RHEOLOGICAL PROPERTIES AND BREADMAKING CHARACTERISTICS OF WHEAT-FABABEAN COMPOSITE FLOURS

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ABSTRACT

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The rheological characteristics and breadmaking properties of three fababean varieties (Diana, Ackerperle and Herz freya) at four different levels (5, 10, 20 and 30%), blended with a strong wheat (Neepawa) flour and two weak wheat (Fredrick and Pitic 62) flours were investigated. Base materials and all composites were analyzed for proximate analyses (moisture, protein and ash contents, as well as amino acid compositions). Generally, the proximate compositions of the composite flours were directly related to the proportion of constituent flours in the composite. Despite large differences in protein content among the wheat flours studied, only minor variations in amino acid compositions were observed. Fababean flours were found to be richer in lysine, arginine and aspartic acid, but contained substantially less glutamic acid, proline and methionine than wheat flour. Increasing concentrations of fababean flour adversely affected the rheological behaviour of wheat-fababean doughs as measured by the farinograph, extensigraph and amylograph, suggesting a dilution of gluten strength. The observed effects increased as the proportion of fababean flours increased.

Three baking methods were compared and used to measure the baking quality of all the composite flours, the standard AACC straight-dough method; a modified (short) straight-dough method; and a modified sheeting roll method. Poor quality bread was produced with the AACC straight-dough method. However, it was possible to obtain acceptable bread by the other two methods.

Baking results showed that satisfactory bread can be produced from composite flours containing relatively high proportion (up to 20%) of fababean flour blended with a strong wheat such as Neepawa and up to 10% fababean flours blended with a weak wheat such as Fredrick or Pitic 62, applying the modified (short) straight-dough method. On the other hand, with weak wheat flours blended with fababean flours (up to 10%), the modified sheeting roll method produced higher bread quality compared to the modified (short) straight-dough method. The use of Emplex (sodium stearoyl-2-lactylate) as a dough conditioner, at 1% concentration level, improved dough handling properties, external bread quality and crumb structure.

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I. INTRODUCTION

The consumption of wheat, especially in developing countries, is continually increasing (De Ruiter 1978). The demand for wheat has surpassed production in many of these countries, thus forcing its importation. Few of these countries with relatively favourable trade balances, may be able to continue the import of wheat for bread production, notwithstanding its higher cost. This situation can be alleviated either by increasing the wheat production (very difficult in many countries), or by replacing at least part of the imported wheat flour with flours that can be produced locally, from indigenous products.

The use of composite flours can exert a positive influence on the general state of nutrition of a given population. The choice of components and proportions of composite flours allows a large measure of control over the nutritive value, and at the same time, constitute a powerful stimulus to the country's own agriculture and to its agricultural industry.

The possibility of improving the nutritional value of wheat flour breads by the addition of high-protein flours, has generated considerable interest. One of the legume crops receiving attention in this aspect is the fababean (*Vicia faba* L., var. minor). Recently breeding, nutritional and chemical studies at the University of Manitoba has shown that fababeans have the potential as a new high protein crop for Western Canada.

Besides, depending on the strength of the flour, wheats are classified into two major groups, namely hard (strong) wheat or soft (weak) wheat. Both groups have quite different properties. For the production of yeast-leavened bread, wheat must have a protein content of at least 12%. This is characteristic of strong flours. In many developing countries, climatic and soil conditions make it impossible to produce wheat of high protein content. These countries usually import wheat which is blended with local wheat or other native crops.

This thesis was initiated to study rheological and breadmaking differences among one strong and two weak wheat flours blended with three varieties of fababean flours. Although the use of fababean for human food is not new, the investigation that forms the basis of this thesis, is considered to be of value in extending the potential uses of this legume in the world.

II. LITERATURE REVIEW

A. General

Wheat consumption in many developing countries has been increasing due to several factors such as: 1) an increase in the normal population growth; 2) a change in eating habits; 3) a greater per capita income and 4) the availability of wheat-derivation products of better quality. To satisfy this growing demand, some countries must resort to massive imports, thus creating a serious economical situation (De Ruiter 1978). According to Olsen (1978),30% of the world population (in the developed countries) uses 60% of the total production of food and agricultural products. In order to change this maldistribution, it is necessary to extend the utilization of vegetable protein instead of meat.

For that reason, the Food and Agricultural Organization of the United Nations, FAO, initiated a composite flours research program in 1964. The aim of this project has been:

> "to determine through intensive research whether it is possible to produce a wide range of acceptable, high quality, nutritious bakery, confectionary and paste goods, from flours and starches other than wheat that can be, or are being processed in the major wheat-importing developing countries. When this is achieved, and such products become part of an established dietary pattern, the potential savings in foreign exchange could be considerable. Further, the stimulation of local agriculture and industry, through creating a growing demand for substantial quantities of raw materials, should have a most beneficial effect on the economies of many countries now dependent on outside sources for one of their basic foodstuffs." (Asselbergs 1973).

As a result of this program, many countries conducted research into a large number of nonwheat raw materials as potential replacements for part or all the wheat flour in bread, biscuits and pasta products. However, many projects have failed because the alternate protein sources introduced have limited applicability due to unfamiliar taste and aroma characteristics. Moreover, Olsen (1978) reported that these products are difficult to accept by people in developing countries unless they are consumed in the developed countries.

Thus, greater emphasis has been placed on the use of composite flour in breadmaking during the last two decades. In general, composite flour refers to any flour containing blends of wheat flour with nonwheat flours. In some cases, the nonwheat materials have been used as a total substitute for wheat. The legumes have been extensively used as a raw material in composite flour studies (Jeffers *et al* 1978).

Botanically, legumes are the edible dicotyledonous seed of leguminous plants that belong to the leguminosae family. Their high nutritive values, mainly in protein content, and their use as a protein supplement in composite flours make them valuable material for investigation (Naivikul and D'Appolonia 1978).

As Molina *et al* (1977) stated, although there are about 13,000 known species of legume grains, only a relatively small number are used directly as food. This fact can be attributed mainly to the eating habits which do not include them as part of the usual diet. The same authors pointed out, that in order to increase legume utilization, it would be necessary to consider the use of the beans of the flours in the formulation of conventional processed food products.

Records show that from the beginning of the Iron Age, the fababean was an important human food product, and consequently one of the oldest cultivated plants. Also, it is well known through archaelogical findings that the early Hebrews were accustomed to mixing bean flour with wheat flour (Olsen 1978). Furthermore, the bean is referred to in the ancient literature of Greece and Rome. According to Olsen (1978), up to about year 1600 the fababean was employed in Europe for culinary purposes, but later the common bean (*Phaseolus vulgaris*) has displaced it. Since that time fababeans were used more for animal feed.

The centers of origin of *Vicia faba* were the Middle East and North Africa. It is believed that fababean was selected in the early history of agriculture because of its erect stems and easily threshed pods (Seitzer 1973).

Fababeans are cultivated and used as human food in almost all countries in the world. Most Eastern European, Mediterranean, African and Asian countries have used fababean as a food for humans as well as for animal feed (Presber 1972). In certain countries such as Uganda, legumes are the staple food. They are consumed in large quantities amounting to 400 or even 500 g daily (Aykroyd and Doughty 1964). Youssef (1978) reported that in Egypt, fababeans are eaten in the stewed form (Medammis) for breakfast as well as in sandwiches any time of the day.

As far as North America is concerned, fababean is a relatively new legume crop. It was introduced as a crop in Western Canada in 1972, stimulated by the initial research conducted by the University of Manitoba, which indicated the potential of this crop for Manitoba (McEwen *et al* 1974). It appears to offer clear agronomic advantages when compared to wheat and barley. The crop has been promoted as an excellent source of protein, and has a good amino acids balance. Durksen (1974) explained the positive advantages of growing fababean in Canada and its tremendous domestic and international market potential. Kaldi

(1978) reported that about 225 tonnes of fababean were sold to Japan for human consumption in 1976 and about 800 tonnes were contracted for the same market.

