Some Factors Affecting the First Break Grinding of Canadian Wheat[1]

F. H. HSIEH,[2] D. G. MARTIN, H. C. BLACK, and K. H. TIPPLES, Canadian Grain Commission, Grain Research Laboratory, 1404-303 Main Street, Winnipeg, Manitoba R3C 3G9

ABSTRACT

Cereal Chem. 57(3):217–223

Effects of tempering moisture, feed rate, roll gap, roll differential, and roll speed on the first break grinding of Canadian hard red spring wheat were investigated. Weight percentages, ash and protein (N × 5.7) contents of various streams from the first break rolls, and starch damage of the first break flour were examined. Although the first break release increased with increase in tempering moisture and roll differential and decrease in roll gap, its change with either feed rate or roll speed was not significant. Ash and protein contents of the various streams, with the exception of overtails, decreased with increasing tempering mositure or decreasing roll differential or roll gap. Starch damage in break flour increased significantly with increasing roll differential. Narrower roll gap caused a slight decrease in starch damage. Tempering moisture, feed rate, and roll speed had little or no effect on starch damage.

The first stage of the modern flour milling process is the break system, in which the wheat kernel is opened up and the contents released so that the endosperm may be separated from the bran. Over the years the best way of opening up wheat kernels has been to pass them through a succession of pairs of spirally corrugated rolls driven at different speeds. The rolls are progressively closer together and more finely corrugated throughout the four or five breaks common in the modern flour milling process (Ziegler and Greer 1971).

The importance of the break system to the overall flour milling process cannot be overemphasized. Although the flour extraction rate is mainly determined by the break releases, the final quality of flour is essentially dependent on the success of the operation that opens up the wheat kernel. Many factors may affect the break system; among them are roll diameter and speed (Niernberger and Farrell 1970), roll spiral (Creason 1975, McCorkle 1973), roll clearance and type of corrugation (Cleve and Will 1966, Gehle 1965), number of corrugations, roll differential, and feed rate (Schumacher 1967), grinding action (Gehle 1965, Heide 1956), and grinding pressure (Schumacher 1967, Ward and Shellenberger 1951).

The first break stage is generally looked upon as the most important (Smith 1944). It must be adjusted with due consideration to the behavior of the various fractions and overtails produced in subsequent processing. The main object of this study was to determine, for Canadian red spring wheat, how the first break operation may be affected by various factors including tempering moisture, feed rate, roll differential, roll gap, and roll speed. The relative importance of these factors on the first break operation was examined in terms of changes in the weight percentages or break releases, ash and protein contents of the products from the first break rolls, and the starch damage of the break flour.

MATERIALS AND METHODS

Wheat

A composite sample of number one Canada Western red spring wheat (*Triticum aestivum* L. em Thell) was used for this study. It was representative of the 1978 Western Canadian crop. The ash and protein (N × 5.7) contents were 1.43% and 12.8%, respectively (13.5% moisture basis).

Rolls

The 10-in. (254-mm) laboratory research mill of the Grain Research Laboratory consists of roll stands (Ferrell-Ross, Oklahoma City, OK) with the addition of feed houses, hoppers, and controlled vibratory feeders to evenly distribute the stock and regulate the feed rate to the rolls. Each roll stand has a 2-HP motor, two each of Gerbing 75 WR and 75 WB drives, one Croft Unidapter gear reducer, plus various gear belts and pulleys. This equipment provides independent roll speeds with a fast roll speed range of 150–1,500 rpm and a slow roll speed range of 115–1,150 rpm. The rolls are 254 mm in diameter and 152.4 mm in length. The effective grinding length is 127 mm. Only the first break rolls were used for this study (Fig. 1). They are corrugated with 16 cuts per 2.54 cm (Allis) and a spiral of 41.7 mm/m roll length running dull to dull.

Fig. 1. The first break rolls of the Grain Research Laboratory 10-in. (254-mm) laboratory research mill.

---

[1] Paper 436 of the Canadian Grain Commission, Grain Research Laboratory, Winnipeg, Manitoba R3C 3G9.

[2] Present address: The Quaker Oats Company, 617 W. Main St., Barrington, IL 60010.

0009-0352/80/03021707/$03.00/0
©1980 American Association of Cereal Chemists, Inc.

Sifter

The Grain Research Laboratory first break sifter is a four-sieve unit that is clothed with 24 W (730-μ), 50 GG (368-μ), 68 GG (246-μ), and 8 XX (193-μ) bolting cloth (Fig 2). The sieve frames are 215.9 mm wide and 482.6 mm long, alternately inclined at an angle of approximately 6°; they oscillate from side to side 384 times per minute. The sieves, which are cleaned by four lightly spring-loaded chains attached on top of each sieve at each end of the frame, can handle stock up to 2 kg/min. Preliminary tests, using the same stock from the first break rolls, showed that the weight fractions of five grade products from the sifter were remarkably consistent.

