# EFFECT OF MILLING YIELD ON FLOUR COMPOSITION AND BREADMAKING QUALITY

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## ABSTRACT

A hard, semi-hard, and soft wheat were milled on an experimental Buhler mill to produce from each wheat a series of flours representing extraction rates ranging from approximately 66 to 82%. The per cent ash and color grade values of the flours increased with extraction rate within each series. Both parameters were related to extraction rate by cubic equations describing three parallel curves displaced according to the grain hardness of the wheats. Protein content and farinograph water absorption both increased with extraction rate. That gluten strength decreased with increasing extraction rate was shown by an increase in farinograph dough breakdown and a decrease in maximum extensigram resistance. Pup-loaf test baking employing a standard formula and constant mixing time showed that the extraction rate giving optimum loaf volume for the hard and semi-hard wheats was 72% and that for the soft wheat was 74%. A range of approximately 10% of maximum loaf volume was obtained within each series.

Since flour yield varies between quality testing laboratories and, in particular, from commercial to laboratory mills, an understanding of the effects of extraction rate on flour properties is necessary. Because of marked differences in composition between the bran and endosperm, and within the endosperm itself (1), flours representing varying extraction rates will differ in composition.

Hinton (2,3) and other workers (4,5,6) observed protein contents of the order of 6% in the inner endosperm compared to 14% in the outer endosperm (subaleurone). Kent (7) reported an even greater differential between the protein content of the subaleurone and the inner endosperm. For two wheats the subaleurone accounted for almost 25% of the total protein of the starchy endosperm, far in excess of its contribution to the weight of the endosperm.

Evidence for this phenomenon also comes from microscopy studies which showed that some outer cells of high-protein hard wheats carried few or even no starch granules whereas inner cells contained many starch granules (8).

Variation in protein composition within the endosperm has also been reported. Kent and Evers (9) observed that storage protein represents a larger proportion of the total protein in subaleurone endosperm than in inner endosperm.

During the latter stages of the milling process, flour yield is increased by regrinding and resieving the bran-rich fraction. The flour gained from this process is from the outer endosperm layers of the kernel and has a different composition than that obtained during the early stages of milling. In addition to these differences, high extraction flours will incur more severe starch damage and will contain higher levels of pentosans resulting in higher water absorption than low extraction flours.

It is now well established that protein content and composition are major factors in determining breadmaking quality. Accordingly, variation in these properties within the wheat kernel, and consequently within flours of different extraction rates, is of prime interest. The aim of this study was to evaluate the combined effect of these differences on the loaf-volume potential and rheological properties of the flours, and to demonstrate the necessity of taking the effect of extraction rate on dough properties into account when evaluating the breadmaking potential of wheat lines in a breeding program.

Although considerable information is available on the variation in ash content and color of flours of different extraction rate, similar data on rheological properties and breadmaking potential are not available. This paper reports on the variation in these properties within three series of flours covering extraction rates of 66 to 82% and produced from three wheats of various hardness.

## MATERIALS AND METHODS

### Wheat Samples

Three wheats grown in Victoria in the 1972 season were selected to represent a range of kernel hardness. The varieties and their protein contents are given in Table I.

### Milling

After conditioning to a moisture level of 15.5% for 48 hr for Emblem and Halberd, and to 14.5% moisture for 24 hr for Summit, the wheats were milled on a Buhler experimental mill at a feed rate of 100 g per min. By progressively resieving the pollard, and then regrinding and resieving the pollard and bran, a series of flours representing extraction rates of approximately 66 to 82% was obtained from each wheat. Extraction rates were calculated as per cent total product.

A base flour was obtained in each case by combining flour streams in the order 1st reduction, 2nd reduction, A break, B break, C break, and 3rd reduction until an extraction level of approximately 66% was reached. Extraction levels obtained without resieving and regrinding-resieving of the pollard and bran were 66, 69, and 72% for Emblem, Halberd, and Summit, respectively. After resieving, the Emblem and Halberd bran and pollard required three regrinds to achieve a

**TABLE I**
**Protein Content and Hardness of Wheats**

| Wheat Variety | % Protein (13.5% mb) | Hardness |
|---|---|---|
| Emblem | 12.3 | Hard |
| Halberd | 11.5 | Semi-hard |
| Summit | 11.6 | Soft |

total extraction of approximately 82%. Because of its higher initial extraction, Summit required only two regrinds to reach this level of extraction.

### Flour Color

Color grade values were determined using the Kent-Jones and Martin Series II color grader.

