (sucrose, fructose, lactose, and sorbitol) resulted in different colors and textures and overall acceptability [5]. Moreover, Asian consumers who like processed meat prefer meat products formulated with higher sucrose concentrations compared with Western-style processed meat products. Therefore, many Chinese-style processed meat products are formulated with significantly higher sucrose concentrations [4].

In Taiwan and Thailand, sucrose has long been used as a sweetener in traditional processed meat products such as sausage and dry pork. Sucrose can be added to TSDCM at a concentration of up to 35% based on the weight of meat [5]. Further, pork jerky with a higher sucrose concentration appears high hardness, sweetness, and overall acceptability [4]. Sugar types and concentrations considerably influence the quality of CSPJ and affect the preference of the panelists. According to the sweetness scores obtained from the sensory panel tests, the panelists preferred pork jerky with 21% sucrose. Similarly, the optimal sucrose concentration of Chinese-style dried meat products was approximately 20% [17]. However, both finding reported lower sucrose concentration than the TSDCM with 35% sucrose [5]. Therefore, to estimate the improved quality of CSPJ is worth by adding very higher supplementary concentrations (HSC) of sugars. The objective of this study was to investigate the effects of various disaccharides and their concentrations on the quality characteristics, processing yields, and sensory attributes of CSPJ.

MATERIALS AND METHODS

Preparation of traditional CSPJ

In this study, traditional CSPJ was manufactured according to the modified formula and manufacturing methods [4,15,18]. The preparation process is illustrated in Figure 1, and the formula is presented in Table 1. Pork jerky was processed using the following procedure: i) Subcutaneous fat and connective tissue were removed from ham; ii) 4-mm-thick meat slices were obtained using a slicer (MIRRA 300, SIRMAN Meat Processors, Padova, Italy); iii) the curing ingredients were mixed with the sliced pork; iv) the sliced pork was cured at 4°C for 12 h; v) the sliced pork was dried at 55°C for 120 min in a FRACOMAT Junior Universal Smoke House (Commissions-No. 21.689, First Victory Machinery Co., Ltd., Kaohsiung, Taiwan); vi) the smoked pork was roasted at 180°C for 7 or 8 min on each side in an Economic Deck Oven (Jendah Food Machinery Co., Ltd., Chiayi, Taiwan); and vii) the final products were packed in zip bags/polyethylene film without vacuum and stored at ambient temperature (approximately 26°C to 30°C) for subsequent measurement of physicochemical properties and sensory evaluation. The code numbers for the treatments of CSPJ are shown in Figure 2. All ingredients were supplied by Wan Go Far Co. Ltd. (Kaohsiung, Taiwan).

Analysis methods

Measurement of moisture content: Moisture content was determined according to the methods of the Association of Official Analytical Chemists [19]. The total moisture content of 5 g of finely chopped samples placed in aluminum moisture dishes was determined before and after drying in an air oven to a constant weight at 100°C for 24 h. The derived total moisture content is expressed as the percentage of the weight as weight after drying over original weight× 100%. For each jerky sample, the moisture

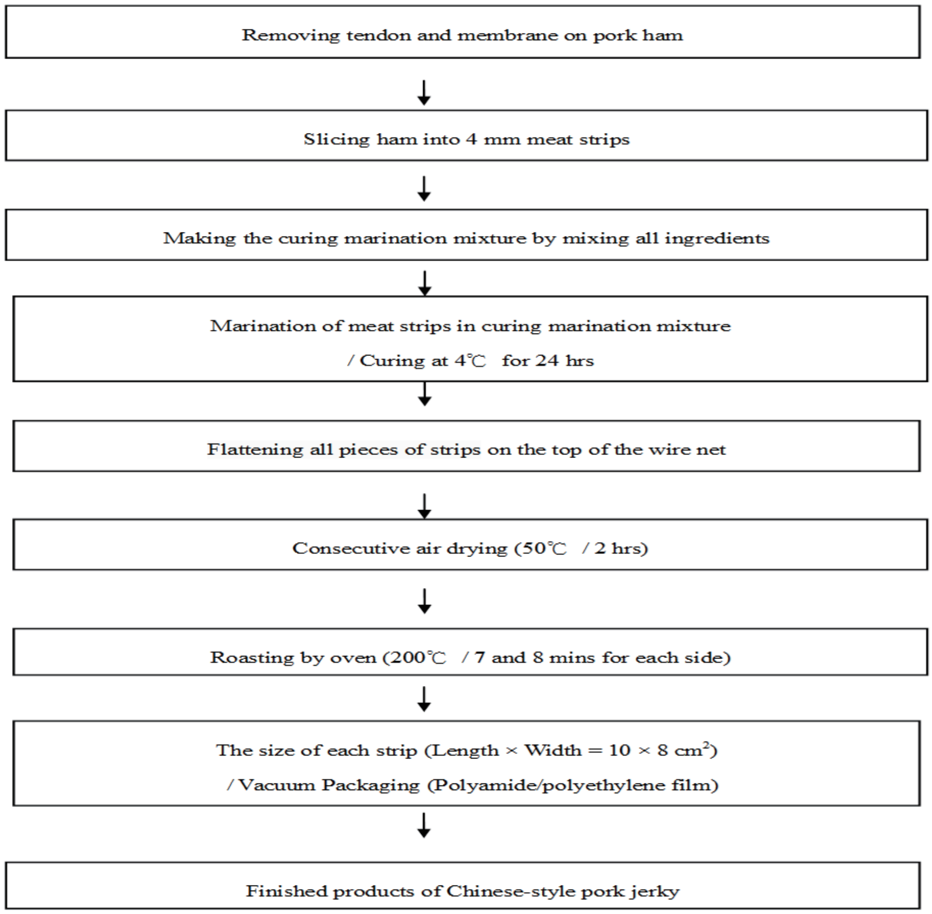

Figure 1. Manufacturing procedures of Chinese-style pork jerky.

content was determined in triplicate.