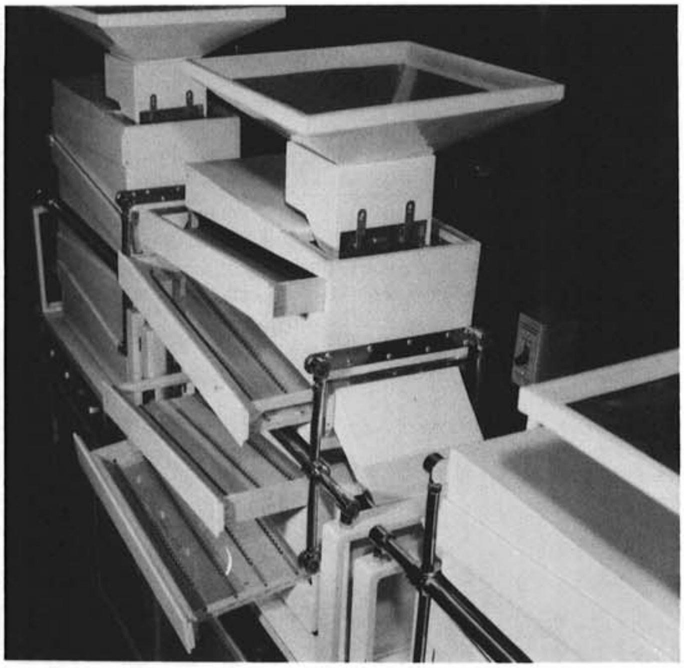

Fig. 2. The Grain Research Laboratory first break sifter.

Milling

One-kilogram samples of cleaned wheat were tempered to the desired moisture content for 18 hr before milling. The mill room was controlled for both temperature (22° C) and relative humidity (60%). After careful adjustment of the rolls at a certain roll gap, roll speed, and roll differential, the samples were fed to the first break at a preset rate. The milled products were then sifted, using a feed rate of 1 kg/min. Five streams were obtained: overtails (OT, over 24 W); coarse fraction (CF, through 24 W and over 50 GG), medium fraction (MF, through 50 GG and over 68 GG), fine fraction (FF, through 68 GG and over 8 XX), the first break flour (FL, through 8 XX). At least two samples were milled at the same condition and sifted. The weight distribution among five streams was highly reproducible.

Analysis

Each stream of milled products was analyzed for moisture, ash, and protein (N × 5.7), using standard AACC methods (AACC 1962). In addition, starch damage of FL was determined by Farrand's method (1964).

RESULTS AND DISCUSSION

Effect of Tempering Moisture

The effect of tempering moisture on the weight percentages and ash and protein contents of five streams from the first break rolls is presented in Fig. 3. Starch damage of FL is also shown in the same figure. Increasing the tempering mositure from 14.5 to 17.5% had the following effects: FL yield decreased slightly, FF remained relatively constant, MF increased slightly, and CF increased significantly. As a result, OT decreased steadily with increase in tempering moisture. Thus, the first break release as measured by the 24 W sieve increased with tempering moisture. Similar results were reported by Anderson (1937) in studying the effects of tempering time and moisture content on the first break release from