The classical division of the species *Vicia faba* is into the three subspecies: *V. faba major; V. faba equina* and *V. faba minor*, based mainly on seed size. All three subspecies are used for animal and human consumption. Traditionally, the ssp *major* has been used in Europe, while in some regions of Africa and Asia the ssp *equina* and *minor* are used (Bond 1969). The ssp *minor* is preferred in Canada because seed can be manipulated with conventional cereal equipment and seed costs are lower than for larger-seeded types (Crafts 1979).

Because of the cultivation of fababeans since ancient times and its wide range of adaptability in large number of countries, many common names can be found in the literature (Presber 1972). In addition to minor antinutritional factors, a hemolytic disease called favism is associated with fababean consumption. However, in many places where this bean is consumed, no cases of favism were reported. Mager *et al* (1969) concluded that the unidentified toxic constituents in fababean probably differ among the many international varieties. Also, the variations in preparation and eating habits are possibly as important as the genetic makeup of people susceptible to the disease (Liener 1978). The inhibitors found in fababeans are relatively insignificant when compared with the overall nutritional value of fababean protein. Thus, in wheat-fababean composite flours, the amino acid composition of this legume tends to complement that of wheat in certain amino acids. The most notable result is the improvement in lysine content, which is deficient in wheat flour. On the other hand, fababeans are low in sulfur-containing amino acids and small quantity of these amino acids can be supplied by wheat in wheat-fababean composite flours (McConnell *et al* 1974, Lorenz *et al* 1979). According to McDonald (1974), when fababeans are supplemented with methionine, protein equivalent to casein in nutritional quality is obtained.

B. Proximate Analyses

The composition of hard and soft wheats and their flours has been reported by many investigators. Also, several reports on the composition of fababeans can be found in the literature including Cerning *et al* (1975), Sarwar *et al* (1975), Vose *et al* (1976), Cerning and Filiatre (1976), Naivikul and D'Appolonia (1978), Naivikul and D'Appolonia (1979a,b), and Lorenz *et al* (1979). However, some variability in the results for each species is evident because the chemical composition is affected by variety, growing conditions, storage and milling. Furthermore, variability can result when some values are reported on a whole bean basis, while others are reported on a de-hulled bean basis.

The results obtained by Patel and Johnson (1974) (Table 1) represent closely those obtained by other workers. In general, the amount of protein increases as the strength of the wheat increases; being higher in strong varieties; intermediate in medium varieties; and lower in weak wheats. The study showed that compared to wheat flours, fababean flour contains higher amounts of protein, ash, crude fat and crude fiber.

TABLE 1. Proximate analysis of wheat flour and fababean flour (14% m.b.)[1]

Ingredient	Moisture %	Protein[2] %	Ash %	Crude fat %	Crude fiber %
Wheat flour					
Strong	11.5	13.3	0.41	0.97	0.29
Medium	11.7	11.2	0.48	0.92	0.31
Weak	12.3	8.9	0.49	0.65	0.41
Fababean flour	10.1	27.1	3.30	2.26	1.44

[1] Patel and Johnson (1974).

[2] N x 5.7.

C. Rheological Studies

Rheology is the branch of physics dealing with forces and deformations, their relationships and their interrelationships with time. Wheat flour dough, especially bread dough, has probably received more attention from researchers all over the world than any other food material studied (Charm 1962). It is generally accepted that the rheological properties of dough are very important for the baking performance of a product and its final quality.

About 85% of the proteins in wheat flour consist of the gluten components, gliadin and glutenin. These fractions differ markedly in their physical properties. Gliadin is extensible and inelastic whereas glutenin is elastic but relatively inextensible. The gluten of a good breadmaking flour contains gliadin and glutenin in approximately equal proportions.

Gluten does not exist in wheat flour but is formed when the protein fractions, gliadin and glutenin become hydrated on the addition of water (Wheat Flour Institute 1971). Mechanical handling or mixing is necessary to develop the gluten, and forms a matrix in which the other dough components are embedded. This matrix is responsible for the gas retaining ability of the dough. As a result of the changes taking place during dough development, the product exhibits both elasticity and extensibility properties which are highly desirable in breadmaking. (Rasper 1976).

Flour strength refers to wheat or flour protein and encompasses both its quality and quantity. On the basis of flour strength, wheats can be classified into two major groups, namely hard (strong) or soft (weak). Hard wheat flours have a relatively high protein content, high water absorption, and form an elastic gluten with good gas retaining properties. Soft wheat flours, on the other hand, have a lower protein content and yield a gluten which is less elastic. Such flours are generally better suited for other baked goods such as cakes, biscuits and crackers (Wheat Flour Institute 1971).

Pomeranz (1968), reported that the viscoelastic and gas-retention properties of dough during fermentation, resulting in a light soft-textured bread, are due to the gluten protein. Further, Kasarda *et al* (1978), pointed out that the rheological properties of a dough result from the integrated contribution of its many components. The gluten proteins are of fundamental importance in contributing elasticity and extensibility to the dough.

The rheological dough characteristics are possible to determine by using equipment such as the farinograph, the extensigraph, and the amylograph. De Ruiter (1978) stated that these apparatus are appropriated to characterize wheat flours. However their use and results with composite flours should be interpreted carefully.

Rheological research reported on fababeans used in composite flours is limited. One of the first reported study in wheat-fababean flour blends was that of McConnell *et al* (1974). They reported a gradual decrease in farinograph absorption with increased levels of fababean flour in the formulation. Patel and Johnson (1975), studied the rheological properties of fababean blended with three different types of wheats (strong, medium and weak). They found that increasing levels of fababean greatly reduced dough-mixing time and stability. However, fababean protein concentrates tended to increase the mixing stability and reduce the mixing time. The extensigraph results showed that increasing levels of fababean reduced the elasticity and caused the dough to have putty-like properties.

D'Appolonia (1977) investigated the rheological characteristics of flours obtained from various legumes blended with wheat flour. The legumes used, beside fababeans, were pinto beans, navy beans, mung beans and lentils. As the proportion of the legume flour in the composite increased, farinogram mixing time and stability decreased, which indicated an overall weakening of the dough. In addition, the farinograph absorption decreased, except with 5% and 10% fababean in wheat flour, where a slight increase was detected. These findings agree with the results reported by Patel and Johnson (1975) and Lorenz *et al* (1979).

D'Appolonia (1977) calculated the proportional numbers (also called ratio figures) from the extensigrams for the different legume-wheat flour blends. He reported a reduction in the proportional number when the percentage of legume flour in the blend increased. A notable result was the large proportional values for the 5 and 10% fababean-wheat flour blends at the 180-min rest period.

Recently, farinograph results by Lorenz *et al* (1979) showed that the arrival times and the mixing tolerance index increased, while dough stabilities decreased, as the percentage of fababean flour or fababean protein concentrated in the blend increased. These trends indicate that dough mixing becomes quite critical at higher wheat flour substitution levels.

D. Breadmaking Studies

It is well established that nonwheat flours can be blended with wheat flour to produce baked products of acceptable quality. It is also well-known that these types of flours, when used in composite flours for bread, affect the breadmaking and rheological properties of wheat flour. There is a maximum amount of any given nonwheat flour that can be added to wheat to obtain acceptable bread.

Great differences in baking characteristics existed among composite flours. They depended on: a) the quality of the wheat flour present, b) the proportion and type of nonwheat present, and c) the method in which the nonwheat component was processed (De Ruiter 1978).

In general, the addition of high starch or high protein flours to wheat flour almost invariably result in poorer baking performance. However, good quality bread can be made from composite flours. This has become quite feasible due to a number of recent developments in bakery technology, such as mechanical and chemical dough development and the use of new additives (De Ruiter 1978).

Where fababeans are a significant part of the diet, they are eaten fresh or are prepared in several different ways, including steeping, boiling, baking, roasting or frying. The bean is often included in soups or other hot dishes, but rarely in bread (Finney *et al* 1980).

Some work has been published on fababean flour, protein isolates and concentrates in yeast-leavened wheat breads (McConnell *et al* 1974), Patel and Johnson 1975, D'Appolonia 1977, Patel *et al* 1977, Lorenz *et al* 1979, Finney *et al* 1980). According to De Ruiter (1978), the acceptable proportions of composite flour are lower for high protein flours than for starchy flours. Wolf and Cowan (1971) reported that the United States, used 60 million lbs of soy products in the baking industry in 1970.