Measurement of water activity (a_w): Three CSPJ samples from each treatment were selected, cut into small pieces using sharp scissors, and then homogenized. Specifically, 5 g of the samples were placed in special cups that were maintained at 25°C±0.1°C. Subsequently, a water activity meter (Aqualab-CX3, Decagen Devices, Inc., Pullman, WA, USA) was used to measure their water activity levels in distilled water (a_w = 0.999) and saturated solutions of NaCl (a_w = 0.756) and KCl (a_w = 0.853). Water activity

Table 1. The formula of Chinese-style pork jerky

Ingredients	Concentration (%, wt/wt)
Pork ham	100.00
Salt	1.00
Monosodium glutamate	1.00
Rice wine	0.50
Soy sauce	1.00
Liquorice powder	0.15
Five spices	0.15
Cinnamon	0.10
Sodium tripolyphosphate	0.30
Sodium erythobate	0.05
Sodium nitrite	0.10
Disaccharides[1)]	0.00/15.00/18.00/21.00/24.00

[1)] Disaccharide treatments: addition of 15%, 18%, 21%, and 24% concentrations of sucrose, lactose and maltose based on raw meat weight (wt/wt).

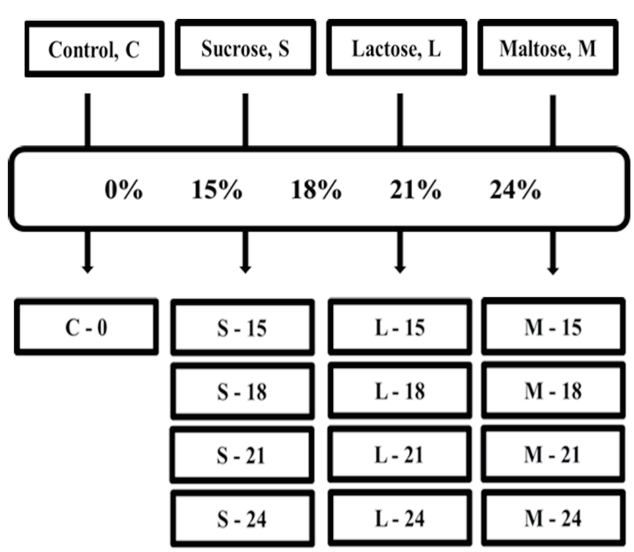

Figure 2. The code numbers for treatments of Chinese-style pork jerky.

was measured in triplicate.

Measurement of crude protein: The sample protein content was determined using a Kjeldahl nitrogen analyzer (KjelFlex K-360, Buechi Labortechnik, Flawil, Switzerland), according to the Kjeldahl procedure [19]. In this process, 0.5 g of the sample was placed in a digestion tube along with two tablets of selenium powder, mixed with 20 mL of concentrated H_2SO_4, and then heated for 5.0 h. After cooling for 30 min at ambient temperature, 50 mL of distilled and 50 mL of H_3BO_3 was added to absorb NH_4 gas from the distillation apparatus. Subsequently, the absorbed solution was titrated using 0.1 N HCl solution until the the color of the solution changed to pink. The titration volume was divided by the nitrogen factor (6.25) to calculate the crude protein content (CP %) of CSPJ samples.

Measurement of processing yield, pH, and shear force values: Processing yields were calculated as follows: Processing yields (%) = Jerky weight after drying (g)/marinated meat weight before drying (g) (×100%). Approximately 5 g ground CSPJ samples were blended with 45 mL of distilled water for 60 s in a homogenizer (Ultra-Turrax T25, Janke & Kunkel, Staufen, Germany) and The pH of the samples was measured using a pH meter (Suntex SP2-500, New Taipei, Taiwan). Shear force values (kg/cm^2) was measured according to the method [20]. Briefly, CSPJ samples were cut into $2\times1\times0.3\ cm^3$ pieces, and shear force was measured in cross-sectional square cores obtained from each of the five samples at approximately the same location using a texture analyzer (TA.XT.plus, Texture Technologies Corp., Scarsdale, NY, USA) equipped with a heavy duty platform/blade set probe at a height of 6 mm. The samples were sheared crosswise using a 30-kg cell at a speed of 1.5 mm/s. Before measurement, the probe was calibrated by weight.

Measurement of color: The color of five ground CSPJ samples was measured using the CIE L*, a*, b* system on a colorimeter (Color Meter, Nippon Denshoku ZE 2000, Tokyo, Japan) standardized with a standard white plate (X = 92.83, Y = 94.81, Z = 111.27). Color measurements for each of the five replicates were performed in triplicate. Lightness (L*), redness (a*), and yellowness (b*) values were recorded for CSPJ samples.

Sensory hedonic test

To assemble a sensory panel, 20 undergraduate and graduate students from the Department of Animal Science of National Pingtung University of Science and Technology, Taiwan, were invited as panelists. The panelists evaluated the samples using a 7-point hedonic scale ranging from 1 (dislike extremely) to 7 (like extremely), indicating very low to very high desirability for color, aroma, hardness, sweetness, texture (chewiness), flavor, and overall acceptability [21]. The sensory attributes of all samples prepared with the three disaccharides were measured in triplicate. The samples were placed on polypropylene trays and were tagged with three-digit random numbers. The panelists were instructed to rinse their mouths with water between sample tasting.

Statistical analyses

All data were analyzed using the General Linear Model Procedures of SAS (SAS, 2011) [22] (Inst. Inc., Cary, NC, USA). A significance level of $p<0.05$ was applied for all data evaluated using one-way analysis of variance. Treatment means obtained in triplicate were compared using the least significant difference multiple range tests, except for five replications for shear force values.