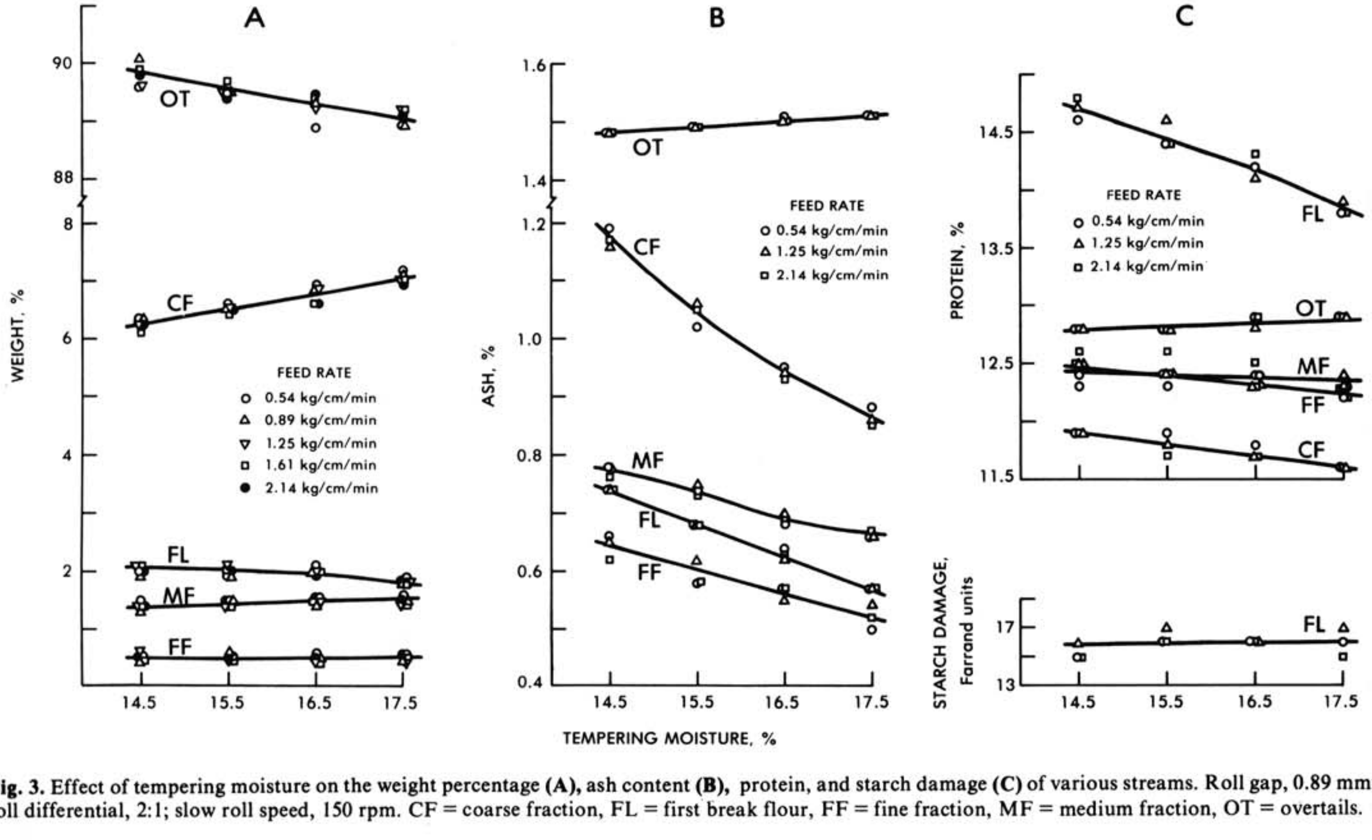

Fig. 3. Effect of tempering moisture on the weight percentage **(A),** ash content **(B),** protein, and starch damage **(C)** of various streams. Roll gap, 0.89 mm; roll differential, 2:1; slow roll speed, 150 rpm. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

Turkey variety wheat. Changing tempering time from 3 to 125 hr, he found that the first break release always showed a steady increase when tempering moisture was increased from 14 to 18%.

Figure 3B shows that the ash contents of all streams except overtails decreased steadily and significantly with increase in tempering moisture. This is because, as the moisture content increases, the bran becomes toughened and separates in larger pieces from the endosperm, with the production of cleaner stocks. The decreases in ash content of the various streams were not uniform for each percentage increase in tempering moisture, however. The decrease was steepest for the coarse fraction at 14% tempering moisture and tapered off slightly with increased moisture. The decrease in ash content of FL with tempering moisture was slightly faster than that of MF or FF, which showed a similar pattern. The rate of these decreases in ash contents, however, remained unchanged with increase in tempering moisture.

Effect of tempering moisture on the protein contents of various streams and on starch damage of FL is shown in Fig. 3C. The

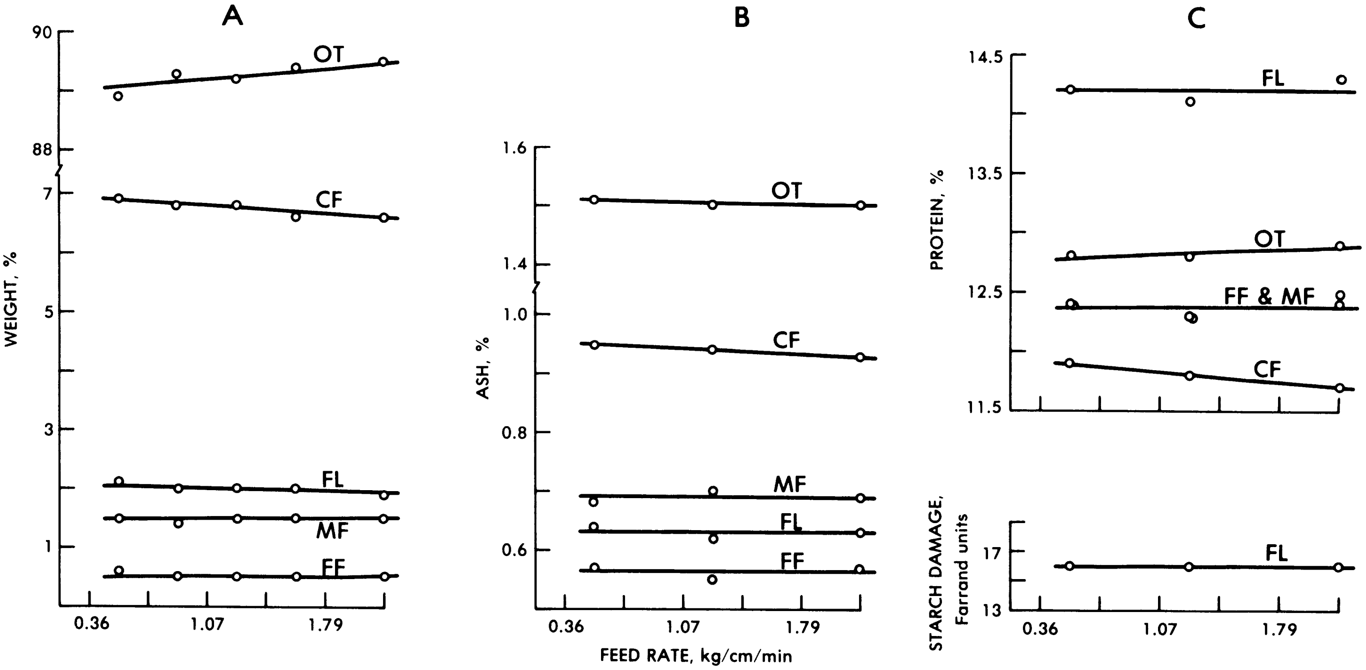

Fig. 4. Effect of feed rate on the weight percentage (**A**), ash content (**B**), protein, and starch damage (**C**) of various streams. Roll gap, 0.89 mm; roll differential, 2:1; slow roll speed, 150 rpm; tempering moisture: 16.5%. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