### Analytical Methods

Ash contents were determined according to standard AACC method (11).

Protein (% N × 5.7) was determined by the boric acid modification of the Kjeldahl procedure using copper sulfate-potassium sulfate as catalyst (11). Wheat and flour proteins are calculated on a 13.5% moisture basis.

### Rheological Measurements

Farinograph and extensograph tests were performed according to standard AACC methods (11).

### Baking Test

The baking test used is one commonly employed in Australia. Since it differs from tests used in other countries, it is outlined in detail below.

One hundred grams of flour, 0.5 g malt flour, 17 ml of a 12% w/v yeast solution, 1 ml of a solution containing 0.1% w/v potassium bromate and 0.5% w/v ammonium chloride, 10 ml of salt solution (20% w/v), and water to make up to baking absorption as determined on the farinograph were mixed for 2.5 min. in a farinograph bowl. After proofing for 105 min, the dough was punched and returned to the proofing cabinet for 50 min. A second punch was then performed and the dough placed in the cabinet for 25 min before panning. Fifty-five minutes later the dough was baked for 25 min in a rotary oven. Loaf volumes were measured by rapeseed displacement 1 hr after the bread was removed from the oven.

**TABLE II**
**Relation between Flour Characteristics and Milling Extraction Rate[a]**

| | |
|---|---|
| Ash (%) | $0.993 - 0.144 \times 10^{-1}\ E + 0.131 \times 10^{-5}\ E^3$ <br> $-0.951 \times 10^{-2}\ V_1 - 0.114 \times 10^{-2}\ V_2$ <br> $100\ R^2 = 95.4$ |
| Color grade value | $16.3 - 0.343\ E + 0.282 \times 10^{-4}\ E^3$ <br> $- 0.427\ V_1 - 0.117 \times 10^{-2}\ V_2E + 0.992\ V_2E^3$ <br> $100\ R^2 = 98.8$ |
| Mixing tolerance index (BU) | $-62.1 + 2.05\ E + 1.38\ V_2$ <br> $100\ R^2 = 92.7$ |
| Resistance (BU) | $822 - 7.833\ E + 21.6\ V_1 - 13.3\ V_2$ <br> $+ 0.144\ V_2E$ <br> $100\ R_2 = 95.7$ |
| Water absorption (%) | $51.7 + 0.180\ E - 0.226\ V_2$ <br> $- 0.316 \times 10^{-1}\ V_1E - 0.285 \times 10^{-2}\ V_2E$ <br> $100\ R^2 = 99.8$ |

[a]E = % milling extraction rate.

## RESULTS AND DISCUSSION

The relations between flour characteristics and milling extraction rate were statistically determined and are given in Table II. Model equations providing a good fit to the actual data were obtained for the relations between per cent extraction and per cent ash, color grade, mixing tolerance index, extensigraph resistance, and farinograph water absorption. Each prediction equation yielded a coefficient of determination (100 $R^2$) above 90%. Since the loaf volume-per cent extraction data did not give a good fit to either a quadratic or a cubic curve, it is not included in this table. Pseudovariables $V_1$ and $V_2$ were introduced to distinguish between varieties. Values for $V_1$ of 0, −1, and +1, respectively, were chosen for Emblem, Halberd, and Summit. Corresponding values for $V_2$ were −16, 7, and 7.

### Flour Composition and Extraction Rate

Figure 1 shows the cubic relationship between per cent ash and extraction rate for the three wheats studied. The data fit parallel curves with ash contents decreasing in the order Emblem, Halberd, and Summit at any one extraction rate. This order is a consequence of decreasing kernel hardness resulting in less fragmentation of the bran during milling. Even at extraction rates of above 80%,