One of the earliest reported studies using wheat-fababean flour blends was the fortified bread procedure developed at the University of Manitoba, Plant Science Department, by McConnell *et al* (1974). They found that the addition of fababean flour to hard red spring wheat flour at the rate of 10, 20, 30 and 40% resulted in a progressive decrease in loaf volume and a deterioration in crumb grain. Improved loaf volume was obtained with fababean protein concentrates.

Patel and Johnson (1975) reported that protein isolates improved physical dough properties and bread quality characteristics. Bread was baked by the straight-dough baking method with fababean protein isolates, and 5, 10, 15 and 20% fababean flour in three different wheat flours. They dound that fababean flour at above 10% reduced mixing time, mixing tolerance and produced inferior quality bread. However, fababean protein concentrates with protein equivalent to 20% fababean flour, produced satisfactory dough properties and acceptable bread quality.

The different legumes used by D'Appolonia (1977), with the straight-dough baking method, showed the same decrease in loaf volume as the proportion of the legume flour in the composite increased. There was an improvement in crumb color with up to 10% legume flour added to wheat flour.

Patel *et al* (1977) pointed out that bread made from wheat flour containing fababean flour is sweeter, beanier, bitter, and less wheaty than bread made from wheat flour containing fababean protein isolate. Based on the effects of the two supplements on various breadmaking properties, as well as on the appearance and eating quality of the bread, it was concluded that bread from flours containing up to 20% protein isolate would be more acceptable than bread from the flour composite of equivalent protein content. Analogous results were obtained by Sosulski and Fleming (1979).

Recently, Lorenz *et al* (1979) studied the effects of adding fababean flour to wheat flour in the production of breads, cookies and pasta products. They found that baking absorption needed to be increased with increasing amounts of fababean in the formulation, which was contrary to the finding of McConnell *et al* (1974). They indicated that this discrepancy could be due to the baking method used. At higher wheat flour substitution levels, bread volume decreased, crust color became darker and the grain a little coarser. These changes also were detected by McConnell *et al* (1974) and by Patel and Johnson (1975).

In a recent study by Finney *et al* (1980), dough-making and breadmaking properties of wheat flour containing 5 to 20% germinated and ungerminated fababean flour were compared. They reported that increasing levels of ungerminated and germinated fababean flour decreased loaf volume and other bread quality characteristics such as crumb grain. In a similar study, Hsu *et al* (1980) found that germination was highly detrimental to both the functional and organoleptic properties of germinated pea or lentil breads.

This review shows that for technological reasons and for consumer acceptance, wheat still is an essential component in composite flours. Fababean flour and fababean protein concentrates have been shown to be suitable protein additives for breads replacing a limited percentage of the wheat flour in the formulations. Significant increases in nutritional value have resulted with only a small reduction in loaf volume and flavor.

III. MATERIALS

Three different wheat varieties were used in this study: Neepawa, Fredrick and Pitic 62. In addition, three varieties of fababean: Diana, Ackerperle and Herz freya, all of which are of the *Vicia faba* minor subspecie, were also used in this study.

Pitic 62, a soft red spring wheat, grown in Saskatchewan in 1978, was obtained from the Saskatchewan Wheat Pool. Fredrick, a soft white winter wheat grown in 1978 in Southern Ontario, was obtained from the King Grain and Seed Co. in Chatham, Ontario. The hard red spring wheat Neepawa grown in Manitoba in 1978 was obtained from the Manitoba Pool Elevators in Winnipeg. All three fababean varieties were grown on experimental plots at the University of Manitoba in 1978.

The blended flour samples were stored at room temperature in tightly closed metal sample tins. The unblended flours were stored at $4^{O}C$ during the study and were withdrawn as required.

IV. METHODS

A. Milling Procedures

The hard red spring wheat Neepawa was cleaned before milling in a Carter Dockage tester using a No. 1 sieve at the top and a No. 0.078 sieve at the bottom. After cleaning, the wheat was tempered overnight to 15.5% moisture and milled into flour in a Buhler experimental mill at the University of Manitoba. Flour extraction was about 70%.

The two weak wheats, Fredrick and Pitic 62 were milled in the Grain Research Laboratory (Pilot Mill) at the Canadian Grain Commission, Winnipeg. Milling yields for both wheats were about 75%.

Fababeans were milled according to the procedure described by Watson *et al* (1975), with minor modifications. The samples were passed initially through the first-break rolls of an Allis-Chalmers experimental mill. Passage through the first break primarily cracked the hull. The material was then passed through the second-break rolls of the same mill, thereby producing a meal-type product which was sieved through a 3/16" round hole sieve in order to isolate as much of the hull from the endosperm as possible. The meal was then milled on a Buhler Experimental Mill, following the same procedure as with the hard red spring wheat.

The moisture content of the fababeans was kept below 11% during milling in order to obtain a more efficient removal of the hulls from the cotyledons. This avoided the adhesion of the hulls to the cotyledons and increased the sifting efficiency (Watson *et al* 1975).

B. Preparation of Blends

Blends containing 5, 10, 20 and 30% of each fababean flour with each wheat flour (as is moisture basis) were prepared by using a Daffin blender. The samples were blended for 4 min at 5 r.p.m. Table 2 shows the identification of the wheat and wheat-fababean blends used. These composite flours were used for all analyses, which included the proximate analyses, physical dough tests and baking tests.

C. Analytical Methods

Proximate analyses were conducted in duplicate on the basic flours (wheats and fababeans) and their blends. These analyses were used to obtain information that might be useful in explaining the effects of the nonwheat component on dough characteristics and breadmaking properties.

1. Moisture Content

Moisture content on 10g flour samples were determined according to the approved method of the American Association of Cereal Chemists (AACC) [method 44-15A; AACC (1969)]. Flour samples were placed in a Brabender semi-automatic moisture tester at 130°C for 1 hr and weighed.

2. Ash Content

Ash content was determined by the standard method of the AACC [method 08-01; AACC (1969)]. For ash analyses, 5g flour samples were weighed out and ashed in a muffle furnace for 7 hr at 586°C.

3. Protein Content

Protein contents were determined by the standard Kjeldahl procedure according to [method 46-12; AACC (1969]. One g flour samples at 0% moisture were used.

TABLE 2. Identification of the wheat-fababean blends used

Wheat flour			Fababean flour			Identification Number
Neepawa (%)	Fredrick (%)	Pitic 62 (%)	Diana (%)	Ackerperle (%)	Herz freya (%)	
95			5			1
90			10			2
80			20			3
70			30			4
95				5		5
90				10		6
80				20		7
70				30		8
95					5	9
90					10	10
80					20	11
70					30	12
	95		5			13
	90		10			14
	80		20			15
	70		30			16
	95			5		17
	90			10		18
	80			20		19
	70			30		20
	95				5	21
	90				10	24
	80				20	23
	70				30	24
		95	5			25
		90	10			26
		80	20			27
		70	30			28
		95		5		29
		90		10		30
		80		20		31
		70		30		32
		95			5	33
		90			10	34
		80			20	35
		70			30	36

4. Amino Acid Analyses

Samples were hydrolyzed as described by Orth *et al* (1974). A Beckman 121 Analyzer was used to determine the amino acid composition. Cysteine, cystine and tryptophan were not determined.

5. Zeleny Sedimentation Value

The Zeleny Sedimentation test was determined on 3.2g flour samples according to [method 56-61A; AACC (1969)].

D. Rheological Measurements

1. Farinograph

Farinograph curves were obtained according to the Constant Flour Weight Procedure [method 54-21; AACC (1969)]. Fifty g of flour (14% moisture basis) was used with water added to produce curve with maximum consistency centered on the 500 B.U. line.

2. Extensigraph

Extensigraph curves were obtained with a Brabender extensigraph according to [method 54-10; AACC (1969)]. Doughs were made with 100g (14% moisture basis) of flour, 25 ml of 2% NaCl solution, and sufficient water to give an absorption of two percentage units less than the farinograph absorption. The dough was mixed for 2½ minutes in a Grain Research Laboratory (GRL) mixer at slow speed (69 r.p.m.). Extensigrams were obtained after 45, 90 and 135 min rest periods; the latter rest period was used for the evaluation.