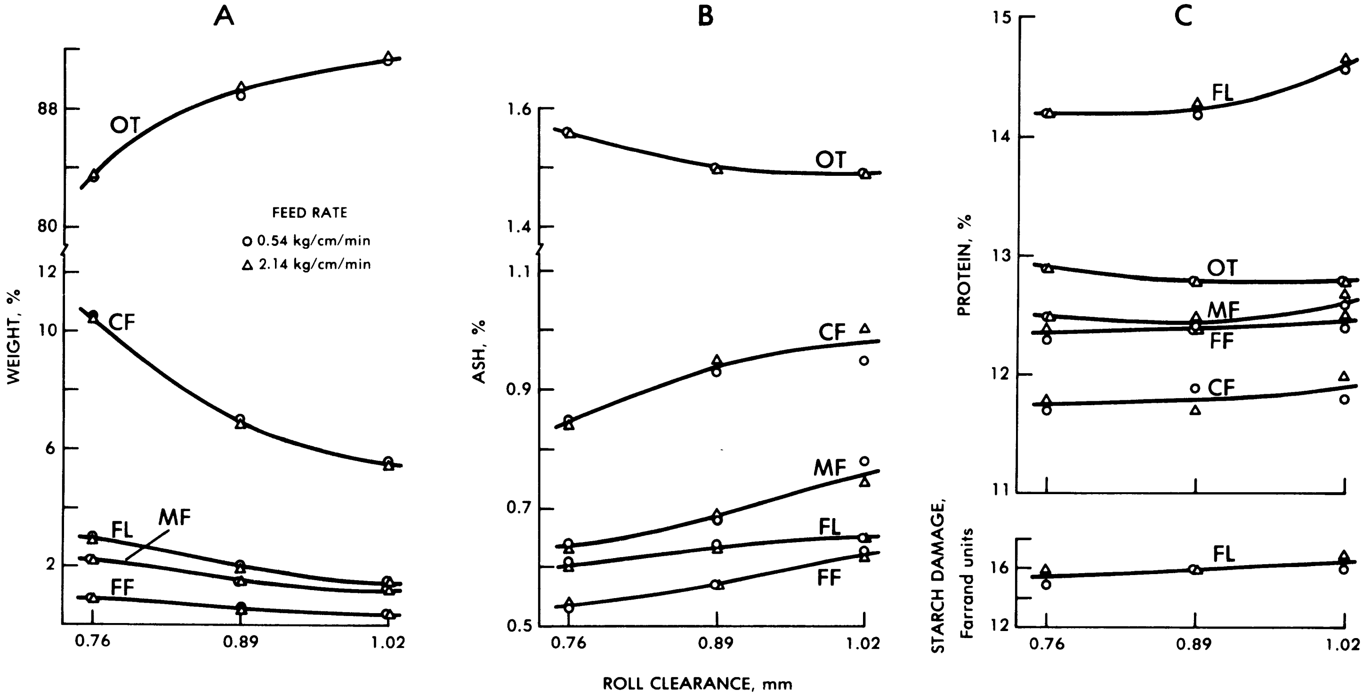

Fig. 5. Effect of roll gap on the weight percentage (**A**), ash content (**B**), protein, and starch damage (**C**) of various streams. Roll differential, 2:1, slow roll speed, 150 rpm; tempering moisture, 16.5%. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

pattern of protein content change with moisture is similar to that of ash content change but to a lesser degree, and the increase in protein content of overtails offsets the decreases in other streams. This is presumably because the bran coat separates more easily from the endosperm with the increase in tempering moisture, and therefore the streams (except overtails) are less contaminated with aleurone layer, which has a higher protein content than does endosperm (Hinton 1947).

The order of protein content in the various streams is also of interest. The protein content decreases from outer to inner endosperm within a wheat kernel (Hinton 1947). Figure 3C shows that CF comes mainly from the inner endosperm, FL comes from outer endosperm, and MF and FF fall in between.

The starch damage of FL is essentially independent of tempering moisture, as shown in Fig. 3C. The starch damage in Farrand units is in line with that reported by Holas and Tipples (1978). Change in moisture content in the roll feed had little direct influence on the extent of damaged starch production during grinding (Jones et al 1961). Williams (1968) suggested, however, that both too little or too much conditioning moisture would result in higher starch damage.

Effect of Feed Rate

Figure 4 shows the effect of feed rate, using wheat tempered to 16.5% moisture content. Similar results were obtained for wheat tempered to 14.5, 15.5, and 17.5% moisture. Except for a slight and insignificant decline in weight percentage and in ash and protein contents for the coarse fraction and a concomitant increase in these values for overtails, increasing the feed rate from 0.54 kg/cm/min to 2.14 kg/cm/min had little effect. This is not surprising because more than 50% free roll surface is still available whether the feed rate is 50 kg/cm/hr or 0.83 kg/cm/min, as demonstrated by Gehle (1965). In fact, the amount of wheat going through the first break rolls maybe very small in comparison to the amount that could, theoretically, be fed through (Gehle 1965).

Effect of Roll Gap

Three roll gaps were studied: 0.76, 0.89, and 1.02 mm. The results are presented in Fig. 5. More severe grinding (ie, less roll clearance) resulted in higher break release. The increase in the amount of coarse fraction was the most significant. Figure 5B shows that the ash contents of all streams except overtails decreased as roll gap was reduced. Similar results have been reported by Gehle (1965) and by Cleve and Will (1966). When roll clearance is wide, the wheat kernel is barely touched and opened up, so that dirt in the crease is released and the amount of bran fragments and hence ash content in the stocks produced is relatively high. With more severe grinding, more low ash endosperm is released from the wheat kernel, causing a reduction in the ash content of the various streams. The direction of protein content change in the various streams was similar to that for ash, but the extent of change was less significant. Starch damage of FL showed a slight and negligible decrease as the roll gap decreased.

