Broiler meat marination: D.P. Smith and L.L. Young

The effect of pressure and phosphates on yield, shear, and color of marinated broiler breast meat

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Keywords: marination; yield; shear; vacuum tumbling; positive pressure tumbling

Summary
A significant portion of raw poultry meat in the U.S. is marinated prior to consumption, usually with a mixture of water, salt, and phosphates that are vacuum tumbled with the meat. This study was designed to determine whether pressure, phosphate, or both were responsible for the increase in marinated weight and retention during cooking after marination. In each of three replicate trials, 60 broiler breast fillets were assigned to tumbler vessels with pressures equivalent to either vacuum (381 mm Hg below ambient, VT), ambient (AT), or positive (PT, 776 mm Hg above ambient), with or without phosphate in the marination solution (added at 15% by weight to raw meat weight - either 91% water, 6% salt, and 3% phosphate or 94% water and 6% salt, respectively) in a 3X2 design. All tumblers were operated at 15 RPM for 20 min at a temperature of 3°C. Raw fillets were weighed, colour measured via colorimeter, marinated, stored 1 h, reweighed, cooked, sheared, colour re-measured, held overnight, and two strips per fillet sheared via the Warner-Bratzler method (WBSHR). Phosphate had no significant (P<0.05) effect on % marinade uptake; the type of pressure application was significant, however, as AT (12.8%) samples picked up more marinade than PT (11.4%), but neither was different from VT (12.0%). There was no effect of pressure or phosphate on % drip loss (mean = -1.06%). For cook yield, there was no effect due to pressure treatment; phosphate, however, significantly increased yield (86.1 vs. 76.6%). For WBSHR, kg force to shear for VT (9.2) was higher than either PT (5.6) or AT (5.5) for the phosphate treatment, but shear force for PT (9.3) was higher than VT (6.0) or AT (6.2) for the non-phosphate treatment. There were no differences in raw colour due to pressure or phosphate treatments, but phosphate increased cooked L* from 70.6 to 71.6, and decreased cooked a* from 1.57 to 0.95 (no practical significance). Overall, the type of pressure application during tumbling has no effect on % marinade uptake, and the major effect obtained with phosphate is increase in yield. Based on these data, processors may improve yield with phosphate in marination where allowed, but vacuum pressure during tumbling provides no advantage compared to ambient or positive pressure.

Introduction
A significant portion of raw poultry meat in the U.S., perhaps as much as 50% of total production, is marinated prior to consumption (Smith and Acton, 2001). Marination is usually conducted with a mixture of water, salt, and phosphates that is either injected into or vacuum tumbled with the meat. Many products, including boneless skinless breast fillets are vacuum tumbled. Vacuum tumbling has been shown to increase uptake of marinade solution into the meat (Young and Lyon, 1997; Young and Smith, 2004). Other reports show that vacuum tumbling with phosphates improves cook yield (Young et al., 2004; Young and Lyon, 1997). The effect of phosphate vacuum tumbling on shear values has been mixed, as Young et al. (1996) and Young and Smith (2004) reported the process had no effect on shear, but Young and Lyon (1997) found the process increased shear values of early harvested broiler breast meat. Vacuum tumbling with phosphates has been reported to decrease cooked chicken meat redness by Young et al. (1996) and Young and Lyon (1997), and to increase lightness (Young et al., 1996). These studies show vacuum tumbling and phosphates may affect many different quality attributes of cooked chicken meat products.

The action of salt and phosphates in the marinade is likely due to extraction of the myofibrillar proteins in the muscle, which then form a matrix that retains moisture (Offer and Trinick, 1983). This matrix is composed of partially unwound proteins with uncovered charged sites, which are able to bind water (Acton and Jensen, 1994). The theories regarding the action of salt and phosphates on muscle
tissue moisture are generally well represented and accepted in the scientific literature and have been previously reviewed (Trout and Schmidt, 1983).

Tumbling meat and marinade solutions together under vacuum pressure is the most widely practiced form of marination in the U.S. for poultry products. Tumbling alone (without vacuum) has been shown to speed the uptake of marinade solution in chicken (Chen, 1982). Theoretically, tumbling with vacuum pressure works even better because some physical expansion of the muscle occurs, enabling the marinade to penetrate further into spaces within the meat. Vacuum pressure also may assist in bringing myofibrillar proteins to the surface of the myofibrils in the fibres. However, the evidence for the action of vacuum tumbling is mostly anecdotal.