RESULTS AND DISCUSSION

In this study, the disaccharides (sucrose, lactose, and maltose) and their higher concentrations (15%, 18%, 21%, and 24%) influenced the majority of physicochemical properties and sensory attributes of CSPJ samples. Significant differences were observed in most of the quality characteristics of CSPJ samples prepared

Table 2. Comparison of moisture content, water activity (aw), crude protein (CP), and moisture to protein ratio (M/P) of Chinese-style pork jerky prepared with sucrose, lactose and maltose at various higher supplementary levels

Items	Disaccharides	Concentration (%)				
		0	15	18	21	24
Moisture	Sucrose	17.9 ± 1.27^{ax}	17.3 ± 2.39^{ax}	17.1 ± 2.57^{ax}	17.6 ± 3.93^{ax}	15.0 ± 0.12^{ax}
	Lactose	17.9 ± 1.27^{ax}	25.2 ± 5.66^{ax}	24.7 ± 3.87^{ax}	23.3 ± 3.04^{ax}	24.8 ± 3.64^{bx}
	Maltose	17.9 ± 1.27^{ax}	23.1 ± 5.85^{ax}	19.4 ± 4.08^{ax}	23.3 ± 3.04^{ax}	23.8 ± 2.23^{ax}
a_w	Sucrose	0.652 ± 0.050^{ax}	0.726 ± 0.060^{ax}	0.733 ± 0.068^{ax}	0.717 ± 0.079^{ax}	0.677 ± 0.029^{ax}
	Lactose	0.652 ± 0.050^{ax}	0.804 ± 0.087^{ax}	0.802 ± 0.056^{ax}	0.817 ± 0.073^{ax}	0.823 ± 0.056^{bx}
	Maltose	0.652 ± 0.050^{ax}	0.754 ± 0.074^{ax}	0.773 ± 0.066^{ax}	0.717 ± 0.064^{ax}	0.785 ± 0.063^{abx}
CP	Sucrose	55.5 ± 6.48^{ax}	41.0 ± 5.89^{ay}	38.8 ± 2.52^{ay}	35.5 ± 1.75^{aby}	36.5 ± 1.11^{ay}
	Lactose	55.5 ± 6.48^{ax}	37.0 ± 2.10^{ay}	37.3 ± 7.68^{ay}	33.0 ± 2.18^{by}	33.4 ± 2.08^{ay}
	Maltose	55.5 ± 6.48^{ax}	42.8 ± 4.67^{axy}	$43.2\pm6.70a^{xy}$	38.4 ± 0.93^{ay}	38.6 ± 4.18^{ay}
M/P	Sucrose	0.32 ± 0.02^{ax}	0.43 ± 0.09^{ax}	0.45 ± 0.09^{ax}	0.50 ± 0.13^{ax}	0.41 ± 0.02^{ax}
	Lactose	0.32 ± 0.02^{ax}	0.69 ± 0.17^{ay}	0.69 ± 0.20^{ay}	0.70 ± 0.08^{ay}	0.75 ± 0.15^{by}
	Maltose	0.32 ± 0.02^{ax}	0.55 ± 0.18^{ax}	0.46 ± 0.13^{ax}	0.61 ± 0.09^{ax}	0.63 ± 0.11^{abx}

[a,b] Mean that different superscripts indicate significantly different between disaccharides ($p<0.05$).
[x,y] Mean that different superscripts indicate significantly different between concentrations ($p<0.05$).

with these three disaccharides ($p<0.05$).

Moisture content

The three disaccharides (sucrose, lactose, and maltose) and the four HSC (15%, 18%, 21%, and 24%) influenced significantly the moisture content of CSPJ samples ($p<0.05$). As presented in Table 2, the moisture content levels were significantly lower in CSPJ samples prepared with sucrose than those of the samples prepared with lactose and those prepared with maltose (15.0% to 17.6% vs 23.3% to 25.2% vs and 19.4% to 23.8%) (Table 2). When compared to the control (C-0) (17.9%), sucrose supplementation reduced the moisture content, on the contrary, lactose and maltose supplementation increased such level. Compared to sucrose treatment and control, a significant increase of the moisture content in CSPJ samples was observed for lactose treatment, not maltose treatment. Furthermore, no marked difference was observed among CSPJ samples treated with four HSC of the disaccharides. The moisture content of CSPJ samples treated with HSC of sucrose measured in this study is similar to the results of Chen et al [4].

In recent study, the crystallization of samples prepared with sucrose was remarkable increasing after drying [5] with identical X-ray diffraction patterns of sucrose [23]. The predominance of sucrose crystallization was probably because the lower moisture content during drying caused moisture migration to the surface layer, and sucrose formed agglomerated matrix particles that crystallized [23]. Moreover, sucrose may penetrate into pork tissue and form crystals inside the tissue, which may enlarge the interval in the tissue. This phenomenon may lead to the easy loss of moisture in the form of vapor, resulting in lower moisture content.

Water activity

Water activity (a_w) of CSPJ samples treated with the four concentrations of the disaccharides was higher than C-0 samples (Table 2). Most a_w values of CSPJ samples treated with the four supplementary concentrations of the disaccharides were similar; however, sucrose treatment displayed the lowest a_w values (0.677 to 0.726), followed by maltose treatment (0.717 to 0.785) and lactose treatment (0.802 to 0.823). Water–solute hydrogen bonds are formed by the interaction between water and hydrophilic solutes [24]. The different a_w values of the samples were probably resulted from water-binding ability of sugars. Our findings confirmed that increase of sucrose concentrations decreased the a_w values of the samples [25]. However, lactose and maltose supplementation had adverse effects on the samples. The lowest and highest a_w values was observed in the samples treated with 24% sucrose (S-24 samples) and the samples treated with 24% lactose (L-24 samples), respectively.