Effect of Roll Differential

The effect of roll differential is shown in Figs. 6–8 for wheat tempered to 16.5% moisture content. Two feed rates, 0.54 and 2.14 kg/cm/min, and three roll gaps, at 0.76, 0.89, and 1.02 mm, were

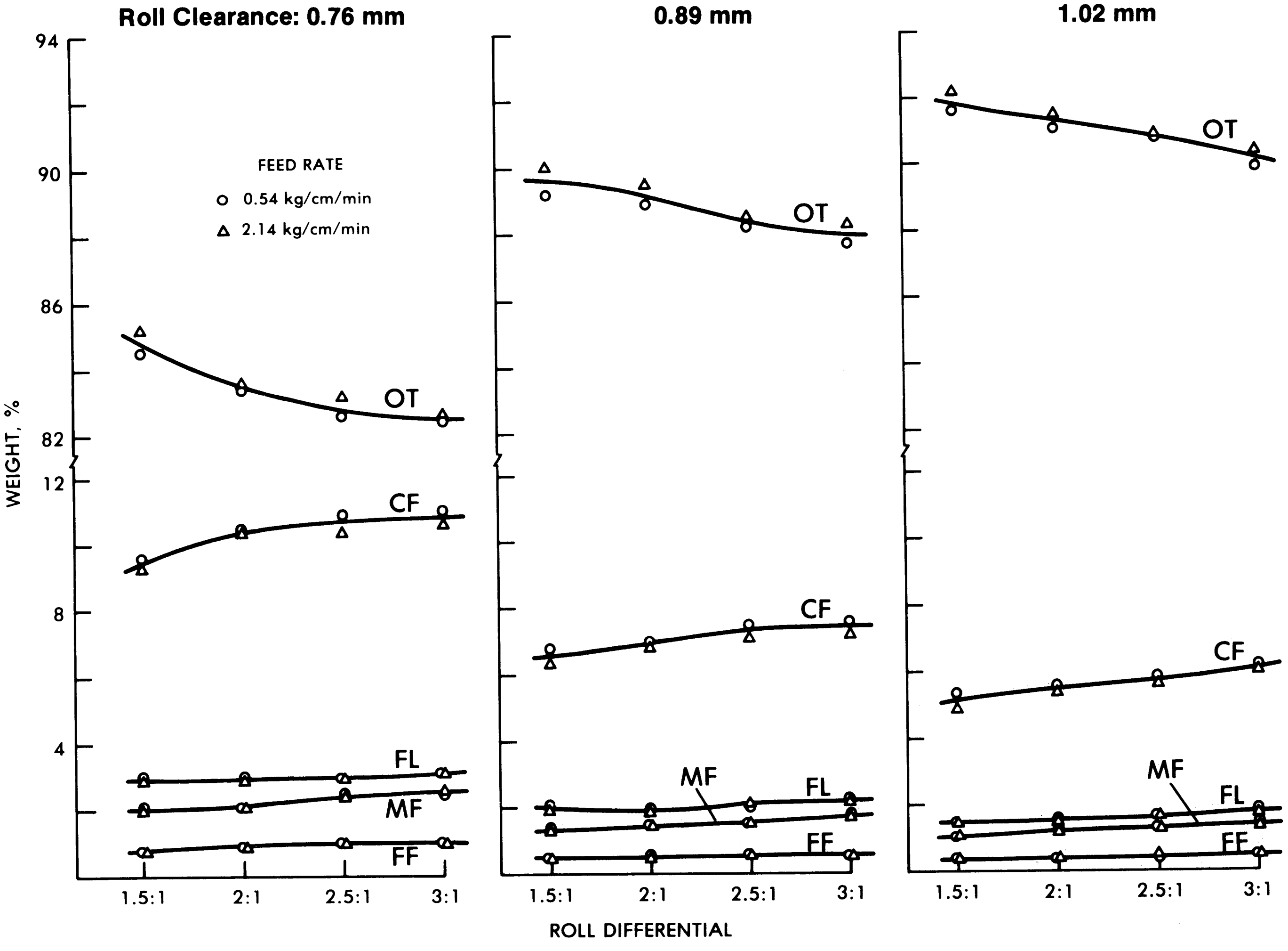

Fig. 6. Effect of roll differential on the weight percentages of various streams. Tempering moisture, 16.5%; slow roll speed, 150 rpm. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