3. Amylograph

Starch pasting curves were obtained with a Brabender Visco/amylo/graph according to [method 22-10; AACC (1969)]. Curves were obtained using 65 g of flour dispersed in 460 ml of tap water at 30°C. The temperature was increased at a rate of 1.5°C per minute to 95°C.

E. Baking Procedures

Baking properties of the composite flours were determined by three baking methods: a straight dough procedure, a modified straight-dough procedure and a modified sheeting roll method. The AACC straight-dough and the sheeting roll procedures (McConnell *et al* 1974) were modified to accommodate the nonwheat flour component used in this study. The optimum baking conditions for these modified methods were determined (see Appendix) and the baking formulas are presented in Table 3.

1. Straight-dough Method

The standard AACC straight-dough procedure [method 10-10; AACC (1969)] was used.

2. Modified Straight-dough Method

The modified straight-dough method was used to make pup loaves from 100 g (14% moisture basis) flour. The flour was mixed in a GRL mixer at 130 r.p.m. (Hlynka and Anderson 1955) using an open bowl. After the mixing, the dough was removed from the bowl, shaped into the form of a dough ball, put in a fermentation bowl and placed into a fermentation cabinet at 30°C and 90% relative humidity (rh) for two hr. The dough was given the first punch after a period of 55 min, by passing the dough through a sheeting roll set at 9/32 in., and then a second punch through the sheeting rolls after an additional 40 min. After an additional 25 min, the dough ball was removed, sheeted by passing the dough twice through the sheeting rolls, first at a setting of 9/32 in. and second at a setting of 3/16 in. The dough was then molded and placed into a bread pan and returned to the same fermentation cabinet for a final

TABLE 3. Breadmaking formulas[1]

Ingredients	Modified straight-dough method	Modified sheeting-roll method
Flour (14% mb)	100.0	100.0
Yeast, compressed	3.0	4.0
Salt	2.0	1.0
Sugar	5.0	2.5
Shortening	3.0	1.0
Barley malt syrup (250°L)	0.05	0.3
Ammonium phosphate (monobasic)	0.1	0.1
Potassium bromate	20 ppm	15 ppm
Ascorbic acid	--	75 ppm
Water	as required	as required

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[1] Based on % of flour weight.

proof period of 55 min.

3. Modified Sheeting Roll Method

The sheeting roll method as developed by Bushuk and Hulse (1974) and McConnell *et al* (1974) was used with some modifications. Flour (100 g, 14% mb) was mixed with all other ingredients in a GRL mixer at 69 r.p.m. The dough so formed was kneaded 20 and 10 times for Neepawa-fababean blends and for Fredrick and/or Pitic 62-fababean blends, respectively. Following kneading, the sample was placed in a fermentation bowl, covered with a damp cloth and allowed to rest for 30 min. The Neepawa-fababean doughs were sheeted 30 times at three different roller separations (10 times at 7/32 in., 10 times at 3/16 in. and 10 times at 5/32 in.), while Fredrick and Pitic 62-fababean doughs were sheeted only 7 times at the same roller separations. After 10 min of fermentation at 35°C and 80% (rh), the dough was sheeted again, once at 11/32 in., 3/16 in. and 1/8 in. separation respectively, molded, panned and proofed for 55 min.

With both baking procedures used in this study, the bread was baked at 210°C for 25 min. Volumes were determined by rapeseed displacement 30 min after the loaves were removed from the oven. The loaf volumes reported are the average volumes for two or three loaves, and the variation in duplicates was less than 50 cc. The external and internal characteristics were evaluated at this time.

V. RESULTS AND DISCUSSION

A. Proximate Analyses

Proximate analyses of the wheat and fababean flours used in this study are presented in Table 4. Results for wheat-fababean blends are reported in Tables 5, 6 and 7.

1. Moisture Content

There is a difference in moisture contents for the two starting materials, wheat flours and fababean flours (Table 4). Fababean flours had a lower moisture content than wheat flours. As a result, the moisture content of the blend decreased with increased amounts of fababean. These moisture contents are comparable to the results reported by Naivikul and D'Appolonia (1978).

2. Ash Content

Fababean flours had a higher ash content (2.59-3.08%) than wheat flours (0.38-0.54%) (Table 4). In relationship to the composition of the fababean seed, the high ash content indicates that most of the mineral components are found in the cotyledons. The ash content of the blends increased as the amount of fababean increased (Tables 5, 6 and 7).

The results obtained for ash content are slightly lower than those of comparable products reported by Lorenz *et al* (1979), and McConnell *et al* (1974), probably due to the additional sieving step followed in the milling procedure. Lorenz *et al* (1979) found that the high ash content of the fababean produce some grittiness in baked products at certain levels of wheat flour substitutions. As a result, the high ash content could limit the amount of the fababean product that can be used

TABLE 4. Analytical data of three wheat and three fababean flours

Sample	Moisture (%)	Ash content[1] (%)	Protein content[1,2] (%)	Sedimentation value (ml)
Wheat flour				
Neepawa	14.5	0.39	14.4	53.0
Fredrick	12.8	0.44	9.2	28.0
Pitic 62	12.4	0.54	8.3	16.0
Fababean flour				
Diana	10.6	2.59	26.3	-
Ackerperle	10.9	3.08	27.8	-
Herz freya	10.5	2.88	25.8	-

[1] On a 14% moisture basis.

[2] N x 5.7.

TABLE 5. Proximate analyses of Neepawa and Neepawa-fababean composite flours

Flour		Moisture (%)	Ash content[1] (%)	Protein content[1,2] (%)	Sedimentation value (ml)
Neepawa (control)		14.5	0.39	14.4	53.0
Composite flour					
Neepawa (%)	Diana (%)				
95	5	14.2	0.50	14.9	51.0
90	10	14.2	0.61	15.6	41.5
80	20	13.9	0.82	16.9	34.5
70	30	13.5	1.09	18.0	30.0
Neepawa (%)	Ackerperle (%)				
95	5	14.3	0.51	15.1	46.0
90	10	14.0	0.68	15.8	41.5
80	20	13.8	0.94	17.0	35.0
70	30	13.5	1.29	18.5	31.0
Neepawa (%)	Herz freya (%)				
95	5	14.3	0.53	15.0	50.0
90	10	14.0	0.65	15.5	42.0
80	20	13.7	0.92	16.7	34.5
70	30	13.2	1.22	18.0	30.0

[1] On a 14% moisture basis.

[2] N x 5.7.

TABLE 6. Proximate analyses of Fredrick and Fredrick-fababean composite flours

Flour		Moisture (%)	Ash content[1] (%)	Protein content[1,2] (%)	Sedimentation value (ml)
Fredrick (control)		12.8	0.44	9.2	28.0
Composite flour					
Fredrick (%)	Diana (%)				
95	5	12.6	0.56	10.1	23.5
90	10	12.7	0.62	11.0	23.0
80	20	12.5	0.84	12.8	21.0
70	30	12.4	1.10	14.5	20.0
Fredrick (%)	Ackerperle (%)				
95	5	12.7	0.56	10.2	25.0
90	10	12.7	0.70	11.1	24.5
80	20	12.4	1.00	13.0	22.5
70	30	12.3	1.23	14.9	22.5
Fredrick (%)	Herz freya (%)				
95	5	12.7	0.58	10.0	23.5
90	10	12.6	0.69	10.9	22.5
80	20	12.4	0.90	12.5	22.0
70	30	12.1	1.12	14.2	21.5

[1] On a 14% moisture bais.

[2] N x 5.7.

TABLE 7. Proximate analyses of Pitic 62 and Pitic 62-fababean composite flours

Flour		Moisture (%)	Ash content[1] (%)	Protein content[1,2] (%)	Sedimentation value (ml)
Pitic 62 (control)		12.4	0.54	8.3	16.0
Composite flour					
Pitic 62 (%)	Diana (%)				
95	5	12.2	0.61	9.3	13.5
90	10	12.2	0.69	10.2	13.0
80	20	12.1	0.89	12.0	14.0
70	30	11.8	1.05	13.8	14.5
Pitic 62 (%)	Ackerperle (%)				
95	5	12.3	0.67	9.4	16.0
90	10	12.2	0.86	10.3	15.0
80	20	12.2	1.12	12.3	14.5
70	30	12.1	1.38	14.2	14.5
Pitic 62 (%)	Herz freya (%)				
95	5	12.3	0.64	9.1	13.5
90	10	12.2	0.78	10.0	13.0
80	20	12.1	1.02	11.7	14.0
70	30	11.8	1.22	13.4	14.0

[1] On a 14% moisture basis.