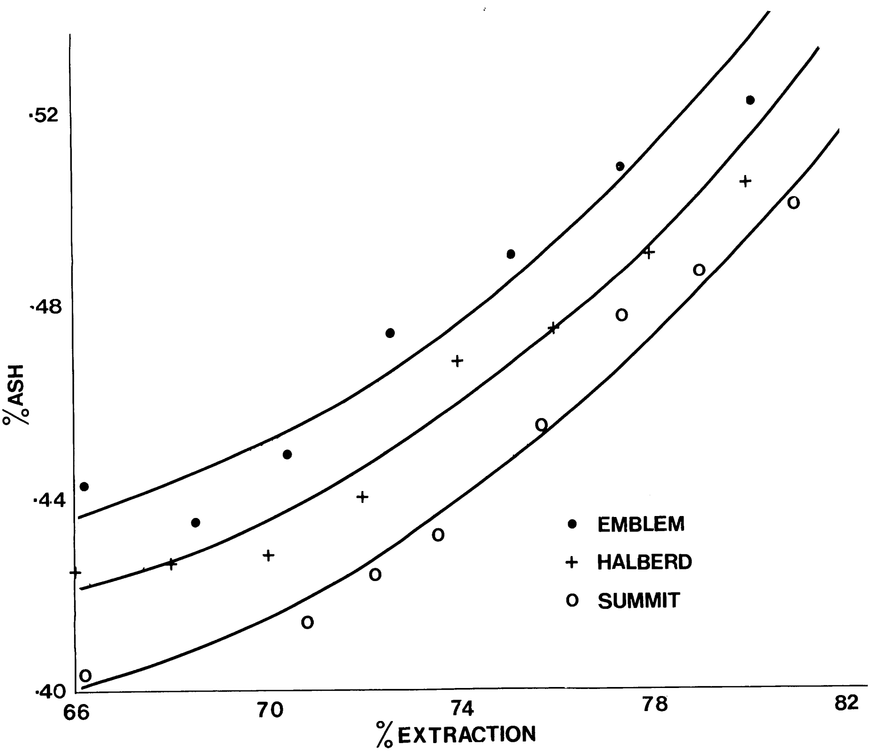


Fig. 1. Relation between per cent ash and per cent extraction for three series of flours.

the ash values of 0.50 to 0.52% obtained are acceptable by present day industrial standards.

A similar cubic relationship exists between color grade value and extraction rate (Fig. 2). Three parallel curves can be drawn to fit these data. The vertical

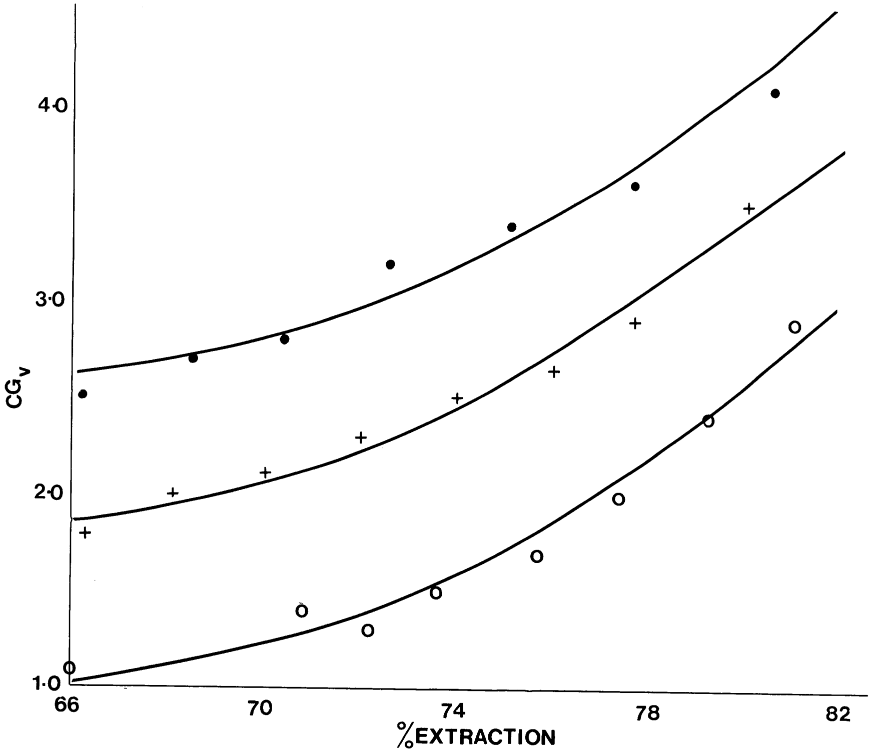


Fig. 2. Relation between color grade value ($CG_v$) and per cent extraction for three series of flours.

