A Literature Review on the Effects of Moisture Enhancement on Pork Quality

Background:

Most of the fresh pork marketed in North America undergoes moisture enhancement, or the injection (pumping) of a solution containing salt and phosphates into primals or subprimals before fabrication into chops and roasts. Moisture enhanced pork is often marketed as seasoned pork in the meat case. This process enhances product tenderness and juiciness which is important since consumers tend to cook fresh pork to advanced degrees of doneness. However, health professional and consumer concerns about the added sodium and phosphates in the pumping process are influencing grocery retailers who are examining marketing of non-enhanced product. Therefore, swine nutritional feeding strategies may become more important to influence the eating quality (tenderness, juiciness, and flavor) of fresh pork as grocery retailers begin to reject seasoned, fresh pork products and promote non-enhanced pork products in their meat cases. The trend for marketing non-enhanced pork is expected to increase due to potential health concerns associated with eating pork products enhanced with sodium and phosphates. Development of nutritional programs in pork production to increase intramuscular fat deposition and improve juiciness and flavor will become important if a fresh, non-moisture enhanced product is extensively marketed in the retail grocery case.

During the past decade, pork quality attributes (appearance, tenderness, juiciness, and flavor) have become increasingly important for the consumer. As indicated by Brewer and McKeith (1999), purchasing intent by consumers is primarily based on
product appearance for fresh pork in the meat case. Consumers tend to prefer product that is reddish-pink in color with minimal intramuscular, intermuscular and subcutaneous fat deposits. Low levels of excess moisture in the storage bag or container are also preferred. However Brewer et al. (2001) also indicated that product tenderness; juiciness and flavor primarily determined if a consumer returns to a particular eating establishment or continues to buy pork from retail establishments. Therefore product enhancement by solution injection (pumping) has been followed by many meat processors to increase fluid retention and improve eating quality attributes (Brashear et al., 2002; Prestat et al., 2002) for increasing pork demand. Phosphates are commonly incorporated into pumping solutions to increase muscle pH which enhances water holding capacity (Keeton, 1983) which influences juiciness (Sheard et al., 1999). Salt and sugar are commonly added to processed meats to improve taste and texture, while sodium nitrate and sodium erythrobate (Williams et al., 2011) are added to preserve product color.

**Public perception - fresh versus moisture enhanced pork**

In a consumer survey conducted by Hayes et al. (2002), 78% of respondents rated enhanced chops more tender than non-enhanced chops while 71% found the enhanced pork chops more juicy. During the same survey, 60% of respondents rated the enhanced chops higher in taste resulting in a 62% preference in acceptability for the injected pork products. In contrast to the findings for more desirable palatability attributes with moisture enhanced pork, 67% of the surveyed consumers stated they would not purchase enhanced pork products (Brewer et al., 2002) due to concerns about specific ingredients listed on product labels such as salt and phosphates. However, the authors concluded that enhancement was beneficial if consumers perceived that enhancement could make the
pork product more acceptable. Brewer et al. (2002) indicated there was a substantial market for enhanced pork if consumers were properly educated regarding the advantages of moisture enhanced products.

The view of health professionals on moisture enhancement of animal protein

Recent health reports have called for reduced dietary sodium intakes as excess sodium in the diet increases the incidence of stroke and renal and heart disease (Williams et al., 2011). Approximately 80% of the sodium content in the North American food supply comes from processed foods with processed pork cuts varying greatly in sodium content (tenderloin = 165±15 mg/100g, shoulder blade = 243±32 mg/100g, top loin = 232±22 mg/100g; Williams et al., 2011) The health aspects of consuming moisture enhanced pork is a concern as the sodium content of enhanced pork is 2.5 to 5.2 times greater than non-enhanced product (Williams et al., 2011). This finding is important as Statistics Canada has indicated that 19% of Canadians (age 20 to 79 years) suffer from high blood pressure with an additional 20% classified in the pre-hypertension range (Rollason, 2010; Sopinka, 2010) which can be reduced with a restricted daily salt intake. Based on these findings and findings across the globe, Mr. William Jeffery (publisher of Nutrition Action magazine) and Kelly Funke (Manitoba Pork Council Communications Manager) were cited as being opposed to sodium enhancement of pork (Rollason, 2010), while Purvis (2011) echoed a similar sentiment in a recent Miami Herald column.