The moisture content and a_w values of CSPJ samples met the standard requirement of intermediate-moisture food (IMF) with normal standard ranges of 0.65 to 0.90 for a_w and 10% to 40% for the moisture content. The a_w values of CSPJ samples were less than 0.85, a critical limit value for the growth of bacteria, particularly for foodborne pathogenic *Clostridium botulinum* [26,24]. For meat jerky such as CSPJ, the stability of a_w is also necessary to avoid quality change, and low a_w can extend the shelf life of such jerky during storage. For example, meat jerky such as CSPJ must be dried to a_w values between 0.70 and 0.85 to achieve stability of their safe quality [27,25]. The aforementioned findings are also consistent with the previous report [1]. Therefore, the samples with lower moisture content and a_w values might have stable quality during storage.

Crude protein

The measured CP % values of CSPJ samples treated with the four HSC of the disaccharides were significantly lower than that of C-0 samples (Table 2). As shown in Table 2, a considerable difference was observed in the CP % values of the samples treated with various HSC ($p<0.001$) after drying. Therefore, the results of this study revealed the following order for the CP % of CSPJ samples with all treatments: lactose<sucrose<maltose (Table 2). Our CP % results are similar to the previous report [4]. In this study, the CP % of C-0 samples was markedly higher than that of the samples with other treatments ($p<0.05$). This finding may be attributed to lower nonenzymatic browning reaction and fewer denatured proteins resulting from no sugar addition. Although no significant difference was observed among the treatments, increasing the concentrations of sugars considerably enhanced the nonenzymatic browning reaction, resulting in reduction of protein dissolution and the decreasing tendency of CP %.

The moisture-to-protein (M/P) ratios of CSPJ samples were markedly influenced by the four HSC of the disaccharides ($p<0.0001$). Significant differences were observed in the samples prepared with the three disaccharides ($p<0.0001$) and in the samples treated with the four concentrations ($p<0.0001$). However, no significant difference was observed among between the disaccharides and the various HSC ($p<0.631$). The results of this study showed that the M/P ratios of all CSPJ samples ranged from 0.32 to 0.75 (Table 2), indicating that almost all of the samples prepared with sucrose or maltose or lactose, except M-21 (0.61) and M-24 (0.63), potentially exhibit a minimal risk of microorganism growth during storage, except for samples prepared with 18% to 24% lactose (0.69 to 0.75). The M/P ratio may be one of the dryness parameters that can be applied to evaluate the shelf life of dried meat products [28]. Borneman et al [29] defined the M/P ratio of 0.75 as the upper limit for ensuring the microbiological safety of meat products. The M/P ratios of our samples prepared with sucrose or maltose are consistent with the industry standard and previous report [1]. Most parameters measured in this study are consistent with the parameters recorded by Konieczny et al [28]. The jerky prepared in this study had low fat (≤3.6%), low moisture content (≤20%), high protein content (≥20%), correspondingly higher salt content (≤6%), and lower a_w (<0.80) and could thus be defined as IMF.

pH value

The pH values of food may influence the Maillard reaction in such food. For food, higher pH value the faster Maillard reaction. A significant difference was observed in the pH values of the samples prepared with different disaccharides and with various HSC ($p<0.002$) after drying (Table 3). The pH values of CSPJ samples treated with sucrose ranged from 6.35 to 6.36, whereas those for lactose and maltose supplementation ranged from 6.14 to 6.23 and from 5.88 to 6.18, respectively.

The pH values of CSPJ samples were higher in sucrose treatment and lower in lactose and maltose supplementation compared to the control (6.28). With increasing supplementary concentrations, the pH values of CSPJ samples treated with sucrose slightly increased. However, the pH values of the samples treated with lactose or maltose decreased with increasing concentrations.

Processing yield values

In the meat industry, processing yield is one of the most important factors controlling the cost of meat production. As one of the major ingredients in the formulation of traditional CSPJ, sugar has the aforementioned benefits and also determinant effects on the color, aroma, and taste (flavor) of the products. The processing yield values of CSPJ samples were influenced by the different concentrations of the disaccharides (Table 3). Our results revealed that lactose treatment demonstrated the highest processing yields (45.0% to 48.6%), followed by sucrose treatment (42.0% to 45.7%) and maltose treatment (43.0% to 45.4%), moreover, no difference was observed between the samples prepared with sucrose and those prepared with maltose. The processing yields of CSPJ samples treated with various HSC of the three disaccharides ranged from 8.6% to 15.2% ($p<0.05$; Table 3). Indeed, sugar addition may therefore markedly reduce the associated production cost. Specifically, applying HSC resulted in markedly higher processing yields, which may decrease the production cost in processing yields of restructured duck jerky prepared with different humectants, such as honey, rice syrup, and sorbitol [1].

Shear force values

Table 3 demonstrated that CSPJ samples treated with the four various supplementary concentrations of the disaccharides had lower shear force values (1.32 to 2.05 kg/cm^3) than that of C-0 samples (2.13 kg/cm^3). However, M-15, M-18, and L-18 (2.31, 2.36, and 2.15 kg/cm^3) samples had slightly higher values than that of C-0 samples. Although no significant difference was observed among the samples treated with various HSC of the disaccharides, the samples prepared with sucrose had lower shear force values, which produced improved tenderness; those prepared with maltose had higher values (1.71 to 2.36 kg/cm^3), which produced a harder texture; and those prepared with lactose had intermediate values (1.67 to 2.15 kg/cm^3). Except for M-15 and M-18 samples (2.31 and 2.36 kg/cm^3, respectively), the samples treated with much HSC (M-21 and M-24) of maltose had lower values than that of C-0 samples. The shear force values of CSPJ samples with almost all treatments decreased markedly by approximately 0.08 to 0.81 kg/cm^3. Thus, sugar addition markedly improves the hardening of samples.