[2] N x 5.7.

as a wheat flour replacement. In addition, the ash content cannot be used as an indicator of milling efficiency of legumes as with wheat (Watson *et al* 1975).

3. Protein Content

The protein contents for the wheat and fababean flours are presented in Table 4. Protein content of Neepawa (14.4%) is a typical value for a strong-quality wheat flour from a Canadian hard red spring wheat. Protein contents of Fredrick (9.2%) and Pitic 62 (8.3%) are also typical values for these types of weak wheats. These protein values are similar to those reported by Patel and Johnson (1974). The fababean flours were considerably higher in protein content than the wheat flours. Furthermore, the variety Ackerperle had the highest protein content (27.8%), while Herz freya had the lowest value (25.8%). As expected, protein content increased with increasing proportions of fababean flour in the composite (Tables 5, 6 and 7).

4. Zeleny Sedimentation Value

The Zeleny Sedimentation Test is used in North America and Europe as a measure of breadmaking quality in wheat breeding programs and in the assessment of commercial samples of wheat. The value of this test for predicting the breadmaking quality of wheat flour can be demonstrated by the relationship obtained between the sedimentation value and loaf volume. It is known that for wheat, the sedimentation value is directly proportional to the protein content. The sedimentation value presented in Table 4 (Neepawa 53 ml, Fredrick 28 ml, and 16 ml for Pitic 62) was proportional to the protein content and the strength of the flours.

As expected, wheat flours had higher values than their blends with fababean. The sedimentation value decreased as the proportion of fababean flour to wheat flour increased (Table 5 and 6). However, with Pitic 62 (Table 7) this behaviour is not as apparent. At higher levels of fababean blends, the sedimentation values show a slight increase, which may be explained due to the low initial sedimentation value in pure wheat flour of Pitic 62. This effect was obtained with all three fababean varieties used in this study. Further experimentation is required to substantiate this unusual response.

In general, the results indicated that fababean proteins did not react in the same manner as wheat protein in this test. The lower sedimentation value was due to a decrease in amount of wheat flour. The relationship between proportion of fababean flour in the blend and sedimentation value, however, was nonlinear indicating that there is an interaction between the two base flours in so far as their effect on the sedimentation value is concerned. The nature of this interaction was not investigated.

5. Amino Acid Composition

Base materials and all composites were analyzed for amino acid composition. Tables 8 and 9 present the results obtained for wheat flours and fababean flours, respectively. These results are consistent with those of Kasarda *et al* (1978) and McEwen (1974).

Despite large differences in protein content among the wheat flours studied, some variations in amino acid composition were observed. Previous studies have shown that glutamic acid and proline increased proportionately (Miller *et al* 1950) while arginine and lysine decreased (Gunthar and McGinnis 1957) with increasing protein content of whole

TABLE 8. Amino acid compositions of wheat flours (g amino acid/ 100 g protein)

	Neepawa	Fredrick	Pitic 62
Lysine	1.98	2.24	2.68
Histidine	2.14	2.09	2.21
Ammonia	4.27	3.54	4.03
Arginine	3.72	3.76	4.17
Aspartic acid	4.04	4.51	5.38
Threonine	2.81	2.90	3.06
Serine	4.88	4.78	5.08
Glutamic acid	40.50	38.24	37.49
Proline	12.75	12.72	11.96
Glycine	3.41	3.76	3.90
Alanine	2.89	3.19	3.40
Valine	4.14	4.32	4.12
Methionine	1.49	1.72	1.80
Isoleucine	3.76	3.82	3.82
Leucine	7.33	7.79	7.61
Tyrosine	2.96	3.21	2.91
Phenylalanine	5.45	5.22	4.90
% N recovery	91.71	88.76	92.26

TABLE 9. Amino acid compositions of fababean flours (g amino acid/ 100 g protein)

	Ackerperle	Diana	Herz freya
Lysine	6.36	6.48	6.13
Histidine	2.58	2.54	2.42
Ammonia	1.80	1.78	1.68
Arginine	10.48	9.94	9.25
Aspartic acid	12.69	11.62	12.38
Threonine	3.70	3.70	3.85
Serine	4.90	4.70	5.21
Glutamic acid	18.77	18.31	19.02
Proline	4.74	4.64	4.52
Glycine	4.48	4.34	4.56
Alanine	4.44	4.23	4.49
Valine	5.03	4.85	4.91
Methionine	0.73	0.74	0.73
Isoleucine	4.38	4.30	4.37
Leucine	8.37	8.10	8.30
Tyrosine	3.34	3.17	3.46
Phenylalanine	4.60	4.42	4.65
% N recovery	89.97	86.94	86.76

wheat. The results indicated that glutamic acid was one of the principal amino acids affected by protein content.

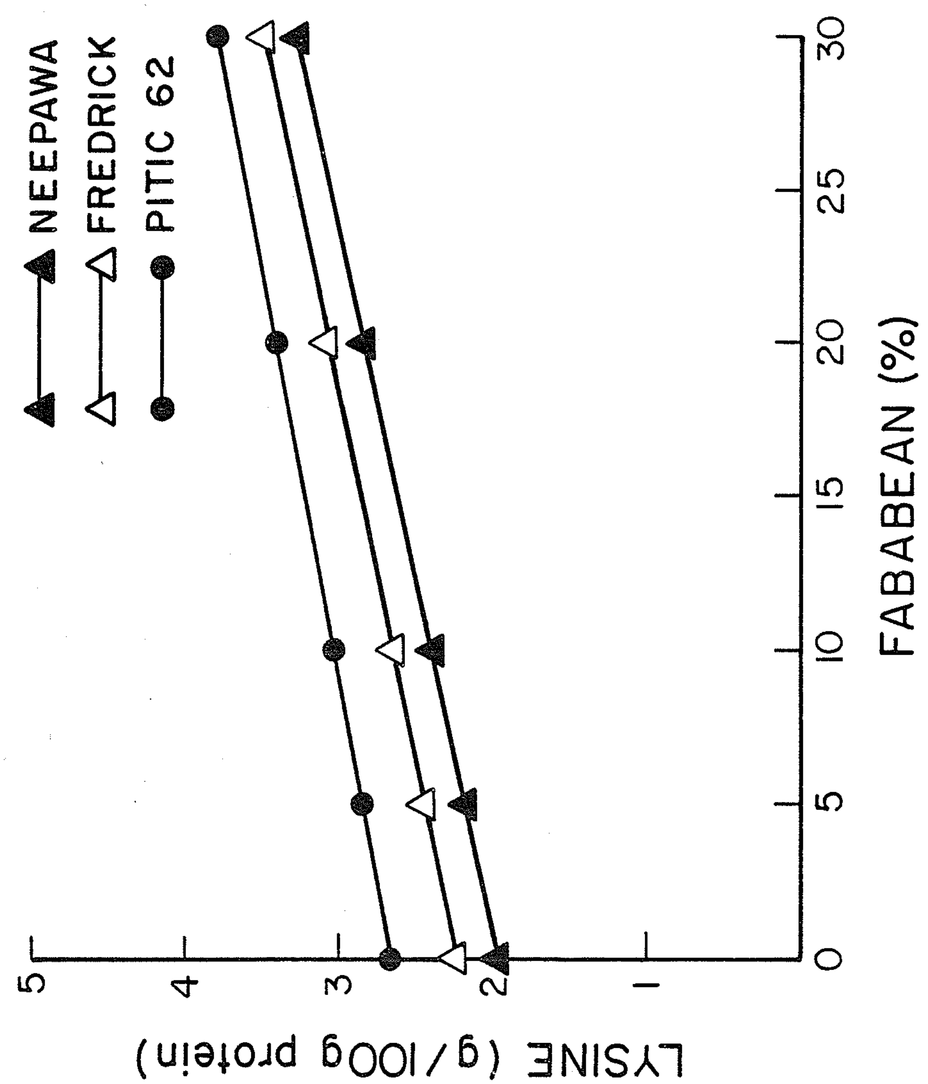
On the basis of the analyses in Table 9, the data indicate that there is virtually no difference in the amino acid composition among the three varieties of fababeans. The slightly higher values for almost all the amino acids for the Ackerperle sample reported by McEwen (1974), as compared to the other fababean varieties are believed to be a result of a higher percent nitrogen recovery obtained.