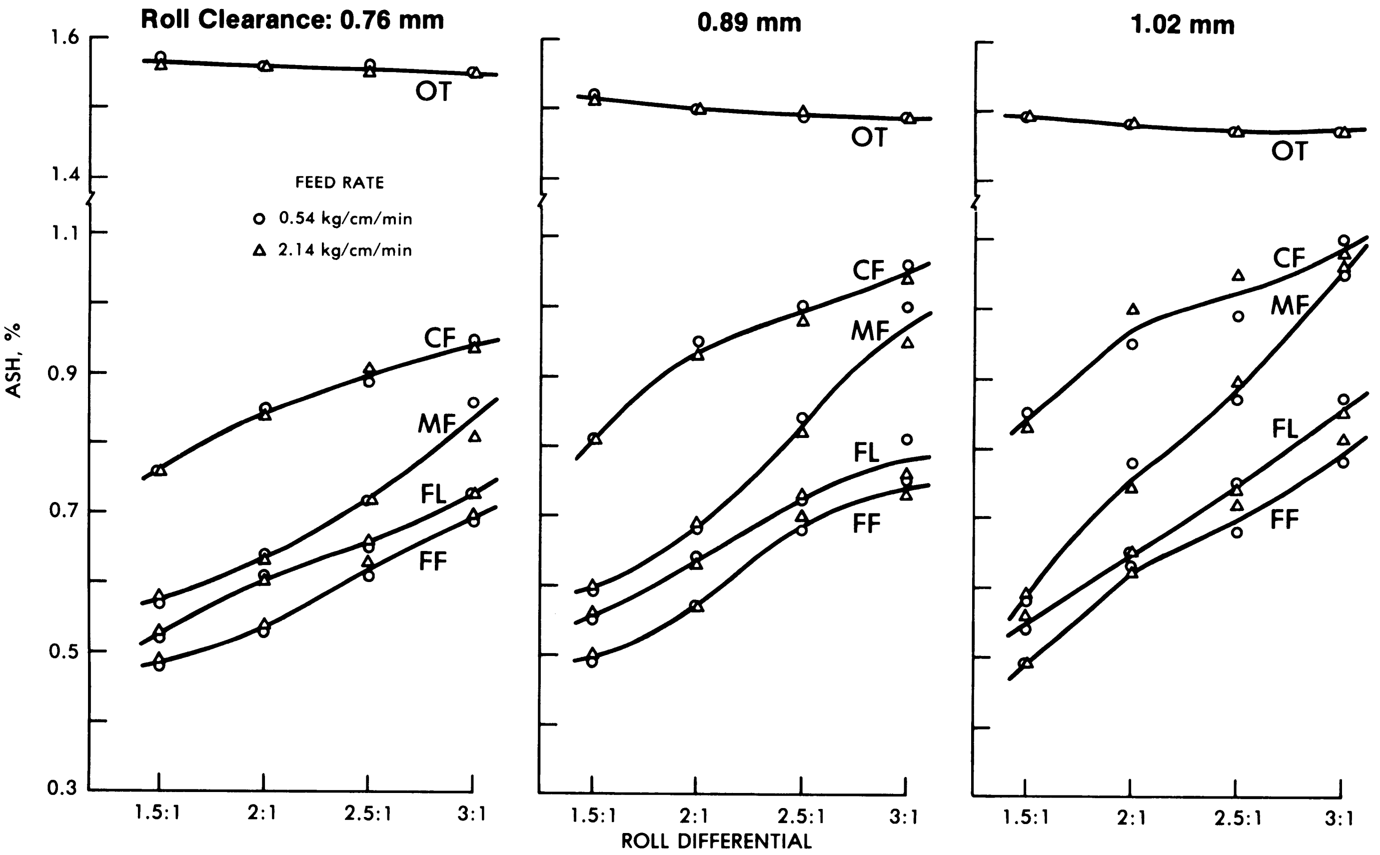

Fig. 7. Effect of roll differential on the ash contents of various streams. Tempering moisture, 16.5%; slow roll speed, 150 rpm. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

