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DETERMINATION OF BEEF AND PORK CUTTING PROPERTIES THROUGH THE ANALYSIS OF WARNER BRATZLER CURVE

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The measurement of cutting forces in meat was carried out to define the degree of constituting forces: compression, friction and disintegration forces in dependence on internal (fibre orientation, type of meat) and external factors (cutting speed and temperature). In this experiment, Warner Bratzler knife with 3 mm width of the edge blade were used to puncture meat at 3 different temperature and two feed speeds. Triangular shape was used to minimize friction for more accurate interpretation of curve. Total cutting works for beef and pork increased with decreasing temperature and increasing speed. Average compression works reached maximum at 0 °C and intensified with cutting speed. In meat, compression works were higher at chilled temperature than at frozen temperature. Average friction work reached maximum value at 4 °C and its value at frozen temperature was lower than that at chilled temperature. Disintegration works exhibited maximum value at frozen temperature; and lengthwise beef cuts produced the highest value of overall works while perpendicular produced the least. Cutting forces were influenced by many factors such as type of meat, temperature, cutting speed, and fibre direction. The variability of meat material and its anisotropic characteristics gave rise to marked inconsistency; nevertheless the tendency could still be discerned.

Cutting Works, Warner Bratzler, Compression, Friction, Disintegration, Temperature, Cutting Speed

I. INTRODUCTION

Grinding is an important and complex operation in meat industry which includes compression, shearing, extruding, rubbing, and size reduction. According to Kamdem & Hardy /5/, there is a correlation between grinding parameter and cutting force by blade shear, thus this high correlation can be used to predict energy requirement for grinding. Cutting test with Warner Bratzler blade which consists of compression, friction, and disintegration force can also be regarded as simplified grinding operations. The presence and intensity of those cutting forces are not only influenced by the properties of cutting machine i.e. meat grinder but are also influenced by the characteristics of meat being cut such as type of meat, part of meat, fat tissues, and connective tissues. The purpose of this research is to determine the cutting properties of meat in dependence on different factors such as type of meat, temperature, and cutting speed through analyzing the contribution of different types of forces occur during cutting. By understanding the relationships among those factors and cutting properties of meat, an effort to optimize meat mincing process can be done. This is important to know as the grinding operation is a highly consuming energy process in meat industry.
II. MATERIALS AND METHODS

- **Sample preparation**
  Two kinds of meat were selected for measurements: beef (topside and silverside) and pork (shoulder). Three days post-slaughtered cooled meat was sourced from Flepro Fleisch und Wurstwaren GmbH, Bernburg. Fat and connective tissues were trimmed from meat when necessary, then meat were cut to get a piece of meat with certain fibre direction: lengthwise, crosswise, and perpendicular (Fig. 1) by cutting into equilateral triangular area of 3 x 3 x 3 cm with certain width. The samples were then wrapped to avoid moisture loss and put in Styrofoam box and were conditioned in refrigerator (0 °C) or freezer (-20 °C) until it reached certain temperature (4, 0, -4 °C). The temperature was checked before and after cutting by IR thermometer to assure there were no considerable temperature changes.

- **Equipment preparation**
  The Warner Bratzler measurement was done by placing heavy duty platform on the base of the machine and the slotted blade plate was inserted into heavy duty platform. The samples were centrally put under the blade and the blade were moved towards the slotted blade insert by a TA-XT Plus Texture Analyzer (Stable Micro Systems, Surrey, UK) fitted with a 30 Kg load cell. The distance is set at 42 mm as this is the actual height of triangular area of Warner Bratzler knife (Fig. 2). The speed of Warner Bratzler knife was set at 2.0 and 20.0 mm/s.