**TABLE III**
**Protein Content of Flours**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Emblem | | | | | | | | |
| Extraction rate, % | 66.2 | 68.5 | 70.4 | 72.6 | 75.1 | 77.6 | 80.5 | |
| Protein content, % (13.5% mb) | 11.3 | 11.3 | 11.3 | 11.5 | 11.5 | 11.5 | 11.6 | |
| Halberd | | | | | | | | |
| Extraction rate, % | 66.3 | 68.1 | 70.0 | 72.0 | 74.0 | 76.0 | 77.7 | 80.0 |
| Protein content, % (13.5% mb) | 10.6 | 10.7 | 10.7 | 10.7 | 10.7 | 10.7 | 10.8 | 11.0 |
| Summit | | | | | | | | |
| Extraction rate, % | 66.2 | 70.8 | 72.2 | 73.6 | 75.7 | 77.4 | 79.0 | 81.0 |
| Protein content, % (13.5% mb) | 10.7 | 10.8 | 10.8 | 10.8 | 10.9 | 10.9 | 11.2 | 11.3 |

displacement of these curves is a consequence of the higher ash figures and, hence, color grade values for Emblem and Halberd flours when compared to those from Summit.

This relation confirms that reported by Ziegler and Greer (12) who also obtained parallel curves for the relation between flour color grade and extraction rate for four wheats. Their results and those of the present study indicate that the gradient in ash content from inner endosperm to bran is of approximately the same degree for all wheats.

Table III lists the protein content of each flour. The wheats were selected to produce flours of approximately the same protein content at any one extraction rate, thus minimizing the influence of this variable when making intervarietal comparisons of flour properties.

The increase in protein content with extraction rate for each variety reflects the presence of the well-established protein gradient within the wheat kernel (2–8). The subaleurone layers and bran are higher in protein and ash than the inner endosperm. As the former contribute a greater proportion to the flour, an increase in flour protein and ash is observed.

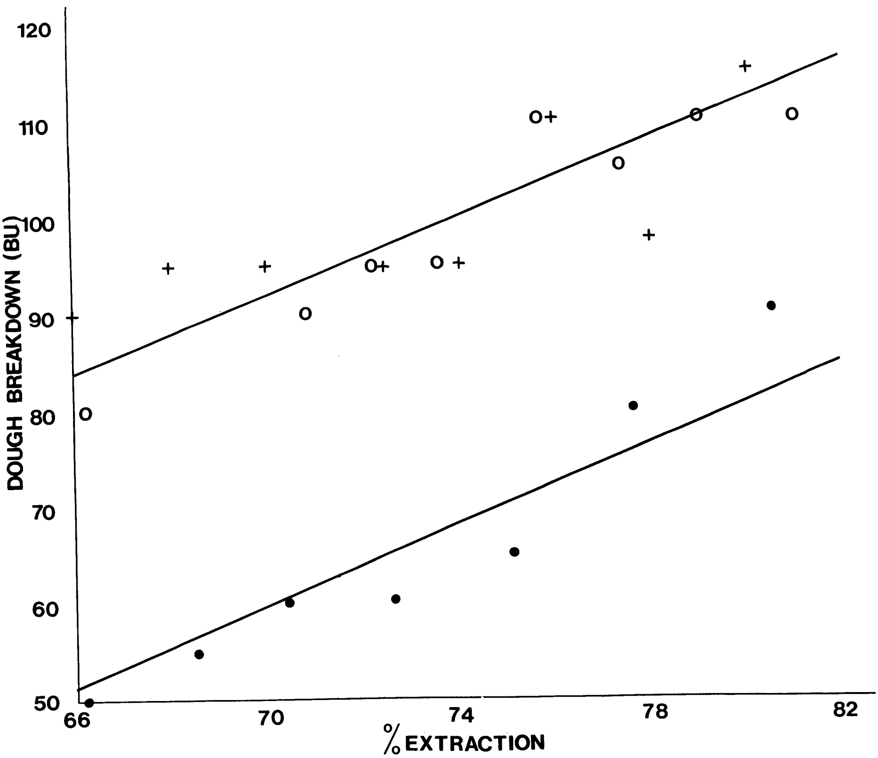


Fig. 3. Relation between farinograph dough breakdown and per cent extraction for three series of flours.

**Rheological Properties and Extraction Rate**

Within each series of flours, dough strength decreased with increasing extraction rate. Figures 3 and 4 illustrate linear relations between extraction rate and commonly used indices of dough strength.

Farinograph dough breakdown increased significantly with extraction rate for each variety (Fig. 3). Ranges of 40, 30, and 25 Brabender Units (BU) were obtained for dough breakdown within the Emblem, Summit, and Halberd series, respectively. Maximum resistance as determined by the extensigraph showed a marked decrease with extraction rate for each variety (Fig. 4). A decrease of approximately 10 BU for an increase of 1% in extraction rate was found for each variety.

