EFFECTS OF AN EXHAUST TUBE CONSTRICTIVE VALVE ON SEPARATION OF DENSE PARTICLES DURING MEAT GRINDING

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INTRODUCTION: In the production of ground meat, the presence of bone chips, gristle and connective tissue is an important factor affecting the product quality. Several commercial bone-removal systems have been investigated (Huebner et al., 1989); none of the systems currently used are 100% effective for removal of hard particles from ground meat. There is considerable interest in improvement of bone-removal systems. It has been found that pressure developed and pressure differentials during the grinding operation is an important factor for hard particle migration (Wild et al., 1991). Wild et al. (1991) suggested that increased pressure would improve bone particle removal through a central-axis removal system. However, Wild et. al. (1991) found that increased pressure also resulted in an increase in the loss of red meat through the exhaust port, which will adversely affect product yield.

The concept of adding a constrictive valve to the exhaust tube of bone removal systems has been incorporated into some systems to control the flow of separated materials. However, no information is available concerning the performance and efficiency of adding a constrictive valve on particle separation during operation of bone-chip removal systems. Moreover, factors such as meat temperature, fat content, and species which affect the efficiency of bone-removal system may have interaction with valve-controlled back pressure, but no specific information is available.

The objective of this work was to evaluate the effects of using a exhaust tube constrictive valve on grinding pressure and separation efficiency of dense materials using fresh beef, pork, and turkey. Also, temperature, fat level, and meat species effects were examined to determine if any interactions occurred between these factors and valve/back pressure setting.

MATERIALS & METHODS: Three experiments were conducted in this investigation. First, four valve closure positions (100%, 75%, 50% and 25% open), two product temperatures (-2^{0}C and 4^{0}C) and two fat levels (12% and 45%) were examined during grinding of fresh beef. Second, fresh pork lean (15% fat), tempered to -2^{0}C, was ground using five valve settings (100%, 75%, 50%, 25%, and 0% open). Third, bone separation efficiency was evaluated during grinding of 0.5% bone added beef (27% fat) and turkey thighs (4% fat) at -2^{0}C using four valve settings (100%, 75%, 50% and 25% open).

Fresh beef, pork trimmings and turkey thighs (boneless and skinless) were prebroken through a 9.5 mm hole plate, formulated to desired fat content, tempered to required temperature, and then assigned to one of valve setting treatments. Each batch was 11.4 kg in experiments 1 and 2, and 45.4 kg in experiment 3. The final grinding of the meat batches utilized a 3.2 mm hole plate. The grinder plate used for the final grind had a central-axis removal port, where a exhaust tube was used for collection of the dense materials. A 1.0 inch diameter polypropylene ball valve was connected to the exhaust tube. The constrictive valve can be easily adjusted to the desired degrees of closure. Bone chips (~ 9.5 mm diameter) used in experiment 3 were prepared as described by Huebner et al. (1989) and mixed well with each meat batch. The material exhausted through the bone removal system (Exhausted Material-EM) was collected and weighted at the end of each treatment. Then the grinder was disassembled, and samples of the material retained in the barrel after grinding were obtained and weighted (Barrel Residue-BR). Bone chip content of final product (FP), EM, and BR fractions from each treatment was analyzed by an alkaline digestion method. The final results were expressed as a percentage of the original weight of bone chips added to the meat mixture.

The measurements for the pressure developed at the interface of grinder plate/blade were accomplished using three pressure transducers that were mounted close to the center, close to the periphery, and 12 mm (about midway) from the center of the grinder plate, respectively. Pressure for each location was recorded during the grinding operation and average values from each of the three locations were reported. Grinding time for each batch was recorded in seconds.

All the treatments were replicated twice, and results were analyzed by using the Statistical Analysis System (SAS, 1986) to calculate treatment means and detect treatment differences. Least significant difference was used as a method of mean separation. The general Linear Model (GLM) procedure was used to evaluate treatment interactions.

RESULTS & DISCUSSION

Beef. Results are listed in Table 1. Statistical analysis indicated that valve setting, temperature and fat level were all significant factors affecting surface pressure values ($p<0.05$). Closing the constrictive valve increased pressure values, however, there was no significant ($p<0.05$) difference until the valve was closed to 50%. Also there was no further significant increase in pressure when closing the valve to 25% open ($p<0.05$) even though the pressure trend continued. This evidence suggests that a 50% valve opening might be a critical point for pressure values; a 25% change in the degree of valve closure was not large enough to cause significant ($p<0.05$) pressure changes.

Table 1. Effect of valve setting, temperature, and fat level on pressure, grinding time (GT), and amount of exhausted materials (EM).