In the present study, the three disaccharides utilized in this study predominantly affected the shear force values and moisture content of CSPJ samples. Sucrose and lactose recrystallization in the tissues of CSPJ samples and the higher moisture content in the samples prepared with maltose may influence the shear force values and hardness. CSPJ samples prepared with lactose had the highest moisture content and the lower shear force values, demonstrating that lactose can aggregate into a cluster and prevent the interactions between surface tension and meat protein. Generally, sugars can accelerate hydration by increasing the surface tension of water [27]. However, lactose may have worse penetration ability into the tissue of meat products; this is maybe another reason for the lower shear force. Differences in the shear force values of meat samples can indicate differences in their total shear force values [4]. Consumer acceptance of meat and meat products depends, to some degree, on tenderness, which is commonly determined by the shear force.

Color

Color development of jerky can be influenced by the sugar types

Table 3. Comparison of pH, processing yield and shear force values on Chinese-style pork jerky prepared with sucrose, lactose and maltose at various higher supplementary levels

Items	Disaccharides	Concentration (%)				
		0	15	18	21	24
pH	Sucrose	6.28 ± 0.06^{ax}	6.36 ± 0.27^{ax}	6.36 ± 0.16^{ax}	6.35 ± 0.12^{ax}	6.43 ± 0.15^{ax}
	Lactose	6.28 ± 0.06^{ax}	6.23 ± 0.12^{ax}	6.15 ± 0.28^{ax}	6.15 ± 0.22^{ax}	6.14 ± 0.20^{acx}
	Maltose	6.28 ± 0.06^{ax}	6.15 ± 0.95^{axy}	6.18 ± 0.24^{axy}	6.10 ± 0.22^{axy}	5.88 ± 0.14^{bcy}
Processing yield (%)	Sucrose	33.4 ± 0.77^{ax}	42.0 ± 0.27^{ay}	44.3 ± 1.51^{ayz}	43.8 ± 1.41^{abyz}	45.7 ± 0.60^{abz}
	Lactose	33.4 ± 0.77^{ax}	45.0 ± 0.44^{by}	45.92 ± 1.38^{ay}	46.4 ± 0.14^{by}	48.6 ± 1.81^{ay}
	Maltose	33.4 ± 0.77^{ax}	43.0 ± 0.81^{by}	43.1 ± 0.78^{ay}	43.2 ± 1.83^{by}	45.4 ± 2.02^{ay}
Shear force value (kg/cm^2)	Sucrose	2.13 ± 0.65^{ax}	1.48 ± 0.84^{ax}	1.32 ± 0.90^{ax}	2.05 ± 1.76^{ax}	1.89 ± 1.18^{ax}
	Lactose	2.13 ± 0.65^{ax}	1.89 ± 1.27^{ax}	2.15 ± 1.33^{ay}	1.67 ± 1.18^{ax}	1.98 ± 1.19^{ax}
	Maltose	2.13 ± 0.65^{ax}	2.31 ± 0.80^{ax}	2.36 ± 0.90^{ax}	1.98 ± 1.73^{ax}	1.71 ± 0.70^{ax}

^{a,b} Mean that different superscripts indicate significantly different between disaccharides ($p<0.05$).
^{x,y} Mean that different superscripts indicate significantly different between concentrations ($p<0.05$).

[5]. Color is an indicator of meat quality and critical to consumers' purchase decisions. No significant difference was observed in the color (L*, a*, and b* values) of CSPJ samples treated with various HSC of three disaccharides (Table 4). The color of the samples with all treatments was not different from that of control samples. As shown in Table 4, L*, a*, and b* values respectively ranged from 37.02 to 47.45, 9.76 to 11.33, and 15.38 to 21.20 for CSPJ samples treated with various HSC of the disaccharides, and the corresponding values of C-0 samples were 42.32, 10.58, and 16.12.

L values*: Compared to control samples, lactose treatment increased the of CSPJ samples, while sucrose, except S-15 (43.56) and maltose treatment decrease the L* values. However, the L* value of S-24 samples (37.21) was lower than that of M-24 samples (39.34). Among CSPJ samples with all treatments, L-24 (47.45) had the highest L* value, whereas M-21 samples (37.02) had the lowest value. Statistical analysis revealed that the difference between S-24 and L-24 samples was almost significant ($p<0.065$). Although the differences in L* values of the samples treated with various HSC and the three disaccharides did not reach significance, the maximum differences in the values of the samples prepared with the disaccharides could reach 5.13 to 5.35.

a values*: The a* values of CSPJ samples showed no significant difference among treatments. M-15 had the highest a* value, whereas S-18 had the lowest value. The a* values of S-21, L-15, and M-15 samples (10.76, 10.75, and 11.33, respectively) were higher than that of control samples. CSPJ samples treated with higher sucrose (S-21 and S-24) had slightly higher a* values than the samples treated with much lower concentrations (S-15 and S-18). Therefore, the a* values of the samples prepared with sucrose increased with the concentrations. By contrast, the a* values of CSPJ samples prepared with lactose or maltose decreased with increasing concentrations. Slight differences were observed among the samples prepared with the three disaccharides, and no significant difference was observed among all treatments.

b values*: In this study, the b* values of the samples treated with various HSC of the three disaccharides showed a similar tendency to the L* values. The samples prepared with lactose showed higher b* values than those treated with sucrose and maltose. L-24 samples (15.69) had the highest value, whereas S-18 (15.33) samples had the lowest value. The b* values of CSPJ samples prepared with lactose and maltose (17.05 to 21.20 and 15.38 to 16.63, respectively) were higher than that of control samples (16.12). Moreover, lactose treatment displayed the highest b* value, followed by maltose and sucrose treatments. These results are consistent with those findings [5], in which the b* values of TSDCM samples were higher than those of samples prepared with sucrose.