Phosphorus is also being added to meats (Gutekunst, 2011) in the moisture enhancement process to add flavor and juiciness; this may be very deleterious to people suffering from chronic kidney disease (Uribarri, 2007). As indicated by Uribarri (2007), added phosphorus via moisture enhancement becomes highly absorbed by the intestinal
tract and can lead to hyperphosphatemia in dialysis patients, increasing the risk for cardiovascular morbidity and mortality. Sherman and Mehta (2009) also indicated that enhanced meat products varied widely in phosphorus and potassium content. They concluded that potassium content should also be more closely monitored to reduce the risk of hyperkalemia in dialysis patients.

Bohaychuk and Greer (2003) investigated the effects of moisture enhanced pork (bone-in and boneless pork loins) on bacterial contamination and shelf life. Although the brine injection process increased bacterial contamination, it did not affect the storage life of vacuum packed loins. Non-significant differences in lactic acid bacteria, Brochothrix thermosphacta and Enterobacteriaceae were also observed in this study. To conclude, the minerals added to pork via moisture enhancement provide excess levels of the respective minerals well above daily requirements for sodium and phosphorus; excessive intakes of these minerals can lead to nutrition health problems (high blood pressure) or confound existing health problems.

**Instrumental and sensory data comparing eating quality attributes (tenderness, juiciness, and flavor) of non-enhanced versus moisture enhanced pork products.**

The meat processing industry has incorporated injection technology to enhance pork for tenderness and juiciness with phosphates commonly used (Hayes et al., 2006). These authors compared the effects of salt, phosphate and milk proteins on sensory and physical properties of pork. Cooking losses were similar between enhanced and non-enhanced pork chops which agrees with past studies (Brashear et al., 2002; Brewer et al., 2002; Sheard et al., 1999). Hayes et al. (2006) indicated that pumping with a sodium tripolyphosphate (STPP)/salt containing solution increased fluid retention when pork was cooked; this is important from a product juiciness perspective and for perception of
tenderness. Brashear et al. (2002) also reported non-significant differences in cooking losses when pork chops were cooked to either 70 or 80°C. Water holding capacity in meat is also evaluated by measuring drip loss, with high drip loss indicating a drier meat, while less drip loss indicates increased water retention and juicier meat product. There were no differences in drip loss measurements between moisture enhanced and non-enhanced pork chops (Hayes et al. 2006). These authors hypothesized that injecting with a solution containing sodium tripolyphosphate increased the pH of meat which increased water holding capacity.

Meat tenderness is often assessed using Warner-Bratzler shear force which measures the force required to cut across muscle fibers, and use of taste panels where individuals assess products for the primary palatability attributes, tenderness, juiciness, flavor. Lower shear forces are associated with more tender meat while higher shear force values are associated with tough meat. Hayes et al. (2006) reported reduced shear force values when three different pumping solutions were compared to a non-pumped control with significant correlations between shear force and taste panel evaluations for juiciness and tenderness noted. Other studies have also found improved tenderness when pork was moisture enhanced with STPP and salt (Brashear et al., 2002; Brewer et al. 2002; Smith et al., 2002). The added phosphates in conjunction with salt assist in breaking the actomyosin bonds in meat which will then increase tenderness (Cannon et al., 1993; Ellenger, 1972; Sheard et al., 1999; Smith et al., 1984; Sutton et al., 1997). In contrast, Brashear et al. (2002) reported lower shear force values (more tender pork) for moisture enhanced chops versus a non-enhanced product cooked to 70°C while there were no differences in shear force when pork chops were cooked to an 80 °C endpoint. Therefore
temperature endpoint may need to be considered when evaluating the effects of moisture enhancement on product tenderness.

