Effects of High Level of Sucrose on the Moisture Content, Water Activity, Protein Denaturation and Sensory Properties in Chinese-Style Pork Jerky

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ABSTRACT : The effects of a high level of sucrose on the moisture content, water activity, protein denaturation and sensory properties in Chinese-style pork jerky were investigated. The pork jerky with different levels (0, 12, 15, 18 and 21%) of sucrose was prepared. Fifteen frozen boneless pork legs from different animals were used in this trial. Sucrose is a non-reducing disaccharides and would not undergo non-enzymatic browning. Some studies pointed out that sucrose might be hydrolyzed during freezing, dehydration and storage into glucose and fructose, and cause non-enzymatic browning in meat products. The results showed that moisture content and water activity of pork jerky decreased with increase of the level of sucrose. At the same time, shear value was increased due to the reduced moisture content and water activity by osmotic dehydration. However, a higher level of sucrose had a significantly negative effect on protein solubility and extractability of myosin heavy chain of pork jerky due to non-enzymatic browning. From the results of sensory panel tests, the pork jerky with 21% of sucrose seems to be more acceptable by the panelists in hardness, sweetness and overall acceptability. *(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 4 : 585-590)*

Key Words : Chinese-Style Pork Jerky, Sucrose, Water Activity, Protein Denaturation

INTRODUCTION

Most Chinese-style processed meats are formulated with a significantly higher level of sucrose compared to western style processed meats. In Taiwan, sucrose also has long been used as a sweetener in traditional processed meat products, such as sausage, dry pork and etc. The sucrose level of Chinese-style dried meat product is approximately 20% (Wang and Leistner, 1994; Chen et al., 2001) but does show some variation.

Osmotic dehydration as an intermediate step in air drying of food was studied by Kim and Toledo (1987). The most commonly used osmotic agents are sucrose and sodium chloride. Osmotic dehydration consists of immersing meat materials in aqueous solutions of high osmotic pressure such as sucrose or sodium chloride, and allowing water to transfer from the meat material into the solution by osmosis.

Non-enzymatic browning involving amino groups (such as ε-NH$_2$ groups of lysine residues and α-NH$_2$ groups of protein) and reducing sugars (such as fructose, glucose, and etc.) is an important cause of functionality loss in stored proteins (Cerami, 1994). Non-enzymatic browning may have detrimental effects on nutrients in some stored food products and may be a limiting factor in shelf-life of some products (O'Brien and Morrissey, 1989). Sucrose is a non-reducing disaccharide and would not undergo non-

enzymatic browning. Some studies showed that sucrose might be hydrolyzed during freezing, dehydration and storage (Karel and Labuza, 1968; Schoebel et al., 1969) into glucose and fructose, and induce non-enzymatic browning in meat products. No systematic study has been reported to evaluate the usage level of sucrose for the processed Chinese-style pork jerky. The objective of this study was to investigate the physico-chemical characteristics of a high level of sucrose in manufacturing Chinese-style pork jerky.

MATERIALS AND METHODS

Preparation of Chinese-style pork jerky

Fifteen frozen boneless pork legs (right side of carcass) were obtained from a local meat plant and trimmed of all subcutaneous fat and connective tissue. The formula of curing ingredients (based on raw meat weight) included 1% sodium chloride, 1% monosodium glutamate, 5% soybean sauce, 0.3% sodium tripolyphosphate, 0.2% sorbic acid, 0.1% cinnamon, 0.05% ascorbic acid, 0.01% sodium nitrite, 0.01% sodium nitrate, 0.1% five-spices powder (containing anise, cinnamon, clove, fennel, and watchou), and different levels (0, 12, 15, 18 and 21%) of sucrose.

The pork jerky was processed by the following procedure: (1) removed subcutaneous fat and connective tissue from pork ham; (2) slice meat to 4 mm thickness by slicer (JWS-330, Woo Jin Co., South Korea); (3) mix curing ingredients with sliced pork; (4) cured at 4°C for 48 h; (5) dried at 55°C for 80 min; (6) roasted at 180°C for 5 min and (7) pack final products in polyethylene film without vacuum and store at room temperature (26°C) for subsequent measurement of physico-chemical properties.

The determined items including moisture content, water activity, shear value, absorbance at 420 nm for non-enzymatic browning, protein solubility, sodium dodecyl sulfate-polyacryamide gel electrophoresis (SDS-PAGE) and sensory panel test. All analyses were performed in triplicate.

Measurement of moisture content

The moisture content was determined by oven drying the sample to constant weight at 100°C for 18 h (AOAC, 1980).