Although the differences in b* values of the samples treated with various concentrations and in the values of the samples prepared with the three disaccharides did not reach significance, some considerable differences were still observed. The maximum difference in the b* values of CSPJ samples prepared with lactose could reach approximately 4.15. This result shows that HSC could influence the intensity of the Maillard reaction. The addition of HSC may lead to a stronger Maillard reaction, resulting in a darker brown color and higher b* values.

The L*, a*, and b* values of CSPJ samples were influenced by the disaccharides added at different concentrations (Table 4). Because both lactose and maltose are reducing sugars and can thus produce a Maillard reaction, the b* values of CSPJ samples prepared with these two disaccharides were higher. The strong recrystallization properties of lactose caused the formation of a thin white layer on the sample surface, resulting in light reflection. Previous research has indicated that sucrose may (or partially) be hydrolyzed to glucose and fructose during processes such as freezing, dehydration, and storage; this may further lead to the generation of a nonenzymatic browning reaction in meat products [12,13] including CSPJ and meat jerky products. This phenomenon may be one of the possible reasons why the b* values of CSPJ samples prepared with sucrose were still not lower despite curing overnight (approximately 12 h), which is necessary for CSPJ preparation. This result is similar to that of Buera et al [30], in which the nonenzymatic browning reaction rate of sucrose was faster than that of other sugars.

Table 4. Comparison of color (L*, a*, b* values) on Chinese-style pork jerky prepared with sucrose, lactose and maltose at various higher supplementary levels

Items	Disaccharides	Concentration (%)				
		0	15	18	21	24
L*	Sucrose	42.32 ± 4.89^{ax}	43.56 ± 1.86^{ax}	41.28 ± 5.29^{ax}	40.97 ± 5.32^{ax}	37.21 ± 6.31^{ax}
	Lactose	42.32 ± 4.89^{ax}	45.28 ± 2.60^{ax}	45.77 ± 2.20^{ax}	45.80 ± 1.71^{ax}	47.45 ± 0.67^{ax}
	Maltose	42.32 ± 4.89^{ax}	39.46 ± 3.55^{ax}	39.34 ± 4.20^{ax}	37.02 ± 8.96^{ax}	39.34 ± 4.20^{ax}
a*	Sucrose	10.58 ± 6.10^{ax}	9.88 ± 4.69^{ax}	9.76 ± 5.05^{ax}	10.76 ± 4.62^{ax}	10.40 ± 3.98^{ax}
	Lactose	10.58 ± 6.10^{ax}	10.75 ± 6.46^{ax}	10.51 ± 6.28^{ax}	10.16 ± 6.55^{ax}	10.14 ± 6.48^{ax}
	Maltose	10.58 ± 6.10^{ax}	11.33 ± 7.17^{ax}	10.57 ± 6.62^{ax}	10.24 ± 3.94^{ax}	10.57 ± 6.62^{ax}
b*	Sucrose	16.12 ± 10.16^{ax}	15.96 ± 6.68^{ax}	15.33 ± 10.40^{ax}	16.81 ± 9.32^{ax}	15.69 ± 8.77^{ax}
	Lactose	16.12 ± 10.16^{ax}	17.05 ± 9.02^{ax}	20.02 ± 10.64^{ax}	19.60 ± 10.67^{ax}	21.20 ± 8.56^{ax}
	Maltose	16.12 ± 10.16^{ax}	16.44 ± 8.19^{ax}	16.63 ± 9.55^{ax}	15.38 ± 8.17^{ax}	16.63 ± 9.55^{ax}

a,b Mean that different superscripts indicate significantly different between disaccharides ($p<0.05$).
x,y Mean that different superscripts indicate significantly different between concentrations ($p<0.05$).

Sensory evaluation

The sensory attributes of CSPJ samples were influenced by the disaccharides and the concentrations (Table 5). The overall acceptability of CSPJ samples was observed in the sucrose treatment with the highest hedonic scores (4.64 to 5.80) with concentration dependent manner. The order of the scores of the overall acceptability of the samples was sucrose (4.64 to 5.80)>maltose (2.71 to 3.98)>lactose (2.22 to 2.74). The scores of the overall acceptability of CSPJ samples prepared with sucrose and maltose, except M-21 (2.71) were higher than that of control samples (2.82). However, those of the samples prepared with lactose (2.22 to 2.74) were slightly lower than that of control samples. Overall acceptability was previously defined as the mixing taste and other attributes of CSPJ samples in the mouth [4]. Overall acceptability may be the most important factor used to evaluate the overall quality of food products such as CSPJ and other meat products.

The sensory evaluation scores of all attributes obtained from CSPJ samples treated with sucrose tended to increase with the sugar concentration ($p<0.05$). Remarkable differences were observed in the scores for the samples prepared with the disaccharides and in the scores for the samples treated with various HSC ($p<0.05$). Although differences in hardness remained nonsignificant among the samples treated with various sugar concentrations, a significant difference was observed between sucrose supplementation and lactose or maltose supplementation. The hardness and texture of S-24 samples had the lowest hedonic scores. This finding may be attributed to decreased protein dissolution, resulting in a harder texture of the samples. The sweetness of CSPJ samples prepared with sucrose had the highest hedonic score (5.21) when the concentration was increased up to 18%. However, the scores tended to decrease at concentrations exceeding 18%. This finding implies that the intense sweetness could reduce the panelists' sweetness preference. However, the hedonic scores of the sweetness of samples treated with all concentrations (4.58 to 5.21) were higher than 4.00, which was accepted by panelists. This information is strongly recommended as a reference formula for manufacturing CSPJ products in the meat industry.