Numerous studies have reported improvements in product juiciness when pork was moisture enhanced with phosphate/salt solutions (Hayes et al., 2006; Brashear et al., 2002; Brewer et al., 2002; Cannon et al., 1993; Keeton, 1983; Sheard et al., 1999; Smith et al., 1984; Smith et al., 2002; Sutton et al., 1997). Xiong (2005) described the mode of action for increased water holding capacity and juiciness with moisture enhancement. The addition of phosphates expands muscle fibers which causes increased water uptake by the meat fibers. However, moisture enhancement does not always increase water holding capacity. Brashear et al. (2002) indicated that vacuum package purge loss increased for longissimus muscle when pumped to 12% added solution. A similar trend was observed for retail purge loss with increased values for moisture enhanced product. Cooking losses also increased for pork loins which were moisture enhanced to contain an 18% pump with the lowest losses observed in non-enhanced loins. These authors indicated that 18% of the difference in retail purge loss was due to pumping level while 52% of the variation was due to vacuum purge loss. In contrast, Baublits et al. (2006) reported no weight loss when a sodium triphosphate/NaCl solution (0.4% and 1% respectfully) was used for moisture enhancement at a 12% pump rate. Therefore differences in weight loss reported were probably due to specific enhancement ingredients used and their concentrations and injection percentage or pump rate (Jensen et al., 2003). In support of these findings, enhanced loins (Hayes et al. 2006) were also found to be less firm than the non-enhanced, control while firmness was similar for 3 moisture enhancement treatments which were evaluated in the study.
Product flavor was also improved for pork chops with moisture enhancement using a phosphate/salt solution (Hayes et al., 2006), but not when chops were injected with either a salt/β-lactoglobulin or salt/WPC80 solution. In contrast, flavor intensity was reduced when pork was moisture enhanced with STPP (Smith et al., 1984; Jones et al., 1987; Sutton et al., 1997) while Brashear et al. (2002) determined no differences in flavour intensity when loins were moisture enhanced at an 18% pump rate. These authors also reported an increase in sensory evaluated saltiness as phosphate level increased due to the use of sodium tripolyphosphate for moisture enhancement.

Perception of off flavors in pork was not affected by moisture enhancement (Eikelenboom and Hoving-Bolink, 1992; Brashear et al., 2002). Overall acceptability scores favored moisture enhanced product in several studies (Brashear et al., 2002; Smith et al., 2002; Glaeser et al., 2003).

**Enhancement on color properties**

Product appearance in the meat case is important for influencing consumer purchases. Meat colour is often assessed objectively in studies using the Commission International de l’Eclairage (CIE; (Commission Internationale de l'Eclairage, 1978) L* a* b* scale with: (1) L*, a measure of luminosity or lightness with a higher value being indicative of a lighter colour, (2) a*, a measure of the continuum from red to green with higher values indicative of a redder colour and (3) b*, a measure of the continuum from yellow to blue with higher values indicative of a more yellow colour. Hayes et al. (2006) indicated that L* values (product lightness) were unaffected by moisture enhancement up to 7 days postmortem for pork chops; these findings are supported by Prestat et al. (2002). Brashear et al. (2002) reported a linear increase in product lightness as pumping
level increased to 18% due to a dilution effect as more fluid was added from higher pump rates. A similar response was found for redness with decreases in product redness as pumping level increased. Hayes et al. (2006) also found decreased redness ($a^*$) for chops enhanced with salt/STPP on day one while $a^*$ values increased at 7 days postmortem for chops enhanced with a salt/$\beta$-lactoglobulin or salt/whey protein concentrate (WPC80) solution. Comparable results were also observed for yellowness scores ($b^*$) with $b^*$ values decreasing with higher pumping rates. Hayes et al. (2006) concluded that the increased phosphate content with moisture enhancement was probably increasing the pH and influencing color readings. Prestat et al. (2002) reported increases in product redness and decreases in product yellowness when chops were enhanced with phosphate and salt, while Sutton et al. (1997) reported similar $L^*$, $a^*$ and $b^*$ values when 0 to 2% sodium lactate and/or 0 to 0.4% sodium tripolyphosphate were added to boneless pork loins. In contrast Krause et al. (1978) reported a visual improvement in external color when hams were pickled in a 3.3% sodium tripolyphosphate solution. The effect of aging on pork color was investigated by Davis et al. (2004) with pork loins injected with a commercial brine solution on day 1 or 4 postmortem. Similar $L^*$ and $b^*$ values were reported for the day 1 and 4 postmortem treatments after 14 days in post injection storage. In contrast, $a^*$ (redness) was increased by day 14 of storage for the day 1 injection treatment only. Therefore the authors concluded that timing of injection was not a critical factor in determining color or product quality differences.

**Conclusions**

As indicated above, the effects of enhancing pork with various pumping solutions have been well documented. Dependent on the level and type of brine solution used,
flavor, tenderness, juiciness, and overall consumer acceptability can be improved.

Pumping also is an effective method to increase product weight which may improve wholesale and retail margins. However concerns related to an increased consumer intake of sodium and phosphates have also been identified which can lead to serious health related issues (high blood pressure, hyperphosphatemia) especially in high risk consumers.

**Literature Cited**


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