These results (Figs. 3 and 4) indicate a pronounced decrease in gluten strength with an increase in extraction rate for each variety. This decrease in strength occurs despite an increase in flour protein for the higher extraction flours. These flours produced doughs with gluten networks that were more easily disrupted by prolonged mixing and offered less resistance to extension than did those of the lower extraction flours. This indicates a change in flour protein quality and, hence, composition.

Figure 5 illustrates the linear relation between farinograph water absorption and extraction rate. The additional milling required to produce high extraction flours causes increased starch damage by physical abrasion and consequently higher water absorption. The water absorptions obtained reflect the relative hardness of the wheats used, with Emblem greater than Halberd greater than Summit.

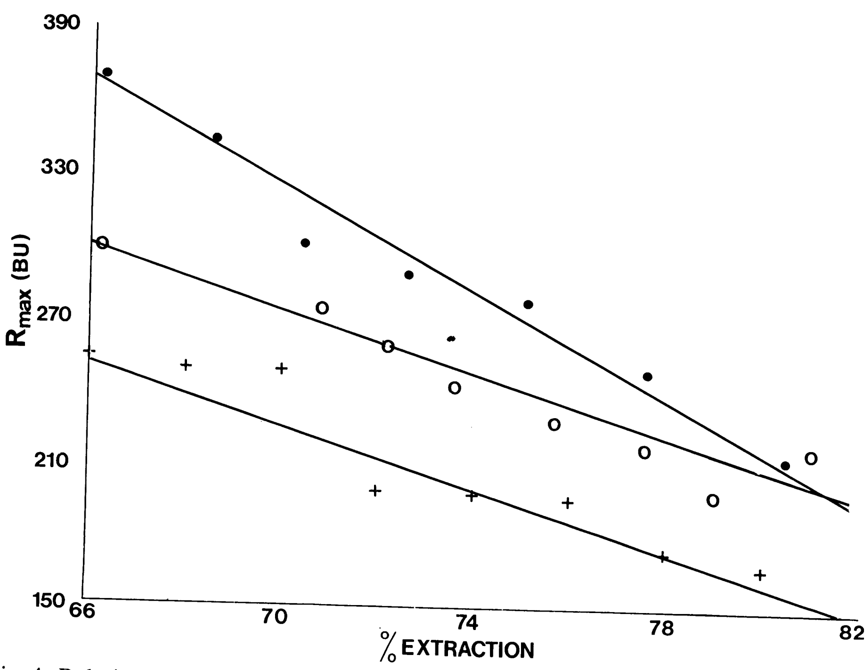


Fig. 4. Relation between extensigraph maximum resistance ($R_{max}$) and per cent extraction for three series of flours.

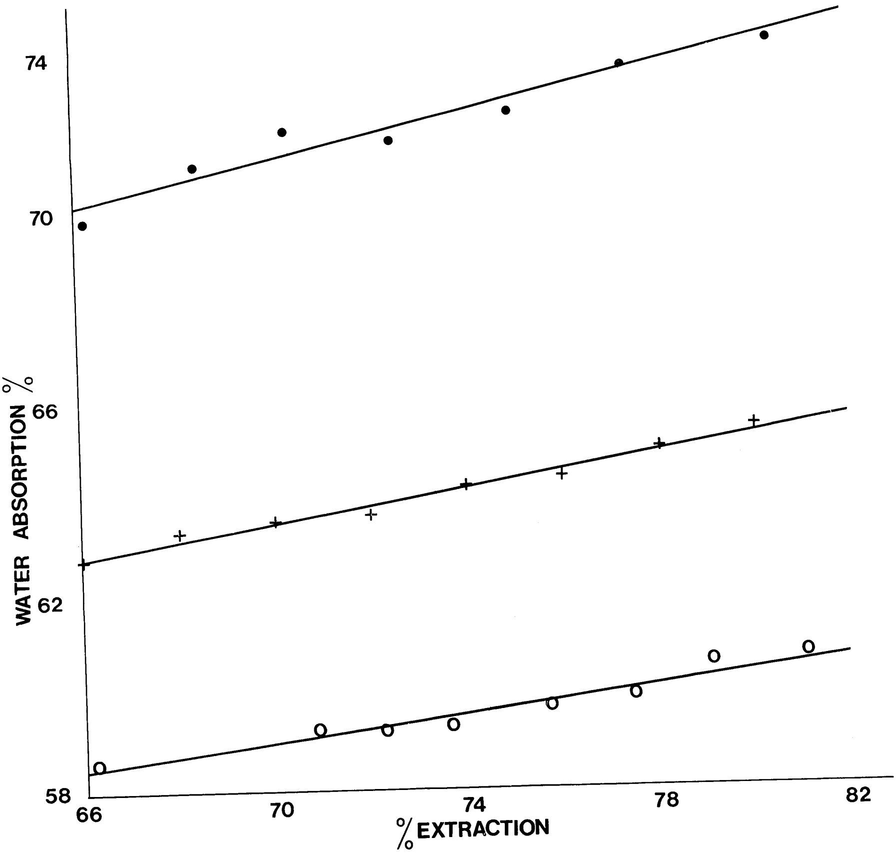


Fig. 5. Relation between farinograph water absorption and per cent extraction for three series of flours.