The hedonic scores of color, aroma, flavor, and overall acceptability for CSPJ samples prepared with lactose tended to decrease with increasing concentrations. Although a slight difference was observed between them, both color and aroma were remarkably different ($p<0.05$). Moreover, the scores of hardness, sweetness, and texture tended to increase first and then decrease with increasing concentrations. A slight difference was observed between them, but no significant difference was observed. The sensory attributes of aroma, sweetness, flavor, and overall acceptability for M-18 samples had the highest hedonic scores. All scores of the sensory attributes of M-24 samples were the highest compared with those of the sensory attributes of other samples.

According to the sensory evaluation results, the effects of sweetness and flavor were higher than those of color. The CSPJ samples prepared with sucrose had the highest sweetness scores, followed by those prepared with maltose and those prepared with lactose. The flavor of CSPJ samples prepared with sucrose was

Table 5. Comparison of sensory evaluation on Chinese-style pork jerky prepared with sucrose, lactose and maltose at various higher supplementary levels

Items	Disaccharides	Concentration (%)				
		0	15	18	21	24
Color	Sucrose	3.45 ± 0.66^{ax}	4.90 ± 0.05^{ay}	5.07 ± 0.58^{ay}	5.25 ± 0.27^{ay}	5.73 ± 0.28^{ay}
	Lactose	3.45 ± 0.66^{ax}	2.22 ± 0.02^{byz}	2.77 ± 0.17^{bxz}	2.20 ± 0.30^{byz}	1.54 ± 0.34^{by}
	Maltose	3.45 ± 0.66^{ax}	3.92 ± 0.71^{ax}	4.70 ± 1.25^{abx}	3.52 ± 0.81^{cx}	4.79 ± 0.39^{cx}
Aroma	Sucrose	3.76 ± 0.31^{ax}	3.91 ± 0.75^{ax}	4.48 ± 0.97^{axy}	4.77 ± 0.26^{axy}	5.55 ± 0.45^{ay}
	Lactose	3.76 ± 0.31^{ax}	3.15 ± 0.40^{axy}	3.31 ± 0.67^{axy}	2.82 ± 0.41^{bxy}	2.45 ± 0.55^{by}
	Maltose	3.76 ± 0.31^{ax}	3.50 ± 0.03^{ax}	4.11 ± 1.67^{ax}	3.35 ± 0.25^{bx}	3.52 ± 0.06^{cx}
Hardness	Sucrose	3.18 ± 0.18^{ax}	4.45 ± 0.15^{ax}	4.46 ± 0.05^{ax}	4.51 ± 0.10^{ax}	3.42 ± 1.43^{ax}
	Lactose	3.18 ± 0.18^{ax}	3.18 ± 0.30^{bx}	3.23 ± 0.11^{bx}	3.29 ± 0.54^{bx}	3.12 ± 0.64^{ax}
	Maltose	3.18 ± 0.18^{ax}	3.35 ± 0.57^{bx}	2.88 ± 0.85^{bx}	3.05 ± 0.20^{bx}	3.39 ± 0.09^{ax}
Sweetness	Sucrose	2.32 ± 0.27^{ax}	4.58 ± 0.08^{ay}	5.21 ± 0.21^{ay}	4.97 ± 0.28^{ay}	4.70 ± 0.70^{ay}
	Lactose	2.32 ± 0.27^{ax}	2.46 ± 0.26^{bx}	2.44 ± 0.17^{bx}	2.42 ± 0.40^{bx}	2.23 ± 0.42^{bx}
	Maltose	2.32 ± 0.27^{ax}	2.50 ± 0.28^{bx}	2.91 ± 0.96^{bx}	2.34 ± 0.12^{bx}	2.54 ± 0.15^{bx}
Texture	Sucrose	2.94 ± 0.24^{ax}	3.96 ± 0.97^{axyz}	4.85 ± 0.45^{ay}	4.90 ± 0.07^{ay}	2.94 ± 0.06^{axz}
	Lactose	2.94 ± 0.24^{ax}	3.10 ± 0.22^{ax}	3.03 ± 0.14^{bx}	2.99 ± 0.55^{bx}	2.80 ± 0.80^{ax}
	Maltose	2.94 ± 0.24^{ax}	3.25 ± 0.58^{ax}	3.01 ± 0.43^{bx}	2.97 ± 0.30^{bx}	3.90 ± 1.00^{ax}
Flavor	Sucrose	2.99 ± 0.19^{ax}	4.01 ± 1.15^{ax}	5.47 ± 0.42^{ax}	5.23 ± 0.32^{ay}	5.88 ± 0.13^{ay}
	Lactose	2.99 ± 0.19^{ax}	2.82 ± 0.48^{ax}	2.79 ± 0.35^{bx}	2.64 ± 0.19^{bx}	2.24 ± 0.58^{bx}
	Maltose	2.99 ± 0.19^{ax}	2.98 ± 0.33^{ax}	3.86 ± 1.86^{abx}	2.63 ± 0.09^{bx}	2.88 ± 0.53^{bx}
Overall acceptability	Sucrose	2.82 ± 0.07^{ax}	3.94 ± 1.24^{ax}	4.56 ± 1.42^{ax}	5.19 ± 0.27^{ay}	5.80 ± 0.20^{ay}
	Lactose	2.82 ± 0.07^{ax}	2.69 ± 0.49^{ax}	2.74 ± 0.25^{bx}	2.58 ± 0.42^{bx}	2.22 ± 0.60^{bx}
	Maltose	2.82 ± 0.07^{ax}	2.84 ± 0.22^{ax}	3.98 ± 1.75^{bx}	2.71 ± 0.15^{bx}	2.88 ± 0.40^{bx}

[a,b] Mean that different superscripts indicate significantly different between disaccharides ($p<0.05$).
[x,y] Mean that different superscripts indicate significantly different between concentrations ($p<0.05$).

determined to be similar to commercial CSPJ products in the market. The overall acceptability of the samples prepared with sucrose had the highest scores. This finding is probably because Taiwanese consumers have a preference for the palatable sweet taste from CSPJ. In particular, consumers in Southern Taiwan favor the sweeter taste of food.