Measurement of water activity

Water activity (a_w) of the sample was determined by using a hygrometer (TH/RTD 523, Novasina, Swiss) equipped with thermoconstanter. The a_w was determined from triplicate 2 g ground samples held at 25±0.1°C until equilibrium reached.

Measurement of shear value

Shear value was measured for the pork jerky (samples cut into 1.2×1.2×0.3 cm) using a Fudoh Rheometer (NRM-2010 J-CW, Rikadenki Kogyo Inc., Japan). A Rheo Plotter (FR-801, Rikadenki Kogyo Inc., Japan) was used to plot the picture. The measuring table speed was 6 cm/min and a peak force required to shear across the meat fibres was determined.

Determination of non-enzymatic browning

Non-enzymatic browning was determined by the procedure of Resnik and Chirife (1979). Ground samples of 1.5 g each were placed in a 250 ml Erlenmeyer flask and extracted with 100 ml of a 50% (v/v) methanol-distilled water mixture. Extraction was carried out by placing the flasks in a mechanical shaker at 27°C for 24 h. The suspension was placed in a centrifuge tube and clarified by a centrifuge (SCR20B, Hitachi, Japan) for 100 min at 2,000 rpm. The absorbance value of supernatant was obtained at 420 nm by a spectrophotometer (U-2001, Hitachi, Japan) and the absorbance value was given as optical density (OD_{420}) per gram of dry mass.

Determination of protein solubility

The protein solubility of pork jerky was measured by the method of Xiong and Brekke (1989). Total protein was extracted from 1 g of ground pork jerky using 20 ml of 1.1 M potassium iodine in 0.1 M phosphate buffer (pH 7.2). The samples were homogenized and shaked at 4°C for overnight. Samples were centrifuged at 1,500 rpm for 20 min and protein concentration in the supernatants was determined by the Kjeldahl method (AOAC, 1980). Protein solubility was expressed as a percentage of protein concentration of the supernatant to the protein concentration of the original suspension.

Sodium dodecyl sulfate-polyacryamide gel electrophoresis (SDS-PAGE)
Sample preparation

Ground pork jerky sample (3 g) was added to 15 mL of myofibrillar extracted buffer containing 75 mM KCl, 10 mM KH_2PO_4, 2 mM $MgCl_2$, 2 mM EGTA, pH 7.0 and homogenized for 45 sec. The homogenate was centrifuged at 1,500 g, 4°C for 10 min and the supernatant decanted and saved. Fresh myofibrillar extracted buffer 15 mL was added to the saved sample and the homogenization repeated. Sample was mixed 1:1 with standard sample buffer which contained 8 M urea, 2 M thiourea, 3% (w/v) SDS, 75 mM Dl-dithothreitol, and 25 mM Tris-HCl at pH 6.8, and heated at 85°C for 20 min in a water bath then cooled and applied for gel electrophoresis.

Electrophoresis operation

SDS-PAGE was performed on tube gels containing 7.5 to 20.0% polyacrylamide according to the method of Laemmli (1970). The same amount of protein (50 μg) from each sample was loaded onto gels. The separated protein bands were identified by comparing against those of molecular weight standard mixture markers (Sigma) which including myosin (205 KD), β-galactosidase (116 KD), phosphorylase b (97.4 KD), albumin (66 KD), albumon (45 KD) and carbonic anhydrase (29 KD) (Sigma Chemical, St. Louis, MO, USA).

Sensory panel test

Fifteen undergraduate and graduate students of the Department of Animal Science, National Chung-Hsing University were invited as taste panelists. The hedonic test was used to evaluate the chewiness, hardness, sweetness and the overall acceptability of the samples. A score ranged from 1 to 7 which indicated very low to very high desirability in chewiness, hardness, sweetness and overall acceptability (Huffman et al., 1981).

Statistical analysis

All data were analyzed using the General Linear Model Procedures of SAS (SAS, 1988)(Inst. Inc., Cary, NC). Comparison of treatment means was based on a Duncan's multiple range test. A significance level of $p < 0.05$ was applied in all cases.
The GLM model as follows:

$$Yi = \mu + Ti + e$$

Where: Yi=data values; Ti=ith effect of factor T (sucrose), i=1 to 5; e=error.

