PE4.06 Effects of enhancement with non-meat proteins and sodium tripolyphosphate on physicochemical properties of pork loin 24.00

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***Abstract*—This study was carried out in order to evaluate the effects of the injection of non-meat proteins (1.5%) and sodium tripolyphosphate (0.45%) on physicochemical properties of pork longissimus dorsi. Six different treatments with soy protein isolate (SPI), whey protein concentrate (WPC), salt (sodium chloride), sodium tripolyphosphate (STPP) and water were compared to control, non-enhanced loins. Enhanced pork (pumped to 115%) had higher moisture and lower protein values. The use of STTP had a synergic effect with non-meat proteins, being essential to reduce purge loss and to increase cooking yield. All enhanced samples reduced Warner-Bratzler shear force (WBSF) compared to the control, but STTP and WPC yielded significant lower values. Enhancement with WPC inhibited the lipid oxidation, resulting on lower 2-thiobarbituric acid reagents (TBARS) values than other treatments during refrigerated storage. Lightness (*L**) and redness (*a**) increased between days 5 and 35, but yellowness (*b**) has not been significantly affected by enhancement. Due to the evident synergic effect of STTP with non-meat proteins, enhancement will be more functional if these ingredients are combined in brine formulations to be injected into pork loins.**

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***Index Terms*—pork, enhancement, non-meat proteins, sodium tripolyphosphate.**

I. INTRODUCTION

Although Brazil is among the main pork producers in the world, Brazilian *per capita* pork consuming is still very low, near 4.0 kg/year. Compared to poultry and beef, Brazilian pork consuming is three and four times lower, respectively [1].

In several countries, pork enhancement seems to be a strategy to meat industry, improving sensory attributes such as juiciness, tenderness and color of the final product [2, 3]. Enhancement typically consists of brines containing salt, alkaline phosphates, flavoring agents and sometimes other functional ingredients and extenders, injected into the muscle [4, 5]. Enhancement of pork usually increases the weight of saleable product, due to the retention of added water, but special attention shall be paid in order to avoid adverse effects such as over-tenderization or excessive stripping, which could induce consumer's rejection [4, 5].

Non-meat proteins are often added to processed meat products as binders and extenders. SPI and WPC are among the most used ones, reducing cost of production while adding functionality and nutritive value [6, 7]. Nevertheless, the addition of non-meat proteins to meat products may cause health problems, being subjected to legal limitations [8]. In the other hand, proteins and peptides, such as whey and soy, have been reported to act as natural antioxidants in processed meats. This is particularly advantageous, because of pork relatively high content of unsaturated fatty acids, which oxidizes more rapidly than either beef or lamb [9, 10]. Thus, research on possible advantages for consumers of enhanced pork is still needed in Brazil, in order to provide the government authorities with technical and scientific subsidies and to discipline its production.

Therefore, the aim of this study was to evaluate the physical and chemical effects of enhancement with SPI, WPC and STTP in pork loin.

II. MATERIALS AND METHODS

A. Loin preparation

Five whole fresh pork loins (24 h post-mortem, pH 5.6-5.9) were selected to each treatment and then cut into three sections each. The loin sections were randomly assigned for enhancement and pumped to 115% of original weight with a brine solution using a multi-needle brine injector. Six brine solutions were formulated: 5% salt (treatment II); 5% salt and 3% STTP (treatment III); 5% salt and 10% SPI (treatment IV), 5% salt and 10% WPC (treatment V), 5% salt, 10% SPI and 3% STTP (treatment VI) and 5% salt, 10% WPC and 3% STTP (treatment VII) for comparison with non-enhanced control loins (treatment I). Each specific treatment marinade was manufactured by adding in sequence, the appropriate amount of cold water (4°C) and non-meat ingredients, until their complete dissolution. Treatment marinades were randomly assigned to 15 loin sections each. The injection machine was thoroughly cleaned between each treatment. After injection, loins were vacuum packaged and held for 72 h at 2°C to allow for equilibration of the injected solution throughout the loin. Loins were then sliced into chops, vacuum packaged, stored at 4°C and analyzed within 30 days. Final concentrations in the injected meat were 5 g of salt, 0.45 g of STTP and 1.5 g of non-meat proteins per 100 g of meat depending on the brine, and assuming all the injected ingredients are retained. The ingredients used in the brine formulations were sodium chloride (NaCl); WPC (protein content as is 75% w/w); SPI (protein content as is 80% w/w) and STTP ($Na_5P_3O_{10}$).