Several differences are evident in the amino acid composition of wheat flours and fababean flours (compare data of Tables 8 and 9). In contrast to wheat, fababeans are richer in lysine, arginine and aspartic acid, but contain substantially less glutamic acid, proline and methionine.

As was reported in the literature review of this thesis, fababeans are best considered as a supplement to other protein sources especially those from cereals. This complementation improves the biological utilization of the wheat protein because of the higher overall lysine content. Furthermore, cysteine and methionine, which are deficient in legume flours, are provided by the wheat flour.

The relationship of the lysine contents of wheat flour to increasing levels of fababean supplement, on the basis of calculated percentages found in the two initial materials, wheat and fababean flours are plotted in Figure 1. According to this data, Neepawa flour, which gave the lowest value in lysine content (1.98g/100g protein), blended with 20% fababean flour, could have a lysine content higher (2.85g/100g protein) than the highest value obtained with Pitic 62 (2.68g/100g protein). Furthermore, as was

Figure 1. Relation of lysine contents of wheat flours to increase levels of fababean (var. Diana) flour.


LYSINE (g/100g protein)
5
4
3
2
1
0
5
10
15
20
25
30
FABABEAN (%)
NEEPAWA
FREDRICK
PITIC 62

found in baking analyses, subsequently included in this thesis, 20% of fababean content presented quite acceptable bread characteristics blended with Neepawa (strong flour). Similarly, other amino acids such as arginine and aspartic acid, present in large amounts in fababean flour, increase with the percentage of fababean flour.

B. Rheological Characteristics

1. Farinograph

Farinograph curves of wheat flours and their blends with fababean flours were run to determine changes in water absorption, arrival time, development time, stability and mixing tolerance index, due to replacement of the wheat flour with 5, 10, 20 and 30% of the fababean flour. The farinograph data of the controls and their blends are presented in Tables 10, 11 and 12. The farinograms, which accurately reflect the mixing requirements and other important physical dough properties of the wheat-fababean flour blends are shown in Figures 2, 3 and 4 for Neepawa, Fredrick and Pitic 62 and their blends, respectively.

Initial studies in regard to farinogram properties of wheat flours showed a varied response (Tables 10, 11 and 12). The farinogram properties, water absorption, development time and stability, were higher for Neepawa, a strong wheat variety than those for Fredrick and Pitic 62, weak wheat varieties. Furthermore, the mixing tolerance index for Neepawa was lower (meaning a better dough stability) compared to the results obtained for the other wheat varieties.

A similar pattern was detected between Fredrick and Pitic 62 in regards to farinogram properties. Pitic 62 had slightly higher values

TABLE 10. Farinograph data of Neepawa and Neepawa-fababean composite flours

Flour		Absorption %	Arrival time min	Development time min	Departure time min	Stability min	Tolerance index B.U.
Neepawa (control)		62.8	3.00	4.75	10.0	7.00	40
Composite flour							
Neepawa (%)	Diana (%)						
95	5	62.3	3.00	4.50	13.75	10.75	20
90	10	61.8	2.50	4.25	15.00	12.50	18
80	20	62.2	2.75	4.00	7.00	4.25	50
70	30	60.2	3.00	4.25	6.25	3.25	70
Neepawa (%)	Ackerperle (%)						
95	5	62.2	2.75	4.50	13.25	10.50	20
90	10	61.8	2.75	4.00	13.25	10.50	30
80	20	61.5	3.00	4.00	6.75	3.75	55
70	30	58.6	3.50	4.75	7.00	3.50	90
Neepawa (%)	Herz freya (%)						
95	5	62.6	2.50	4.00	12.50	10.00	20
90	10	62.0	2.75	4.00	12.50	9.75	25
80	20	61.2	2.50	3.50	5.25	2.75	65
70	30	58.5	3.25	4.00	5.75	2.50	70

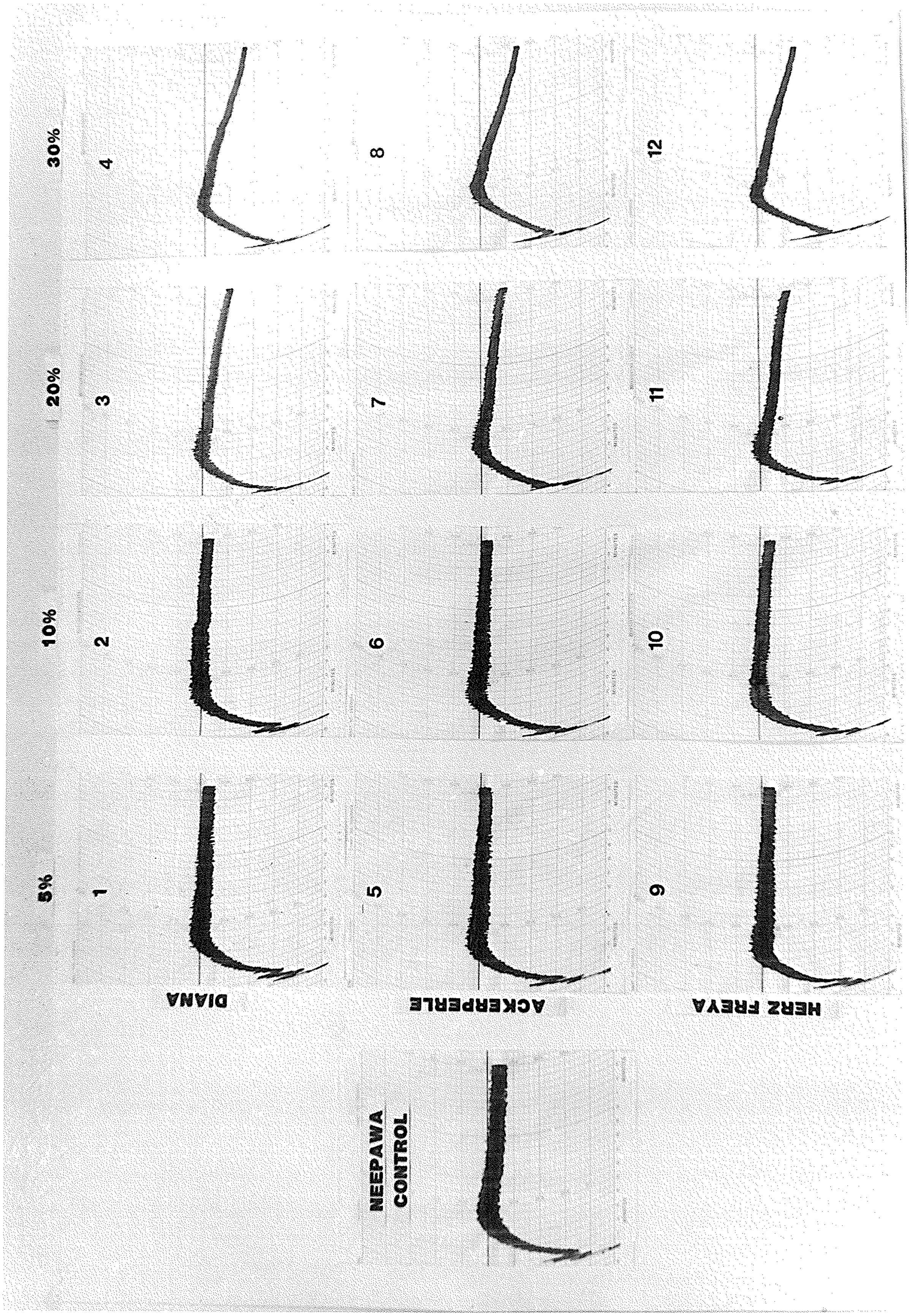
TABLE 11. Farinograph data of Fredrick and Fredrick-fababean composite flours