**Loaf Volume and Extraction Rate**

Figure 6 shows that loaf volume is critically dependent on extraction rate for each variety. A loaf-volume range greater than 10% of the maximum exists within each series. Even within a relatively small range of extraction rate, say 72 to 76%, there exists a significant range of loaf-volume potential for each variety. The extraction rate giving optimum loaf volume is 72% for Emblem and Halberd and 74% for Summit under the milling and baking conditions used in this study.

An extraction rate of approximately 75% appears to be the limit beyond which a rapid decrease in loaf-volume potential is noted. Particularly rapid decreases in this parameter were noted for Summit and Emblem flours.

## CONCLUSIONS

Variation of a few per cent in extraction rate resulted in significant differences in rheological and breadmaking properties for three varieties studied. Therefore,

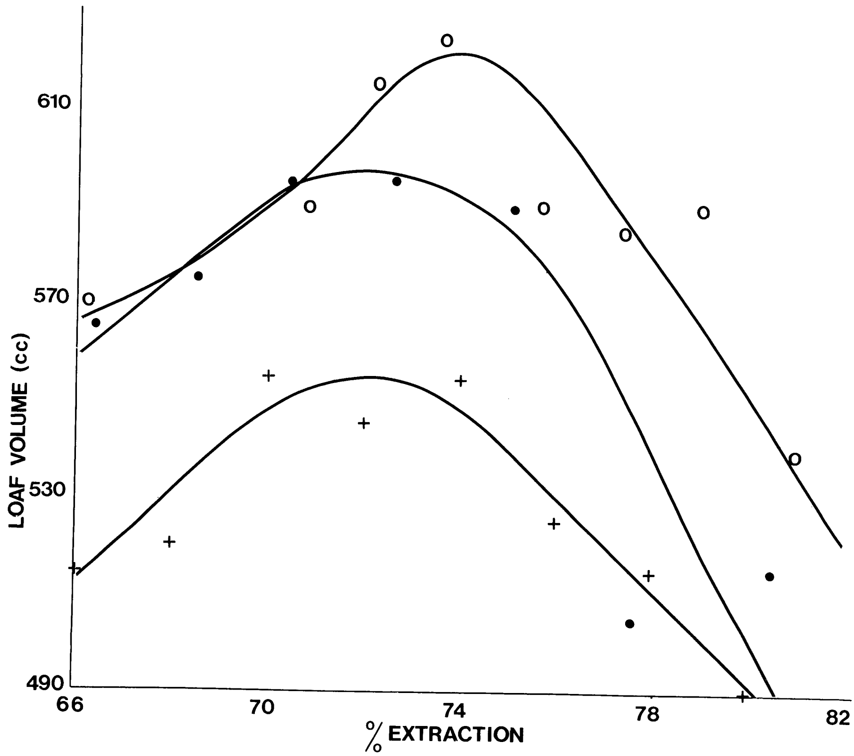


Fig. 6. Relation between loaf volume and per cent extraction for three series of flours.

when comparing quality testing results between laboratories, the effect of extraction rate must be considered. A marked decrease in gluten strength occurs for high extraction flours. This decrease is accompanied by a depression of loaf-volume potential at extraction rates above an optimum when the flours are baked by the standard procedure.

The extent and pattern of these variations will no doubt depend on the milling method used. The observed relations between extraction rate and flour protein, flour ash, and water absorption are similar to the limited published data on this subject dealing with variation in yield for commercially produced flours. These data are reviewed by Ziegler and Greer (12) and confirm that our milling procedure approximates commercial conditions.

An important consequence of the observation that loaf volume depends on extraction rate is that optimum flour yield should be determined for each variety, or more practically for each wheat type, to allow realization of maximum breadmaking potential. This is particularly relevant to the evaluation of experimental lines in wheat breeding programs where variations in loaf volume of 10% may mean the acceptance or rejection of a new line.

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