Treatment	Pressure (kPa)	GT (sec.)	EM (g)
Valve setting (% open)			
100	625.07[a]	23.88[a]	88.75[a]
75	661.94[a]	23.63[a]	77.75[a]
50	708.34[b]	21.75[b]	77.38[a]
25	720.69[b]	20.31[c]	79.88[a]
s.e.	14.66	0.42	5.18
Temperature			
4°C	503.29[a]	27.80[a]	76.19[a]
-1°C	854.73[b]	17.59[b]	85.69[a]
s.e.	10.37	0.30	3.66
Fat			
15%	427.75[a]	29.16[a]	72.56[a]
40%	930.27[b]	15.47[b]	89.31[a]
s.e.	10.37	0.30	3.66

[abc]Means within a group that have different superscripts are significantly different ($p<0.05$).

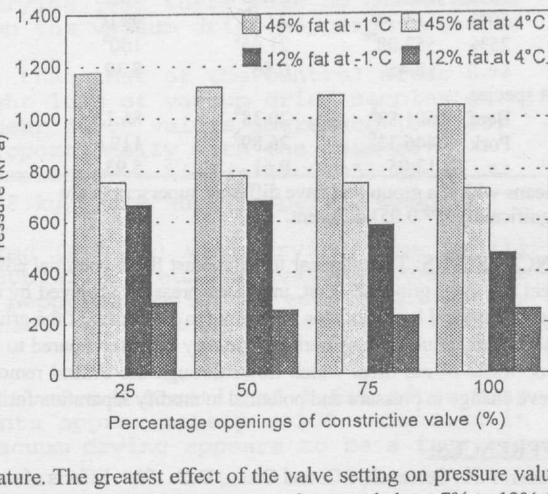

Figure 1. Pressure values at different degrees of valve opening for beef.

There were significant ($P<0.05$) interactions for valve setting with fat level and temperature. The greatest effect of the valve setting on pressure values occurred for low fat beef stored at cold temperature (Fig. 1), in which pressure value was increased about 44%. Pressure was increased about 7% to 13% for other treatments. Beef tissue with low fat content at the warm temperature was relatively soft. The soft tissue usually induced smearing of meat at the interface of the grinder plate/blade, and in this case, changing the degree of valve closure had no significant effect on pressure values. High fat meat created greater grinding pressure in a bone-removal system, but other grinding conditions such as valve setting showed no significant influence on pressure values.

It was suggested that the grinding pressure influences both grinding time and bone particle removal efficiency (Zhao and Sebranek, 1993). The results in the present research indicated that a high pressure significantly ($P<0.05$) shortened grinding time. Closing the valve by 50% resulted in about 9% decrease in grinding time (Table 1). A cold temperature reduced grinding time about 40%, and high fat beef could be ground in about 50% of the time needed for low fat beef again due to significantly increased pressure values. These results are based on 11.4 kg batches and may well differ for larger qualities.

In general, the amount of exhausted materials may be expected to be determined by pressure and the size of the exhaust tube (degree of valve closure). It has been reported that increased pressure on the grinder plate results in improved particle removal. A decreased valve opening increased pressure values which would enhance flow of ground materials, but it also reduced the size of exhaust tube which allows exhausted materials to flow through. Therefore, there should be a optimal valve opening in which high bone separation efficiency without excessive loss of lean meat can be achieved. In this work, the total amount of exhausted material was not found to be significantly ($P<0.05$) different for the four valve settings (Table 1). It is important to remember that relatively small amounts of exhausted materials are produced from grinding small batches and may not provide large enough product flow to reflect the true influence of various conditions.

It was observed that increased valve closure encouraged movement of hard particles to the center of grinder plate which improves the separation of dense materials in meat grinding systems. The influence of valve location (i.e., valve distance from the exhaust port of the grinder plate) on the amount of exhausted material can probably ignored when continuously grinding large amounts of meat. Moreover, the ratio of the exhaust tube capacity (area of valve opening) to grinder plate capacity (total surface area of holes) may be an important consideration. In the present work, this ratio is about 0.05 for the 50% valve opening.