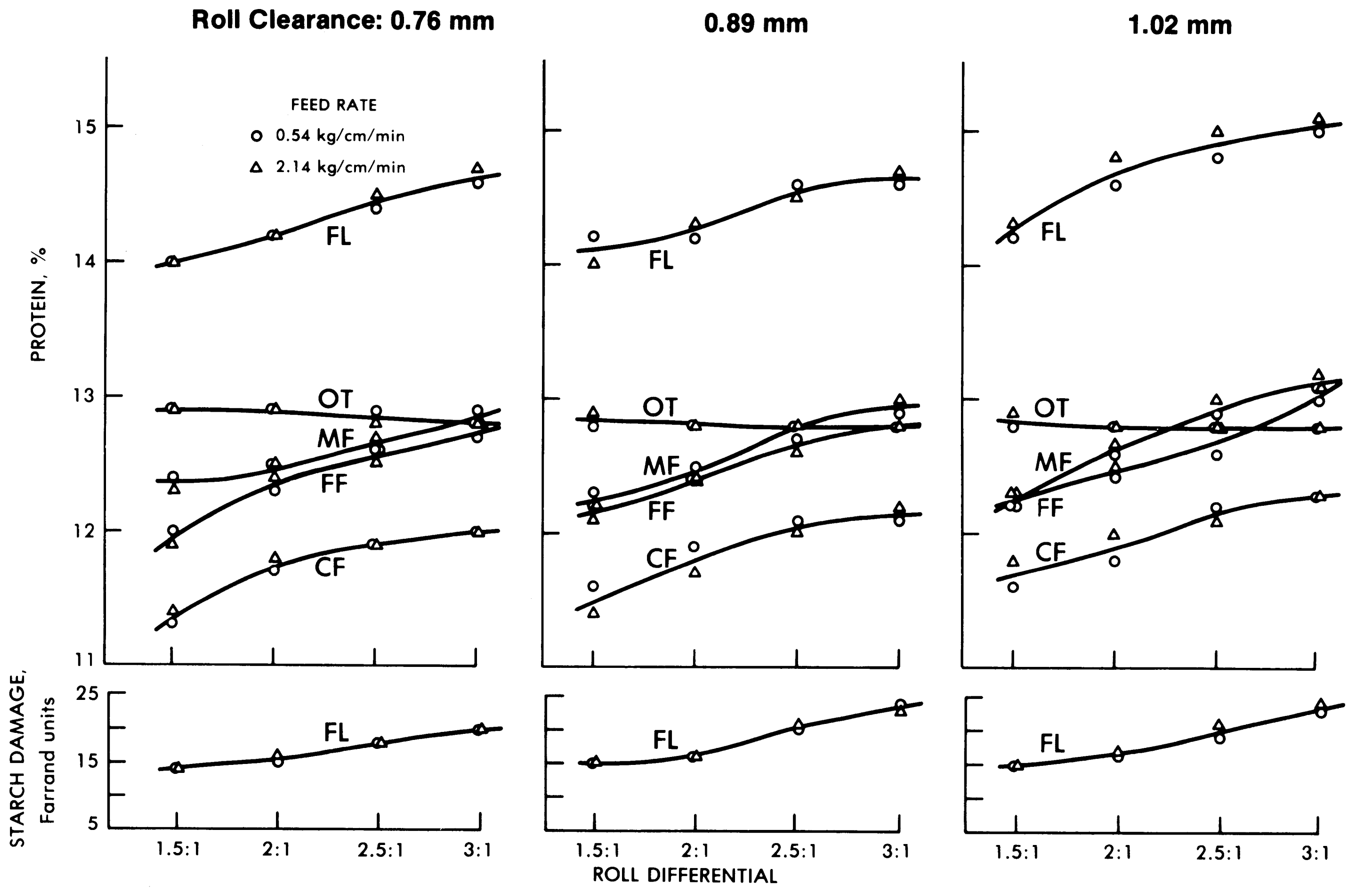

Fig. 8. Effect of roll differential on the protein contents of various streams and starch damage of break flour. Tempering moisture, 16.5%; slow roll speed, 150 rpm. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

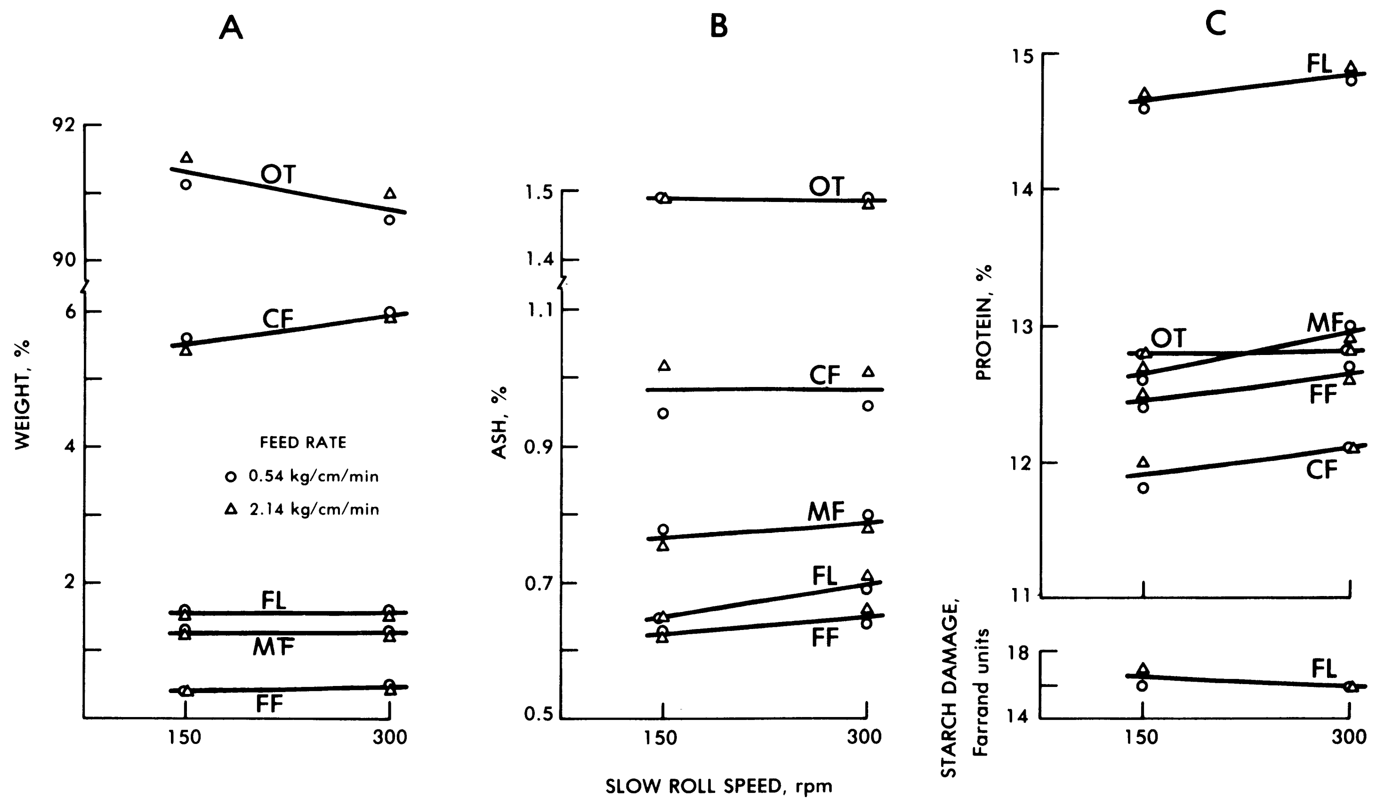

Fig. 9. Effect of slow roll speed on the weight percentage (**A**), ash content (**B**), protein, and starch damage (**C**) of various streams. Roll gap, 1.02 mm; roll differential, 2:1; tempering moisture, 16.5%. CF = coarse fraction, FL = first break flour, FF = fine fraction, MF = medium fraction, OT = overtails.

used. All streams except the overtails increased in weight percentages (Fig. 6), ash (Fig. 7), and protein content (Fig. 8) when the roll differential was increased from 1.5:1 to 3:1.