B. pH measurements

pH measurements were performed on pork loins prior to enhancement to ensure pH was within the range of 5.6 and 5.9, using a portable pH meter, calibrated using buffers of pH 4.0 and 7.0 and compensated for temperature. The pH was also measured in the brines and in pork after injection equilibration.

C. Purge loss

Pork loins were weighed immediately after injection and then vacuum packaged. The loins were then allowed to equilibrate at 2°C for 72 h and re-weighed for purge loss determination [2].

D. Compositional analysis

After removal of epimysial connective tissue and subcutaneous fat, meat was homogenized for compositional analysis, according to AOAC methods. Moisture content was determined by oven-drying at 105°C for 24 h. The ash content was determined by ashing at 550°C in a muffle furnace for 6 h or until light gray or white ash was obtained. The intramuscular fat was determined by Soxhlet extraction with diethyl ether. Total protein (N x 6.25) content was determined by the Kjeldahl method.

E. Lipid oxidation

Lipid oxidation was assessed in pork during refrigerated storage (4°C). Evaluation of oxidative stability was performed using the 2-thiobarbituric acid test [11], with the addition of butylated hydroxytoluene before the blending step, to prevent sample autoxidation. Malonaldehyde absorbances were determined at 532 nm and results were expressed in mg malonaldehyde/kg meat, using a standard curve prepared from 1,1',3,3' tetraethoxy-propane. Mean of values of three independent determinations are given.

F. Cook loss/Warner-Bratzler shear force determination

Cook loss was determined by cooking the loin sections in bags in a water bath at 78°C, until an internal temperature of 75°C was achieved. The loins were allowed to cool to room temperature and then were removed from the bags, dabbed with tissue paper to absorb excess water and the weight was recorded. Percent cooking yield was calculated by determining the difference between the initial and cooked loin weight, dividing that difference by the initial weight and multiplying by 100. In order to assess WBSF, the cooked loins were placed on plastic trays, covered with plastic film and chilled at 4°C for 12 h. Ten cores with 1.27 cm of diameter were taken parallel to the longitudinal axis of the fibers. Cores were sheared perpendicular to the fibers using a Warner-Bratzler head on a TA-HDi Texture Analyzer (Stable Micro Systems). The crosshead speed was 2.0 mm/s. Texture Expert software was employed and data was reported in kg of force.

G. Colour determination

A Hunterlab MiniScan XE Plus colorimeter was used to objectively measure CIE $L^*a^*b^*$ instrumental colour determination. The colorimeter was standardized using black and white tiles. The illuminant D65 was chosen, with 10° standard observer. Colour was measured on the loins surface on seven randomly selected locations on each sample.

H. Statistical analysis

Data were evaluated by general analysis of variance (ANOVA) and comparison of means was done by Tukey's Test. Differences were considered statistically significant at $P < 0.05$. Mean values and standard error of the means are presented.

III. RESULTS AND DISCUSSION

Brine pH and meat pH before and after injection are shown in Table 1. As expected, meat pH ranged from 5.62 and 5.73. Loin pieces assigned to treatments II (water/salt) and IV (water/salt/SPI) had lower and higher pH than the other treatments, respectively, although no statistical significant difference had been observed ($P < 0.05$). Brine pH ranged from 6.25 to 8.32. As expected, the pH for salt was close to neutral whilst phosphate increased the brine pH. Phosphate increased the pH on treatments III (water/salt/STTP) and VII (water/salt/WPC/STTP) by 0.06 and 0.26 units, respectively. Contrary to expected, phosphate did not increase pH on treatment VI (water/salt/SPI/STTP), possibly due to an incomplete equilibration.