Beef and pork comparison. Because the results using beef showed that the most significant ($P<0.05$) effect of the constrictive valve occurred when grinding lean beef at the cold temperature, experiment 2 was designed to evaluate lean pork (~15% fat) at -2^{0}C. Comparison for beef and pork lean at -2^{0}C is listed in Table 2. The results show that closing valve increased pressure values and reduced grinding time for both beef and pork. Again, the 50% valve opening was the most critical point. The interaction between meat species and valve setting was also significant ($p<0.05$). Beef resulted in 150 kPa greater increased pressure values than pork as the valve was closed. Grinding time for 25 lb. beef lean was about 6 sec less than that for pork lean at the same conditions. The amount of exhausted materials for beef and pork were also significantly ($p<0.05$) different. Beef had about 27% lower amount of exhausted material than pork. It was visually observed that exhausted materials for pork had considerably greater amount of red meat included than beef. Therefore, the lower pressures recorded for pork seem to result in inclusion of more lean tissue in the exhaust. Pork, with a softer muscle texture, may react differently at the interface of blade/grinder plate than beef. Pork may also have a softer bone structure due to a less calcified extracellular matrix. This softness may enable pork bones to be more readily sheared than beef bones. Therefore, it might be concluded that adding a constrictive valve is more effective for grinding soft muscle meat to reduce the waste of lean meat through the exhaust port of bone removal systems.

Bone separation during grinding of beef and turkey. Experiment 3 was designed to evaluate the effect of a constrictive valve on bone separation during grinding of beef (27% fat) and turkey thighs (4% fat). The amount of bone detected in the different fractions after grinding is listed in Table 3. The results indicated that closing the constrictive valve by 50% significantly ($P<0.05$) increased the amount of bone detected in the exhausted material for turkey thigh. No differences were observed for beef. Table 3 shows that there was no significant ($P>0.05$) difference in the amount of bone left in the final product between beef and turkey, however, turkey had a significantly ($P<0.05$) higher amount of bone chips in the exhausted material than beef. This may be due to the relatively high amount of exhausted material which occurs for turkey and which was also observed in previous research (Zhao and Sebranek, 1994). Zhao and Sebranek (1994) concluded that the softer tissue of poultry meat resulted in higher amounts of exhausted material than beef. The greater amount of exhausted material, of course, had greater probability of including more bone chips. Results in Table 3 show the greatest amount of exhausted bone from turkey occurring with a 50% closed valve. The separated bone at 50% was a significant improvement over no valve closure and could be due to the increased pressure achieved by closing the valve. Thus, the constrictive valve appears to be more valuable in environments where pressure is low (valve can be used to increase pressure) compared to situations where pressure is already high during grinding (such as beef). Meanwhile, it is important to remember that these data reflect grinding 45.4 kg meat batches. It is likely that effects would be more clear in a sustained operation where several thousand kilograms of meat are ground.

Table 2. Effect of valve setting and meat species on grinding pressure, time and amount of exhausted material at -2^{0}C.

Treatment	Pressure (kPa)	GT (sec)	EM (g)
Valve setting			
100%	438.27^a	26.13^a	100^a
75%	520.32^b	24.45^{ab}	98.25^a
50%	584.74^c	22.5^{bc}	99.0^a
25%	553.08^{bc}	21.45^c	100^a
s.e.	18.45	0.86	8.39
Meat species			
Beef	601.88^a	20.38^a	86.13^a
Pork	446.33^b	26.89^b	119.6^b
s.e.	13.05	0.61	5.93

^{abc}Means within a group that have different superscripts are significantly ($P<0.05$) different.

Table 3. Effect of valve setting on the amount of bone detected in the different fractions during grinding of beef and turkey thigh at -2^{0}C[1].

Item	Valve setting 100%	75%	50%	25%	s.e.
Beef (27% fat)					
Final product	49.19^a	41.86^a	54.26^a	38.61^a	6.64
Exhaust material	4.20^a	4.93^a	3.10^a	3.13^a	0.65
Barrel residue	47.09^a	51.15^a	47.92^a	51.03^a	2.02
Turkey thighs (4% fat)					
Final product	50.05^a	57.03^a	47.73^a	44.37^a	9.62
Exhaust material	2.88^a	5.03^{ab}	7.62^b	4.88^{ab}	0.78
Barrel residue	33.25^a	22.55^a	34.72^a	28.12^a	--

[1]Values in table represent percentage of the 0.5% bone that originally added.
^{abc}Means within a group that have different superscripts are significantly ($P<0.05$)different.

CONCLUSIONS: There appear to be at least three potential advantages of using a constrictive valve on the exhaust tube of a central axis bone removal system for meat grinding. First, increased pressure achieved by controlling the degree of valve closure shortened the grinding time. Second, closing the valve encouraged hard particles to migrate to the center of the grinder plate and improved the separation efficiency of the grinding system for turkey. Third, for soft meat tissue such as pork and poultry meat (compared to beef), using the constrictive valve should help to increase bone separation efficiency and reduce waste of red meat which flows through the central removal port of the grinding system. The most important valve closure was around 50% to achieve change in pressure and potential to modify separation for fresh ground meat.

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