At higher roll differential, the speed ratio between the fast moving roll and the slow moving roll is higher, and more corrugations pass each other in a given time. This increases the shearing and scraping of the wheat kernel, resulting in the production of more endosperm particles and of more and finer bran fragments. The ash content of the streams therefore tends to be higher because of contamination with bran particles. As the roll differential is decreased, the wheat kernel is subjected to less shearing and scraping action and to more crushing or flattening action. This results in less separation of endosperm and bran. Fewer endosperm particles are produced, and the ash content of streams tends to be lower.

The starch damage of FL increased with increasing roll differential (Fig. 8). This can also be attributed to the scraping action. Jones (1940) has shown that increase of the surface factor (ie, the scraping or attritional factor) resulting from the increase of roll differential causes a significant increase in flour starch damage.

A comparison between the effects of tempering moisture (Fig. 3) and roll differential (Figs. 6–8) seems pertinent. Increasing either tempering moisture or roll differential caused an increase in the first break release, but their effects on the analytical values of the various streams were completely different.

Effect of Roll Speed

Figure 9 gives the results for two different roll speeds with differential maintained at 2:1. Two feed rates, 0.54 and 2.14 kg/cm/min, were used for each roll speed. Increasing the slow roll speed from 150 to 300 rpm resulted in a small increase in the amount of CF. The amounts of FL, MF, and FF were not affected. Ash content increased slightly in FL, MF, and FF. The protein content of all streams, with the exception of overtails, also showed slight increases. Although the residence time of wheat kernels between the fast and slow rolls is less at a higher roll speed, the kernels apparently are scraped more severely. Therefore, more endosperm cells are released from the peripheral areas, where the cells are higher in protein and ash than those in the central areas (Morris et al 1945). Starch damage of FL did not change.

Increasing roll speed can be used to form a similar feed flow pattern when an increase in feed rate is desired (Schumacher 1967). The effect of feed rate was not significant under the experimental conditions of this study. Therefore, the effect of roll speed is also small under the conditions studied.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Approved Methods of the AACC. The Association: St. Paul, MN.

ANDERSON, J. E. 1937. What water does to wheat in tempering. Bull. Assoc. Oper. Millers. May, p. 794.

CLEVE, H. and WILL, F. 1966. Research with the help of the varioroll. Cereal Sci. Today 11:128.

CREASON, H. 1975. Grinding and corrugating rolls. Bull. Assoc. Oper. Millers. November, p. 3569.

FARRAND, E. A. 1964. Flour properties in relation to the modern bread processes in the United Kingdom, with special reference to alpha-amylase and starch damage. Cereal Chem. 41:98.

GEHLE, H. 1965. The Miag "vario" rollstand—Design and purpose. Bull. Assoc. Oper. Millers. May, p. 2861.

HEIDE, F. M. 1956. Roll corrugation. Bull. Assoc. Oper. Millers. December, p. 2292.

HINTON, J. J. C. 1947. The distribution of vitamin B_1 and nitrogen in the wheat grain. Proc. R. Soc. London, Ser. B. 134:418.

HOLAS, J., and TIPPLES, K. H. 1978. Factors affecting farinograph and baking absorption. I. Quality characteristics of flour streams. Cereal Chem. 55:637.

JONES, C. R. 1940. The production of mechanically damaged starch in milling as a governing factor in the diastatic activity of flour. Cereal Chem. 17:133.

JONES, C. R., GREER, E. N., THOMLINSON, J., and BAKER, G. J. 1961. Technology of the production of increased starch damage in flour milling. Northwest. Miller 265(19):34.

McCORKLE, F. D. 1973. Development and operation of the modern roller mill. Bull. Assoc. Oper. Millers. May, p. 3362.

MORRIS, V. H., ALEXANDER, T. L., and PASCOE, E. D. 1945. Studies of the composition of the wheat kernel. I. Distribution of ash and protein in center sections. Cereal Chem. 22:351.

NIERNBERGER, F. F., and FARRELL, E. P. 1970. Effects of roll diameter and speed on first break grinding of wheats. Bull. Assoc. Oper. Millers. January, p. 3154.

SCHUMACHER, F. 1967. Technical aspects of grinding with roller mills. Bull. Assoc. Oper. Millers. January, p. 2956.

SMITH, L. 1944. Flour Milling Technology. Northern: Liverpool.

WARD, A. B., and SHELLENBERGER, J. A. 1951. Grinding with controlled roll pressure. Bull. Assoc. Oper. Millers. August, p. 1907.

WILLIAMS, P. C. 1968. The nature of mechanically damaged starch and its production in flour. Bull. Assoc. Oper. Millers. July, p. 3048.

ZIEGLER, E., and GREER, E. N. 1971. Principles of Milling. Page 115 in: Pomeranz, Y. (ed.). Wheat Chemistry and Technology. Am. Assoc. Cereal Chem.: St. Paul, MN.

[Received August 1, 1979. Accepted January 29, 1980]