Flour		Absorption %	Arrival time min	Development time min	Departure time min	Stability min	Tolerance index B.U.
Fredrick (control)		50.6	0.50	1.50	3.25	2.75	110
Composite flour							
Fredrick (%)	Diana (%)						
95	5	51.0	0.75	1.50	4.00	3.25	110
90	10	51.9	1.00	2.50	4.25	3.25	110
80	20	51.3	1.25	3.00	4.25	3.00	130
70	30	50.5	2.50	3.50	4.50	2.00	135
Fredrick (%)	Ackerperle (%)						
95	5	51.2	0.75	2.25	4.25	3.50	100
90	10	51.8	1.00	2.50	4.50	3.50	105
80	20	50.5	1.75	3.25	4.75	3.00	100
70	30	49.6	3.00	4.00	5.00	2.00	125
Fredrick (%)	Herz freya (%)						
95	5	51.4	0.75	1.75	3.75	3.00	120
90	10	51.7	1.00	2.25	3.75	2.75	120
80	20	50.5	1.50	2.75	3.75	2.25	130
70	30	49.3	2.50	3.50	4.50	2.00	140

TABLE 12. Farinograph data of Pitic 62 and Pitic 62-fababean composite flours

Flour		Absorption %	Arrival time min	Development time min	Departure time min	Stability min	Tolerance index B.U.
Pitic 62 (control)		54.0	1.25	2.00	4.75	3.50	110
Composite flour							
Pitic 62 (%)	Diana (%)						
95	5	54.4	1.25	2.25	4.00	2.75	80
90	10	54.4	1.50	2.50	4.00	2.50	90
80	20	53.1	1.50	2.75	4.00	2.50	125
70	30	51.8	2.00	3.00	4.00	2.00	140
Pitic 62 (%)	Ackerperle (%)						
95	5	55.5	1.25	2.50	4.75	3.50	80
90	10	54.2	1.00	2.50	4.50	3.50	95
80	20	52.4	1.75	3.00	4.25	2.50	120
70	30	51.4	2.50	3.25	4.25	1.75	150
Pitic 62 (%)	Herz freya (%)						
95	5	54.5	1.25	2.50	4.25	3.00	90
90	10	54.5	1.25	2.50	3.75	2.50	95
80	20	52.3	1.50	2.50	4.00	2.50	130
70	30	51.0	2.00	3.00	4.00	2.00	145

Figure 2. Farinograms of Neepawa and Neepawa-fababean composite flours.


5%
10%
20%
30%
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2
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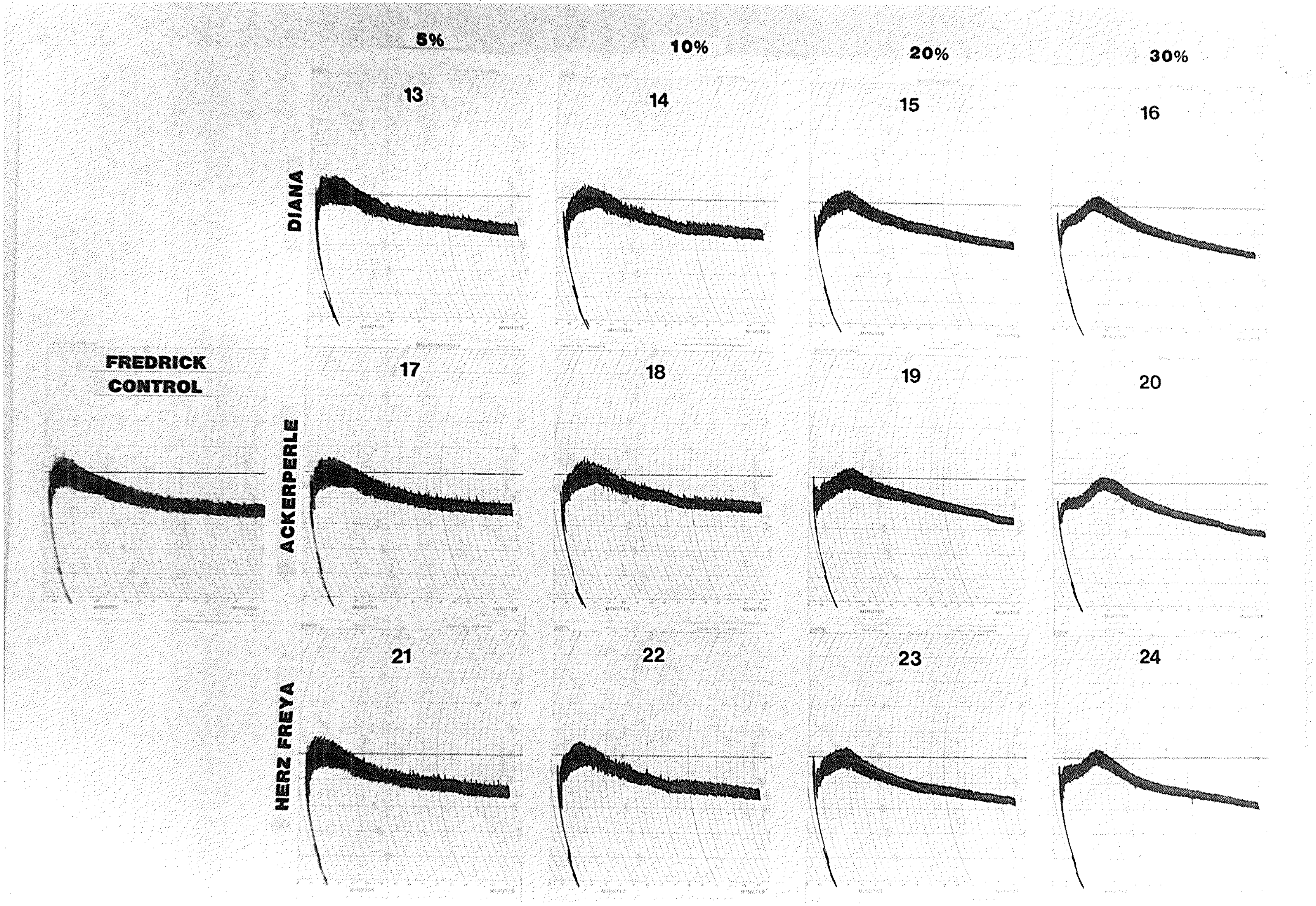
4
5
6
7
8
9
10
11
12
DIANA
ACKERPERLE
HERZ FREYA
NEEPAWA CONTROL
MINUTES

Figure 3. Farinograms of Fredrick and Fredrick-fababean composite flours.