- **Data measurement and interpretation**
  The initial step was to determine points in which compression starts and maximum of compression occurs. This step was done by running the Warner Bratzler knife until the triangular edge of the blade were fully in contact with the meat surfaces. This point was called as start of compression (X3) and it was determined by visual observation and verified by analyzing the curve where it changed the steepness during the beginning of cutting. The point of maximum compression (X1) was determined afterwards by observing at which depth the knife started to cut. When the applied force exceeded the limit that meat could bear, the meat would be cut and this is called as maximum compression. Compression force would start to decrease as the knife entered deeper into the meat, on the other hand the friction force would start to increase because there would be increased contacts between the blade and the knife. Consequently, at the end of the cutting force, point of maximum friction could be obtained.
Fig. 2: The use of Warner Bratzler device in forces measurement

Fig. 3a presents the Warner Bratzler curve which was produced from meat cutting. From the curve, the total area (Ncm), the area from start of compression until max compression (A1), force at start of compression (F1), force at maximum compression (F2), and force at maximum friction (F3) could be obtained by texture analyzer. From above data, equations for friction and compression could be derived (Fig. 3b). These curves are created in order to determine the area under the curve. The total of friction work is represented by the area of A3 while the value of compression work is the sum of area A1 and A2. For disintegration work, the area is denoted by A4. By measuring the area under the curve through integral calculation, the work of compression, friction, disintegration, and total work could be obtained.

Every treatment combination were measured 10 times and the data were statistically analyzed using Analysis of Variance (One Way) to test for the significance of parameter effects at the 5% probability level (P <0.05).

III. RESULTS AND DISCUSSION

➢ Meat cutting properties

➢ Compression

Compression works in beef lengthwise and crosswise reached maximum value at 0°C and they intensified with cutting speed. The average compression works in pork also attained maximum value at 0°C and increased with cutting speed. At low cutting speed, compression works produced in pork cutting were considerably higher than works produced in beef cutting regardless the fibre orientation. The relatively softer texture of pork than beef might have caused pork required more compression before the knife started to cut. Higher cutting speed caused different tendency of compression works compared to what had occurred at 2 mm/s cutting speed. In general, beef showed higher compression
works than pork within three different temperature treatment \((-4, 0, 4 \, \degree C)\). Nonetheless, crosswise pork at \(4 \, \degree C\) and perpendicular pork at \(0 \, \degree C\) showed higher compression work than those cuts of beef.

Meat as a material with flexible fibrous structure requires compression force which is pointing to the centre. This force will be spent on elastic and plastic deformation before friction and disintegration force come to pass. During the compression, the product would be deformed along the line of blade edge. When the compression force was more than the ability of the meat to bear, the meat will be cut. As stated by Fellows /4/, meat are usually tempered just below freezing point to improve efficiency of cutting. However, according to this study, there will be more works spent in meat cutting at \(0 \, \degree C\) than at \(4 \, \degree C\). The slightly rigid structure of meat at \(0 \, \degree C\) would produce more compression force.

The compression works in beef and pork at chilled temperature were greater than at frozen temperature. In frozen state, meat with its solid structure would not change shape in a great extent. Instead, it would require much disintegration force. According to Gac (1976, as quoted by Faraq et al.,/3/, increasing percentage of frozen water may decrease plasticity and increase shear resistance at low temperature; at temperature \(-5 \, \degree C\), the water in meat is 75-80 % frozen.

Friction

The friction work in beef and pork reached its maximum value at \(4 \, \degree C\), slightly decreased at \(0 \, \degree C\), and dropped off at \(-4 \, \degree C\). There was significant reduction of friction works in beef at frozen temperature compared to those at chilled temperature (0 and \(4 \, \degree C\)). Frictional force depends on the type of surfaces, in this case are meat and knife, and how hard the surfaces are pressed together. The knife which cut the frozen sample would melt the ice along the line of blade edge, thus water which emerged would lessen the friction work due to less interaction between surfaces. As stated by Fellows /4/, water will act as a lubricant in some food products.

At low cutting speed, friction works in pork cutting were consistently lower than friction works produced in beef cutting at chilled temperature. Beef tended to attach to the knife stronger than pork did. This might happen because the fat content of beef is relatively lower than that pork. The intramuscular fat content of beef longissimus with slight amount of marbling was approximately 3.4 % (Savell et al.) /10/ while fat content of longissimus muscle of pork ranged from 1.23 – 5.18 % (Prusai et al.) /8/. It is also said that pork contains less muscle tissue than beef (Lawrie) /7/. At frozen temperature, the friction works of pork were higher than beef. The relatively harder structure of frozen beef might make it more liable to breaking which caused much less friction.