Water/salt (II) enhanced pork recorded the highest purge loss of 5.97% (Table 2), which is significantly different than all other treatments ($P < 0.05$). Although all non-meat ingredients yielded low purge loss values, STPP reduced purge loss with a synergic, significant ($P < 0.05$) effect with non-meat proteins on enhanced pork, as reported by other authors [5].

In Table 2 it can be seen that injection of STTP has driven to lower cook loss values, although no significant difference has been observed between enhanced and control loins ($P > 0.05$). Treatments II (water/salt) and IV (water/salt/SPI) had higher cook losses than the non-injected control. This could be due to the absence of STTP to help to hold water in these treatments. Furthermore, injected products can reach higher cooking losses than non-injected controls because they have more liquid to lose, and the injected ingredients cannot hold on to all of the additional liquid introduced into meat [5].

Although all the shear forces values decreased in the enhanced pork samples, treatments II (water/salt) and IV (water/salt/SPI) had no significant differences compared to the control ($P > 0.05$). The control had the highest peak force of 2.38 kg (Figure 1). This is contrary to other authors that have been reporting that enhancement with non-meat ingredients usually promotes a significant reduction in shear-force compared to not injected pork [5, 11]. In the other hand, there was no significant difference for shear force between treatments injected with STTP or WPC ($P < 0.05$) showing that both ingredients were the most effective on reducing shear force.

As expected, injection significantly reached treatments to higher moisture and lower protein content in comparison to the control ($P < 0.05$). Treatment II had the highest moisture content (75.33%) and the lowest protein content (18.83%). According to Brazilian meat regulations, products done with pork loin must have a minimum protein content of 16% and a maximum moisture content of 75%. Excepting for treatment II (water/salt), all treatments were in accordance to that statements (Table 3). Ashes content ranged from 1.15% to 2.29%. As expected, the non-injected control recorded the lower ashes value, which was significantly different from all other treatments ($P < 0.05$). The use of STTP and sodium chloride significantly increased the ashes content, as it has been reported by other authors [1].

TBARS values increased for all treatments during refrigerated storage. WPC was the most effective ingredient in terms of inhibiting lipid oxidation, yielding significantly lower ($P < 0.05$) TBARS values in comparison to the other ingredients (Figure 2). This is in agreement with other authors that have been reporting that whey proteins are effective antioxidants for pork products [6, 8]. STTP had a synergic effect with non-meat proteins, reaching samples to lower TBARS values compared to the other treatments.

L^* and a^* values were affected by enhancement at day 5 and day 35 (Table 4). Enhancement did not have much significant effects on b^* values. Some authors reported a decrease in redness as storage time increased for pork enhanced with STTP and WPC [5]. In the present study, redness increased in all treatments between days 5 and 35, excepting for control and treatment IV (water/salt/SPI). However, enhancement decreased pork's a^* values compared to control, as reported by other authors [3, 4] Lightness increased significantly ($P < 0.05$) in all treatments at both days 5 and 35, compared to the control. This increase could be due to fluid dilution of pigments and increased light refraction by free water [3].

IV. CONCLUSION

Enhancement with non-meat ingredients improved the physicochemical properties of the pork loins. The injection of WPC was significantly more effective than SPI on improving cooking yield, reducing shear-force and inhibiting lipid oxidation. However, due to the evident synergic effect of STTP with non-meat proteins, enhancement will be more functional if these ingredients are combined in brine formulations to be injected into pork loins.

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Table 1. pH of brines and effects on the pH of loin pieces before and after injection.

Treatment	Brine pH	pH before	pH after
I	-	5.68^{ab}	-
II	7.39	5.62^{b}	5.58^{bc}
III	8.32	5.64^{ab}	5.70^{ab}
IV	6.25	5.73^{a}	5.39^{c}
V	6.32	5.65^{ab}	5.53^{bc}
VI	7.26	5.69^{ab}	5.65^{abc}
VII	7.31	5.65^{ab}	5.91^{a}
SEM	-	0.01	0.04

Means in the same column with the same letter do not differ significantly at the 0.05 level of probability. SEM: standard error of the mean.