RESULTS AND DISCUSSION

Moisture content and water activity

The results of this study showed that moisture content of pork jerky ranged from 22.1-32.5% and water activity (a_w) ranged from 0.84-0.75 (figures 1 and 2). The moisture content and water activity (a_w) of pork jerky reduced as sucrose level increased (p<0.05). High level of sucrose was more effective than low level of sucrose in lowering moisture content and a_w. This result of a_w in the present study agreed with the work of Kushner et al. (1979), who reported that increasing the level of sucrose significantly decreased a_w of dried pork jerky. The moisture content and a_w of the product in this study also met the requirement of

the intermediate moisture foods in which normal range in a_w is 0.7-0.9 and moisture content is 20-50% (Karel, 1973).

Shear value

Shear values from the Rheometer can be used to identify if meat products contain a high amount of variability in total shear value. Differences in shear values can be used to determine if differences exist in total force between meat samples. It has been recognized that textural change of food is associated with the moisture content and aw of food. Usually, this is based on the "toughness" of a food and is related to the type of food consumed. Figure 3 shows that pork jerky with the higher level of sucrose had a higher shear value than the control treatment (p<0.05). The pork jerky containing 12 and 15% sucrose had a lower shear value than 18 and 21% treatments (p<0.05). However, there was no significant difference between 18% and 21% of sucrose. Increasing sucrose concentration decreased shear value because it reduced the moisture content and water activity of the pork jerky by osmotic dehydration.

Non-enzymatic browning

It is well known that color development can be induced by non-enzymatic reaction (Favetto et al., 1988). Flink (1983) stated that absorbance value at 420 nm was used as an indicator for detecting color change (non-enzymatic browning). Figure 4 shows that the absorbance values of the pork jerky with 12, 15, 18 and 21% sucrose were higher than the control treatment (p<0.05). Sucrose is a non-reducing sugar and wouldn't undergo non-enzymatic browning. But it has been pointed out that sucrose may be hydrolyzed during freezing, dehydration and storage (Karel and Labuza, 1968; Schoebel et al., 1969) into glucose and fructose, and result in non-enzymatic browning in meat products. This result was similar to results of Buera et al.
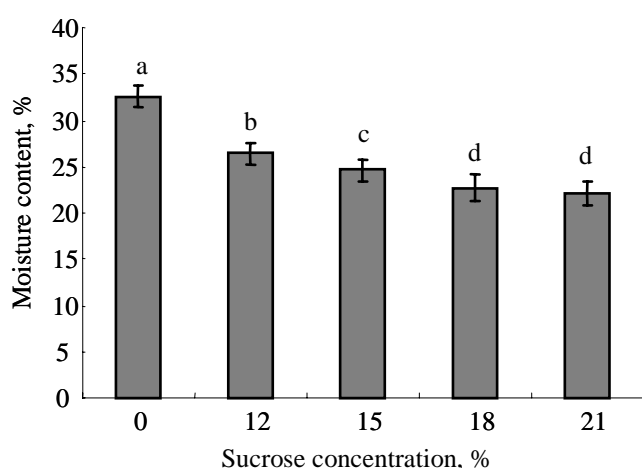

Figure 1. Effect of different levels of sucrose on moisture content in Chinese-style pork jerky. Means without a common superscript letter in the different bars are significantly different (p<0.05).
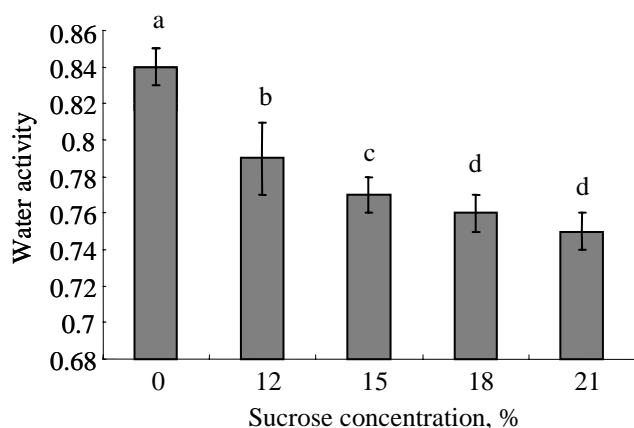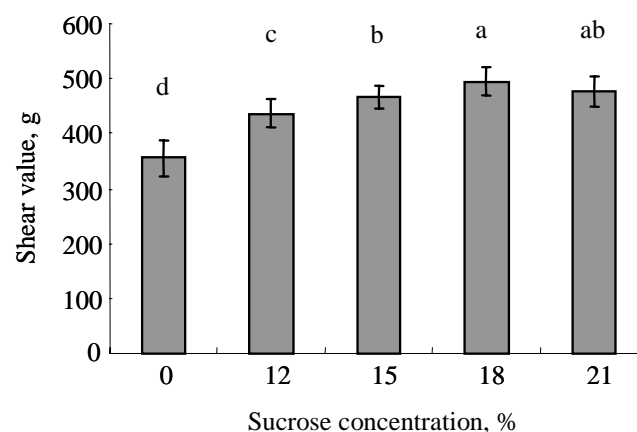

Figure 2. Effect of different levels of sucrose on water activity in Chinese-style pork jerky. Means without a common superscript letter in the different bars are significantly different (p<0.05).