Since vacuum tumbling is the preferred method for delivering salt and phosphates, it is reasonable to assume that vacuum delivers the most marinade into the muscle. Therefore, ambient pressure tumbling should deliver less marinade into the muscle (lower uptake), and then positive pressure tumbling would result in an even smaller uptake. Young and Smith (2004) found no advantage for vacuum pressure over ambient pressure during tumble marination, however, for cook yield or shear. This study was designed to determine whether pressure, phosphate, or both were responsible for the uptake and retention of marinade during cooking, and also whether shear force values or colour measurements were affected.

Materials and methods

In each of three replicate trials, 30 broiler carcasses were obtained from a commercial processor immediately after chilling and transported to the laboratory. At 4 h post-mortem fillets were manually removed from the carcasses, then groups of ten fillets each were randomly assigned to one of 6 treatments in a 3X2 design: three different pressures, either vacuum pressure (VT), ambient atmospheric pressure (AT), or positive pressure (PT), and two different marination solutions, with or without phosphates (P+ and P-, respectively). Marination solution for P- samples was composed of 94% water and 6% NaCl; P+ solution was composed of 91% water, 6% NaCl, and 3% sodium tripolyphosphate (Brifisol STPNEW, B.K. Giuliani Corporation, Simi Valley, CA, USA, 93063). Marination solutions were added to the appropriate raw meat treatment at 15% (weight to weight).

Prior to marination, the raw fillets were weighed, identified with a tag, and then fillets and marinade solutions were placed into laboratory-scale tumblers (Model MC II 10/20, Inject Star, Inc., Brookfield, CT, USA, 06804). VT tumblers were evacuated with a vacuum pump to 381 mm Hg pressure below ambient pressure. PT tumblers were equipped with a valve to allow an air compressor to fill the tumbler with a positive pressure of 776 mm Hg above ambient pressure. AT tumblers were sealed prior to tumbling at ambient atmospheric pressure (approximately 755 mm Hg). All tumblers were operated at 15 RPM for 20 min at a temperature of 3°C (refrigerated room). Immediately after tumbling fillets were reweighed and surface colour (CIE L* - lightness, a* - redness, and b* - yellowness) was measured in triplicate with a colorimeter (Chroma Meter CR-3000, Minolta Corp., Ramsey, NJ, USA, 07446). The fillets were stored in a plastic bag for one hour in a refrigerated room (3°C), then reweighed, placed and sealed into cooking bags, and cooked in a steam kettle for 20 min at 95°C to achieve a minimum internal fillet temperature of 80°C. Fillets were removed from bags, reweighed, and held refrigerated 18 h. A 1.9 cm strip was excised from each fillet parallel to the fibre direction, then it was sheared twice perpendicular to the fibre direction using a Warner-Bratzler device to determine kg force to shear (G-R Electrical MFG. Co., Manhattan, KS, USA, 66502). The two shear force values per fillet were averaged together (WBSHR).

Calculations based on weight determined percentage marinade uptake (MARPCT), percentage drip loss after 1 h (DRPPCT), and percentage cook yield (CKYLD). Calculations were as follows:

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\text{% MARPCT} = \frac{\text{marinated weight} - \text{raw weight}}{\text{raw weight}} \times 100
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\text{% DRPPCT} = \frac{\text{marinated weight} - \text{1 h marinated weight}}{\text{marinated weight}} \times 100
\]

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\text{% CKYLD} = \frac{\text{cooked weight}}{\text{raw weight}} \times 100
\]

An experimental design of 3X2 was used for the main effects of pressure treatment and phosphate presence, with ten fillets in each cell for each of three replicate trials (n=170 due to a group of ten fillets discarded because of marination calculation error). Data were analyzed using general linear models design and means separated using least square means with Tukeys mean separation procedures of SAS, significance P<0.05 (SAS Institute, 1999). Residual error was used as the error term throughout the analysis, except for the WBSHR where a significant interaction required the use of the interaction error term. Data were pooled where significant interactions were absent.
Results and discussion

**YIELDS**
MARPC means, by phosphate and pressure treatment, are shown in Figure 1. Phosphate had no significant (P<0.05) effect on MARPC. The type of pressure application was significant, however, as AT (12.8%) samples picked up more marinade than PT (11.4%), but neither was different from VT (12.0%). Previous reports have shown that tumbling with salt and phosphate marinades increase the uptake of marinade solutions (Young and Lyon, 1997; Young and Smith, 2004; and, Xiong ad Kupski, 1999). Another report did not show an increase in uptake (Young, et al., 2004). Since AT increased uptake more than VT, and there was no difference between VT and PT uptake, this would appear to invalidate the hypothesis that VT allows more marinade to be absorbed and bound in broiler breast meat.