Table 2. Effects of enhancement on the physical properties of pork loins.

Treatment	Purge loss (%)	Cook loss (%)
I	0.00^{a}	30.16^{abc}
II	5.97^{b}	36.50^{a}
III	1.17^{d}	23.50^{c}
IV	3.99^{c}	35.10^{ab}
V	2.78^{cd}	24.03^{bc}
VI	2.06^{d}	21.96^{c}
VII	2.10^{d}	22.49^{c}
SEM	0.32	1.41

Means in the same column with the same letters do not differ significantly at the 0.05 level of probability. SEM: standard error of the mean.

Table 3. Effects of enhancement on the chemical composition of pork loins.

Treatment	Moisture (%)	Protein (%)	Fat (%)	Ashes (%)
I	72.76^{c}	22.72^{a}	2.84^{cd}	1.15^{e}
II	75.33^{a}	18.63^{d}	5.04^{b}	1.65^{cd}
III	74.48^{b}	19.41^{bcd}	2.42^{d}	1.97^{b}
IV	74.65^{ab}	20.29^{b}	2.29^{d}	1.60^{d}
V	74.40^{b}	19.15^{cd}	7.16^{a}	1.64^{cd}
VI	73.20^{c}	19.68^{bc}	3.22^{c}	2.29^{a}
VII	74.41^{b}	19.90^{bc}	3.19^{c}	1.69^{c}
SEM	0.20	0.34	0.45	0.07

Means in the same column with unlike superscripts are different ($P < 0.05$). SEM: standard error of the means.

Table 4. Effects of enhancement on the colour of pork loins.

Treatment	Day 5			Day 35		
	*L**	*a**	*b**	*L**	*a**	*b**
I	55.69^{d}	7.79^{a}	13.73^{a}	59.74^{c}	6.35^{a}	13.85^{bc}
II	61.42^{b}	5.19^{bc}	13.92^{a}	64.17^{b}	5.96^{ab}	13.89^{bc}
III	57.41^{cd}	4.98^{bc}	13.73^{a}	60.36^{c}	4.84^{b}	13.32^{c}
IV	57.23^{b}	6.11^{b}	14.27^{a}	61.34^{c}	5.83^{ab}	14.57^{ab}
V	66.05^{a}	4.54^{c}	14.90^{a}	67.32^{a}	5.91^{ab}	13.27^{a}
VI	60.89^{bc}	4.04^{c}	14.38^{a}	60.14^{c}	5.91^{ab}	14.03^{bc}
VII	58.10^{bcd}	4.69^{bc}	14.28^{a}	60.96^{c}	5.82^{ab}	13.98^{bc}
SEM	0.54	0.21	0.12	0.38	0.13	0.11

Means in the same column with unlike superscripts are different ($P < 0.05$). SEM: standard error of the means.

Figure 1. Warner-Bratzler shear force means (kg) for pork enhanced with non-meat proteins and sodium tripolyphosphate.

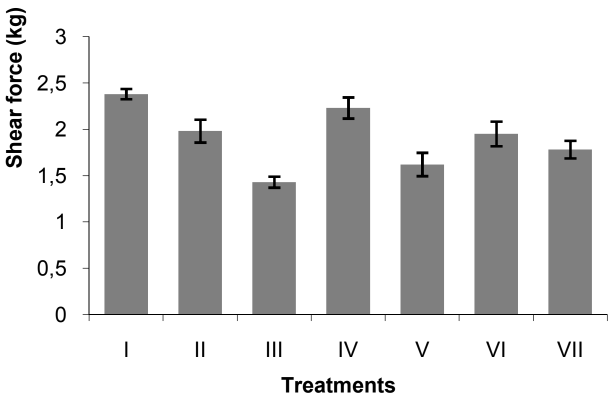

Figure 2. TBARS values for pork loins enhanced with non-meat proteins and sodium tripolyphosphate during refrigerated storage at 4°C.