Figure 3. Effect of different levels of sucrose on shear value in Chinese-style pork jerky. Means without a common superscript letter in the different bars are significantly different (p<0.05).
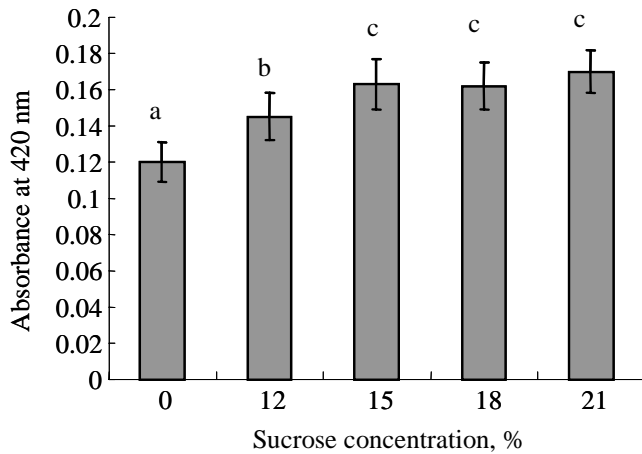
Figure 4. Effect of different levels of sucrose on non-enzymatic browning in Chinese-style pork jerky. Means without a common superscript letter in the different bars are significantly different (p<0.05).

(1987) who pointed out that during non-enzymatic browning, sucrose browned faster than other sugars.

Protein solubility

The properties and functionality of protein depend upon whether they exit in an intact or denatured state. Denatured proteins are frequently less soluble than those in the native state. Denaturation manifests most profoundly in decreasing solubility of protein (Hamm, 1966). The results in figure 5 show that the pork jerky without sucrose had higher protein solubility than any other pork jerky with high levels of sucrose (p<0.05). The changes in extractability of myosin heavy chain (MHC) also could be a useful index of alteration of myofibrillar protein in intermediate moisture meats (Muguruma et al., 1987b), who found that the extractability of MHC, used as an index of changes of myobibrillar protein, decreased in intermediate moisture porcine meat with the addition of salt and was unaffected by addition of humectants. Also, MHC could be extracted easily from intermediate moisture meat dehydrated at low-temperature (4°C) after long term storage (Muguruma et al., 1987a). The results showed that a higher amount of MHC was extracted from the control treatment when compared to other pork jerky samples (figure 6). These results indicated that higher levels of sucrose resulted in non-enzymatic browning which is a major deteriorative reaction in intermediate moisture and humidified dry foods (Labuza, 1972; Warmbier et al., 1976). It has been pointed out that the sucrose system has a potential reducing sugar concentration twice as great as the monosaccharide system and it accounted for a greater degree of browning during the later stages of experiment (Reyes et al., 1982). In addition to deleterious color reactions such foods (e. g., dried milks)
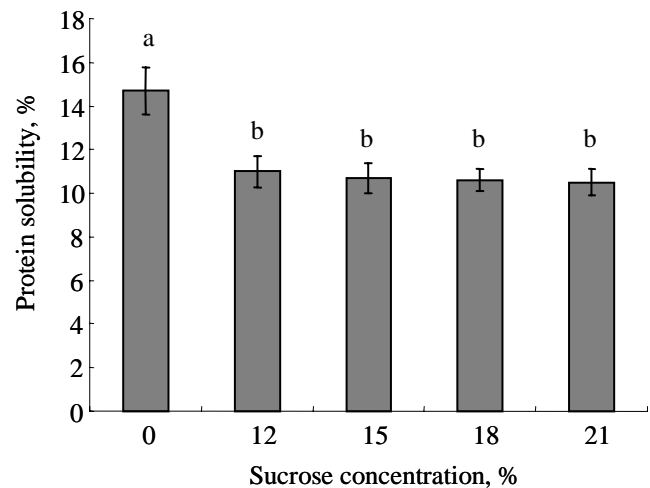