Wongwiwat and Wattanachant [5] reported that the crystalline structure of TSDCM samples prepared with sucrose after frying coincided with the highest score for the glossy attribute. However, samples prepared with lactose showed a high-order crystalline structure, which contrasted with the lowest score for the glossy sensory attribute. This finding is probably because of the dissolution of lactose crystal in the sample. Therefore, this phenomenon may also be the reason for the lowest sensory scores of the color for CSPJ samples prepared with lactose, even including the sensory attribute of overall acceptability. In addition, TSDCM prepared with sorbitol or fructose showed an amorphous structure both before and after frying; this might be because sorbitol and fructose are easily dissolved. Wongwiwat and Wattanachant [5] prepared TSDCM by curing ground chicken meat in 2% salt and 35% sucrose; these samples had intermediate moisture (a_w = 0.7 to 0.8). Their results revealed that TSDCM prepared with different types of sugars had various color, texture, and overall acceptability. Chen et al [4] indicated that the higher concentrations of sucrose may affect the hardness, sweetness, and overall acceptability of CSPJ. The result of the current study is consistent with the results of Wongwiwat and Wattanachant and Chen et al [4,5]. It was found that screening sugar types and selecting the optimal HSC notably affected the CSPJ quality and influenced the preference of panelists.

In this study, CSPJ samples were treated with HSC; the hardness, sweetness, and overall acceptability of these samples seemed to be more acceptable to the panelists, similar to the results of Chen et al [4]. However, the panelists had a decreased sweetness preference for CSPJ samples treated with sucrose concentrations of more than 21%. Furthermore, treatment with sucrose concentrations of up to 24% resulted in decreased preference for the hardness and texture of CSPJ samples. These results are supported by those of Wongwiwat and Wattanachant [5]. It was found that all sensory attributes of meat jerky products, including TSDCM and CSPJ, treated with sucrose had the highest sensory scores; for example, the sensory scores of color, hardness, taste, and overall acceptability for TSDCM and CSPJ samples prepared with sucrose were the highest.

According to the sensory scores of sweetness, the panelists preferred 21% sucrose CSPJ samples. This result is consistent with that of Chen et al [4] and is similar to that of Wang and Leistner [17]. Both of these studies have reported that Chinese-style dried meat products treated with approximately 20% sucrose were more favored by panelists. Some reports have indicated that Asian consumers prefer meat products formulated with HSC over Western-style meat products. Accordingly, the results of this study indicate that sucrose supplementation effectively enhanced the color, aroma, hardness, sweetness, texture, flavor, and overall acceptability of CSPJ samples. For sucrose, the HSC were up to 21% to 24%. The concentration is dependent on the target of formula design for CSPJ production. Furthermore, according to the sensory evaluation results, the panelists accepted the sensory quality of CSPJ samples treated with the disaccharides and the concentrations, particularly sucrose and maltose treatment. However, the samples prepared with sucrose treatment had the highest overall acceptability scores, which were 5.00 at sucrose concentrations of up to 21% to 24%. Overall acceptability was previously defined as the mixing taste and other attributes of CSPJ samples in the mouth [4]. Overall acceptability may be the most important factor used to evaluate the overall quality of foods, such as CSPJ and other meat products.

This result is consistent with the finding that Asian consumers who favor processed meats and prefer meat products treated with higher concentrations of sucrose compared with Western-style processed meat. In particular, consumers in Southeastern Asia (e.g., Thailand) prefer palatable sweet flavors; thus, TSDCM should be treated with a high sucrose concentration (approximately 35%) to produce the sweet taste [1]. Moreover, this result may imply that consumers who live in Southern Taiwan may also accept the intense palatable sweetness of CSPJ treated with sucrose (or supplementary concentrations). In this study, the sweetness scores show that the panelists preferred CSPJ treated with 21% sucrose, which is similar to the result of Wang and Leistner [17] and is consistent with the finding of Chen et al [4], in which the sucrose concentration was approximately 20% for Chinese-style dried meat product. Furthermore, CSPJ samples treated with 21% and 24% sucrose had much higher overall acceptability scores than those with 15% sucrose, 18% sucrose, and the control treatment ($p<0.05$). CSPJ samples with 21% and 24% sucrose had the highest scores for color, aroma, hardness, texture, flavor, and overall acceptability. In addition, 15% sucrose treatment led to higher scores than the control treatment ($p<0.05$) [4]. However, CSPJ samples treated with 18% sucrose had the highest scores for sweetness, which is consistent with the result of Chen et al [4].

In this study, a considerable difference was observed in most of the physicochemical properties of samples treated with different disaccharides ($p<0.001$) and various HSC after drying. However, no statistically significant difference was observed in the interaction between the disaccharides and their higher concentrations. Moreover, the effects of the disaccharides were much higher than those of four different HSC, and this was due to the physicochemical difference in the disaccharides.

CONCLUSION

The data obtained in this study indicate that for the various quality characteristics of CSPJ samples, the effects of disaccharides were much higher than those of HSC. Sucrose has the potential to be used as a natural sugar in the meat industry. Sucrose applied in this study positively influenced the preference of panelists for all sensory attributes of CSPJ samples. The samples prepared with sucrose had higher quality, particularly in terms of providing a palatable sweeter taste for Asian consumers, than those prepared with the same concentration of lactose and maltose. When HSC increased from 21% to 24%, overall acceptability increased from 5.19 to 5.80, respectively. Some physicochemical properties (e.g., color, processing yield, and a_w) of the samples were improved. Addition of the three disaccharides enhanced the processing yield values of the samples, thus reducing the production cost; in particular, those treated with lactose may have higher profits. Further research is required to study the ability of these disaccharides to extend the shelf life and improve the quality characteristics of CSPJ.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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