There was no significant effect of either pressure or phosphate on DRPPCT (mean = −1.06%, data not shown). A previous report by Xiong and Kupski (1999) showed that marinade with salt and phosphates combined and tumbled with chicken fillets resulted in higher moisture retention as compared to control samples. This experiment used lower salt and phosphate levels than was used by the previous researchers, which may explain this difference.

Means for CKYLD, by pressure and phosphate treatment, are shown in Figure 2. There was no effect due to pressure treatment. Phosphate, however, significantly (P<0.05) increased CKYLD (86.1 vs. 76.6). Prior research has shown similar results, where chicken fillets marinated with phosphates had improved cooked yields (Young and Lyon, 1997; Young and Smith, 2004; and, Xiong ad Kupski, 1999). Turkey breast was similarly affected (Froning and Sackett, 1985). Young and Smith (2004), however, did not find that salt and phosphate tumble marination increased cook yield of broiler chicken fillets. Again, the lack of increased yield by VT samples as compared to AT and PT samples shows that VT may not be applicable to maximizing broiler breast meat marination.

**SHEAR**
A significant treatment interaction was observed for WBSHR, as kg force to shear for VT (9.2) was significantly (P<0.05) higher than either PT (5.6) or AT (5.5) for the P+ samples, but shear force for PT (9.3) was higher than VT (6.0) or AT (6.2) for the P- treatment samples. There have been contradictory reports on the effect of marination on shear values of poultry meat. Lyon and Hamm (1986) reported marination decreased shear values of early harvested broiler breast. Other researchers, however, reported no effect on shear values of chicken breast (Young et al., 1996; Young and Smith, 2004) or turkey breast (Froning and Sackett, 1985) due to marination. Young and Lyon (1997) found that marination increased shear values of early harvested broiler breast meat. The findings from this study cannot be readily explained based on meat age or marination methods used. Prior research, with contradictory findings, also does not assist in explaining these results. Relatively small sample size (n=30) may have had some effect, but high coefficients of variation (data not shown) were not observed between the treatment group means.

**COLOUR**
There were no differences in raw colour due to pressure or phosphate treatments, but P+ samples had significantly (P<0.05) increased cooked L* (lightness) values compared to P- samples (71.6 to 70.6, respectively). P+ samples also had significantly lower cooked a* (redness) values compared to P- samples (0.95 vs. 1.57, respectively). Although these differences are significant, there is very likely no practical significance as visual observation probably would not detect these differences. Previous reports have shown similar results, where lightness of cooked meat was increased while redness was decreased by small but measurable levels (Young, et al., 1996; Young and Lyon, 1997).

**Conclusions**
Pressures (negative, ambient atmospheric, or positive) had only a small effect on marination uptake, and no effect on retention, cook yield, or colour values. Any expected advantage of vacuum tumbling (based on widespread commercial usage) was not observed in this experiment, and ambient pressure during tumbling actually provided better marination uptake. Further testing with commercial equipment and larger numbers of samples should be conducted. Phosphate marination produced a large
increase in cook yield, but otherwise no or few effects (slight colour change). Therefore, phosphates can provide the means for enhancing cook yield where allowed, but pressures applied during tumble marination have no effect on yield or meat quality of broiler breast meat.

References

Figure 1. Percent marination uptake of fillets (mean +/- std. err.) marinated with or without phosphates (P+ or P-) and tumbled with positive, vacuum, or ambient pressure (n=30).

Figure 2. Percent cook yield of fillets (mean +/- std. err.) marinated with or without phosphates (P+ or P-) and tumbled with positive, vacuum, or ambient pressure (n=30).
Figure 3. Shear force (Warner-Bratzler, kg/g), mean +/- std. err., of fillets marinated with or without phosphates (P+ or P-) and tumbled with positive, vacuum, or ambient pressure (n=30).

Figure 4. CIE L* (lightness), a* (redness), and b* (yellowness) values of cooked fillets marinated with or without phosphates (P+ or P-) and tumbled with positive, vacuum, or ambient pressure (n=30).