Figure 5. Effect of different levels of sucrose on protein solubility in Chinese-style pork jerky. Means without a common superscript letter in the different bars are significantly different (p<0.05).
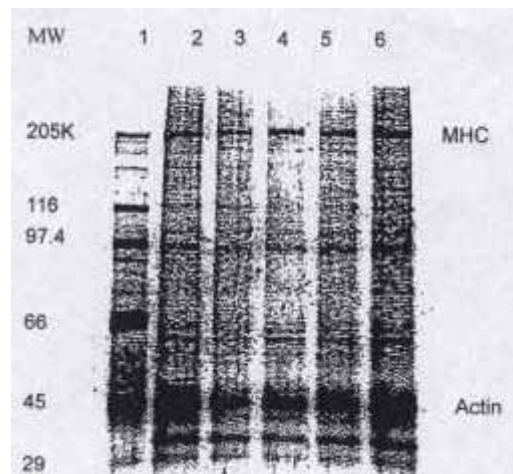

Figure 6. SDS-PAGE electrophoretogram of myofibrillar proteins from Chinese-style pork jerky by different levels of sucrose. (1) standard marker; (2) 12% sucrose; (3) 15% sucrose; (4) 18% sucrose; (5) 21% sucrose; (6) control (0%). MW, molecular weight; MHC, myosin heavy chain.

also may lose nutrients as a result of non-enzymatic browning reaction. Some products from non-enzymatic browning have reduced digestibility of protein (Oste, 1991). The results of decreased solubility and extractability of MHC indicated that the protein of pork jerky was damaged by the non-enzymatic browning when pork jerky was treated with the non-reducing sugar (sucrose). In addition, non-enzymatic browning shows a maximum rate in some intermediate a_w, usually around 0.6-0.8 (Labuza and Saltmarch, 1981).

Table 1. Effect of different levels of sucrose (%) on the sensory panel score of Chinese-style pork jerky*

Items	Levels of sucrose (%)				
	0	12	15	18	21
Chewiness	3.97±1.13	4.88±1.22	4.64±1.30	4.88±1.02	5.01±0.75
Hardness	3.96±1.13[b]	4.78±0.82[ab]	4.30±1.10[ab]	4.78±0.82[ab]	5.14±0.61[a]
Sweetness	2.55±0.69[c]	4.67±0.71[b]	4.59±0.70[b]	5.21±0.59[ab]	5.37±0.46[a]
Overall	2.81±0.61[c]	4.66±0.60[b]	4.40±0.82[b]	5.36±0.74[a]	5.55±0.48[a]

* A score of 1 indicated very low desirability in chewiness, hardness, sweetness and overall acceptability and a score of 7 indicated very high desirability in chewiness, hardness, sweetness and overall acceptability.
[a,b,c] Means at the same row without the same superscript are significantly different ($p<0.05$).

Sensory panel test

The sensory panel used a seven point hedonic score test in this experiment. The sensory characteristics in the present study can be divided into the following parameters: a) Chewiness, defined as the energy required to masticate pork jerky to state ready for swallowing and b) Hardness, defined as the force necessary to attain a given deformation (Szczesniak, 1963); c) Sweetness, defined as the taste on the tongue associated with sugars (Johnsen et al., 1987); and d) overall acceptability, defined as the mixing taste on the mouth associated with pork jerky. The results of table 1 showed that the chewiness score of pork jerky with different levels of sucrose were not significantly different the control treatment. The hardness score of pork jerky with 21% sucrose was significantly higher than the control treatment ($p<0.05$). The sweetness score of pork jerky with 21% sucrose also was significantly higher than the samples with 12%, 15% and the control treatment ($p<0.05$). The overall acceptability scores of pork jerky with 18% and 21% of sucrose were higher than 12%, 15% and the control treatment ($p<0.05$). The pork jerky with 21% sucrose obtained the highest scores in hardness, sweetness and overall acceptability, higher than those of 12% sucrose and the control treatment ($p<0.05$). The sweetness scores showed that the panelists prefered pork jerky with 21% sucrose, similar to the report of Wang and Leistner (1994) mentioned that the sucrose level of Chinese-style dried meat product was approximately 20%. Also, some research showed that the Asian people who like processed meats preferred it to be formulated with higher levels of sucrose compared to western style processed meats (Solina et al., 1998).

CONCLUSION

The pork jerky with the higher level of sucrose seemed to be more acceptable by the panelists in hardness, sweetness and overall acceptability. However, pork jerky with a high level of sucrose had significantly negative effects on protein solubility and extractability of myosin heavy chain due to non-enzymatic browning.

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