At higher speed, friction works of beef is partly higher than pork. Four pork samples from nine treatments showed higher friction works than beef. Even so, the highest friction works were produced by beef samples at \(0 \, \degree C\). At \(4 \, \degree C\), it consistently showed that the friction work in beef decreased with cutting speed. Besides, in pork lengthwise, the friction work at \(4 \, \degree C\) also decreased at higher cutting speed. This might happen because the muscle fibre has less time to respond or attach toward moving blade at higher speed. Even so, at frozen temperature, the friction in beef increased with cutting speed. This could be attributed by stronger holding effect given by rigid structure. The meat is however cut under open condition (without any holder) by vertical moving blade. The result may not be comparable to other studies which did cutting under motionless condition.
Disintegration works in beef and pork showed the clear trend over different fibre orientation and cutting speed. The higher the cutting speed and the lower the temperature, the higher the disintegration works would be required. This finding is aligned with a study done by King /6/, he found that the increase in feed speed would cause an increase in cutting force, and at -1.5 & 5°C, cutting force increased by approximately 10% for each doubling of feed velocity.

At low cutting speed, the disintegration works of beef were almost entirely higher than pork across all temperature and fibre orientation. Only at 4 and -4°C, the disintegration works between lengthwise beef and pork were not significantly different. At higher cutting speed, the results entirely demonstrated consistent inclination that beef produced higher works than pork and the total disintegration works at frozen temperature were the most intensive.

Total works were correlated with disintegration works. Increasing speed and decreasing temperature produced higher total works in beef and pork. This result is comparable with study done by Brown et al. /1/ which showed that cutting force in beef at at -5°C is higher than at 5 and 15°C and force increases with cutting speed. He also concluded that temperature difference from 15 to 5°C had little effect on the maximum cutting force.

At low speed, the overall works required to cut the beef of crosswise and perpendicular cuts were always greater than those required for pork. Nevertheless for lengthwise cut, it needed slightly more total works to cut pork than beef. Despite that, the maximum force occurred in beef cutting at lengthwise direction were always higher than that occurred in pork cutting. At higher speed, it consistently showed that beef cutting required more overall works than pork cutting. Lengthwise cuts of beef produced the highest value while perpendicular cuts of pork produced the least. As stated by Faraq et al. (2009), there was much greater force required to cleave samples cut across fibre than other orientations.

There were obvious differences between different fibre orientation. Perpendicular fibre orientation possessed the lowest amount of works required in cutting. It has been steadily shown that cutting lengthwise direction would require the highest works. In this orientation, the blade would need to cut across the muscle fibre. Consequently, it would need higher force than force required to cut perpendicular direction which is more fragile. According to Sacks et al. /9/, the stress transmitted through perpendicular cut is supported only by connective tissues while cutting meat of lengthwise cut is closely related to myofibrillar component of meat (Cross et al.) /2/. Cutting works in dependence on fibre orientation would be important in meat industry particularly in slicing process. The perpendicular direction will require less works which is necessary to lower the energy requirement during cutting. Nevertheless, to improve the tenderness, meat is usually cut across the grain.

IV. CONCLUSION

Warner-Bratzler involved a combination of compression, friction, and disintegration forces. Its curve is generated by measuring the force as blade is pulled at a constant
speed through a sample of meat. The curve depicts plot of the resultant force \( F(x) \), against distance \( (x) \) travelled by the blade. The value measured is shear force, which can be divided into three constituting forces. Expression of compression force \( f\text{-comp}(x) \) and friction force \( f\text{-friction}(x) \) as functions of \( x \) were calculated through determining points (point of maximum compression and point of maximum friction force/end of cutting force).

This study displayed apparent trends; decreasing temperature and increasing speed resulted in higher total cutting works. Cutting works are influenced by many factors such as temperature, cutting speed, fiber orientation in meat, and type of meat (beef or pork). From the method used, there could be some deviation due to sample movement during measurement.

REFERENCES


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