5%
10%
20%
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13
14
15
16
DIANA
FREDRICK
CONTROL
17
18
19
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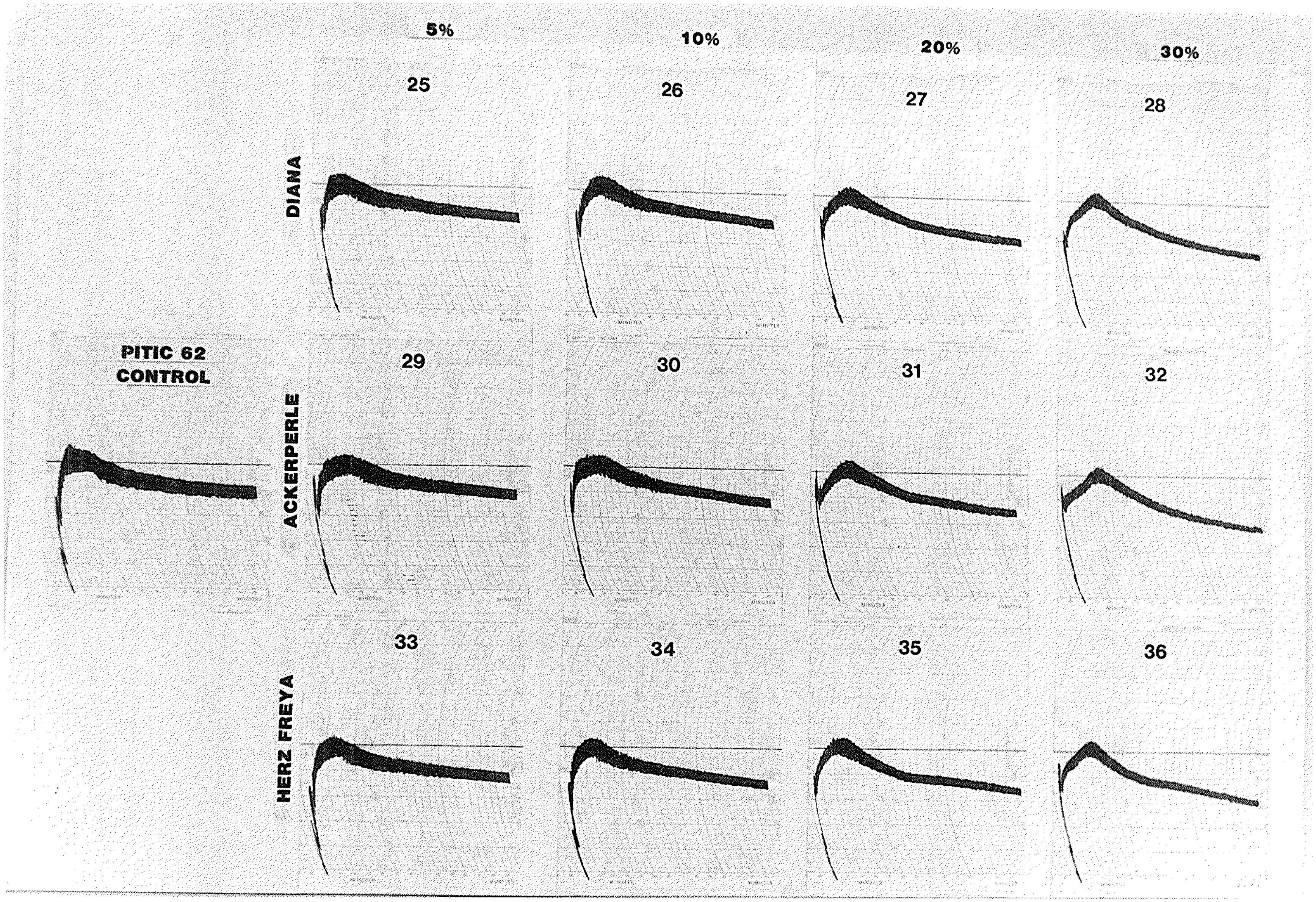
ACKERPERLE
21
22
23
24
HERZ FREYA
MINUTES

Figure 4. Farinograms of Pitic 62 and Pitic 62-fababean composite flours.


5%
10%
20%
30%
25
26
27
28
DIANA
PITIC 62
CONTROL
29
30
31
32
ACKERPERLE
33
34
35
36
HERZ FREYA

in all the farinogram measurements. However, this wheat variety presented poorer results in baking tests than Fredrick. This confirms that in a variety not only the protein content is important in order to obtain optimum results in the finished loaf of bread, but protein quality is also important.

For Neepawa and its blends (Table 10 and Fig. 2), farinograph absorption decreased as the amount of fababean flour in the blend increased. This trend agrees with the findings of McConnell *et al* (1974). Arrival times were lower or equal compared to the control up to 20% wheat flour substitution by all three fababean varieties. Arrival time showed a tendency to increase at levels higher than 20% fababean level. With regards to farinograph stability times, 5 and 10% fababean flour gave higher values than the control. However, mixing tolerance index was lower at the same wheat flour substitutions compared to the control (as a consequence of the increase in dough stability at the same levels). These results showed a clear tendency for the mixing tolerance index to increase as the amount of nonwheat flour increased.

The farinograph data indicates that dough mixing becomes critical at higher % of fababean flour. Furthermore, a pronounced weakening of dough was noted with incorporation of 20 and 30% fababean flours. Dough development time of the Neepawa-fababean blends was less than that of the control flour; however, no extreme differences were noted in developing time for all of them.

A different farinograph behaviour was detected with the weak wheats, Fredrick and Pitic 62, and their blends with fababean (Tables

11 and 12, and Figs. 3 and 4). Farinograph absorption increased as the amount of nonwheat flour increased in the Fredrick-fababean blends up to a level of 10% after which the absorption decreased again. On the other hand, farinograph absorption for Pitic 62-fababean blends remained stable up to the same level. These results compare well with the findings by Patel and Johnson (1975) and mixograph results reported by Morad *et al* (1980). The increase in water absorption may be attributed to the combined effect between the low protein content of these weak wheats with the initial levels of fababean flour, as well as the role of the starch in both types of flours. Arrival time, development time and mixing tolerance index increased markedly, while dough stability decreased as the percentage of fababean flour in the blend increased. Similar results were obtained by Lorenz *et al* (1979), D'Appolonia (1977) and Patel and Johnson (1975).

In relation to fababean flours, a similar behaviour in farinograph properties was detected in all of them; nevertheless, slightly higher results were observed with the variety Ackerperle blended with both weak wheats.

2. Extensigraph

Extensigraph curves of wheat flours and their blends with fababean flours were run to determine changes in energy, elasticity, extensibility and ratio figure values due to replacement of the wheat flour with the different percentages of fababean flour. The data obtained from the extensigrams for the different wheat-fababean blends are presented in Tables 13, 14 and 15, and Figures 5, 6 and 7. The extensigram results were reported for 135 min rest period.

TABLE 13. Extensigraph data of Neepawa and Neepawa-fababean composite flours[1]

Flour		Energy (area) cm^2	Elasticity E.U.	Extensibility m.m.	Ratio figure
Neepawa (control)		176	240	301	0.80
Composite flour					
Neepawa (%)	Diana (%)				
95	5	157	280	253	1.11
90	10	132	240	258	0.93
80	20	87	170	274	0.62
70	30	57	135	265	0.51
Neepawa (%)	Ackerperle (%)				
95	5	164	280	270	1.04
90	10	146	260	269	0.97
80	20	97	180	256	0.70
70	30	76	170	252	0.67
Neepawa (%)	Herz freya (%)				
95	5	150	255	271	0.94
90	10	122	220	254	0.87
80	20	62	130	268	0.49
70	30	36	100	225	0.44

---

[1] Measured at 135 min.

TABLE 14. Extensigraph data of Fredrick and Fredrick-fababean composite flours[1]

Flour		Energy (area) cm^2	Elasticity E.U.	Extensibility m.m.	Ratio figure
Fredrick (control)		115	270	240	1.13
Composite flour					
Fredrick (%)	Diana (%)				
95	5	101	260	216	1.20
90	10	78	245	196	1.25
80	20	61	210	210	1.00
70	30	48	185	198	0.93
Fredrick (%)	Ackerperle (%)				
95	5	103	280	217	1.29
90	10	88	245	195	1.26
80	20	63	230	186	1.24
70	30	54	210	191	1.10
Fredrick (%)	Herz freya (%)				
95	5	90	280	192	1.46
90	10	74	220	228	0.96
80	20	55	205	227	0.90
70	30	47	200	205	0.98

---

[1] Measured at 135 min.

TABLE 15. Extensigraph data of Pitic 62 and Pitic 62-fababean composite flours[1]

Flour		Energy (area) cm^2	Elasticity E.U.	Extensibility m.m.	Ratio figure
Pitic 62 (control)		71	240	198	1.21
Composite flour					
Pitic 62 (%)	Diana (%)				
95	5	64	235	181	1.30
90	10	53	215	176	1.22
80	20	49	205	172	1.19
70	30	39	210	164	1.28
Pitic 62 (%)	Ackerperle (%)				
95	5	66	250	177	1.41
90	10	56	230	167	1.38
80	20	46	220	155	1.42
70	30	40	180	157	1.15
Pitic 62 (%)	Herz freya (%)				
95	5	64	245	188	1.30
90	10	50	200	189	1.06
80	20	41	210	166	1.27
70	30	35	210	140	1.50

---

[1] Measured at 135 min.

Figure 5. Extensigrams of Neepawa and Neepawa-fababean composite flours.

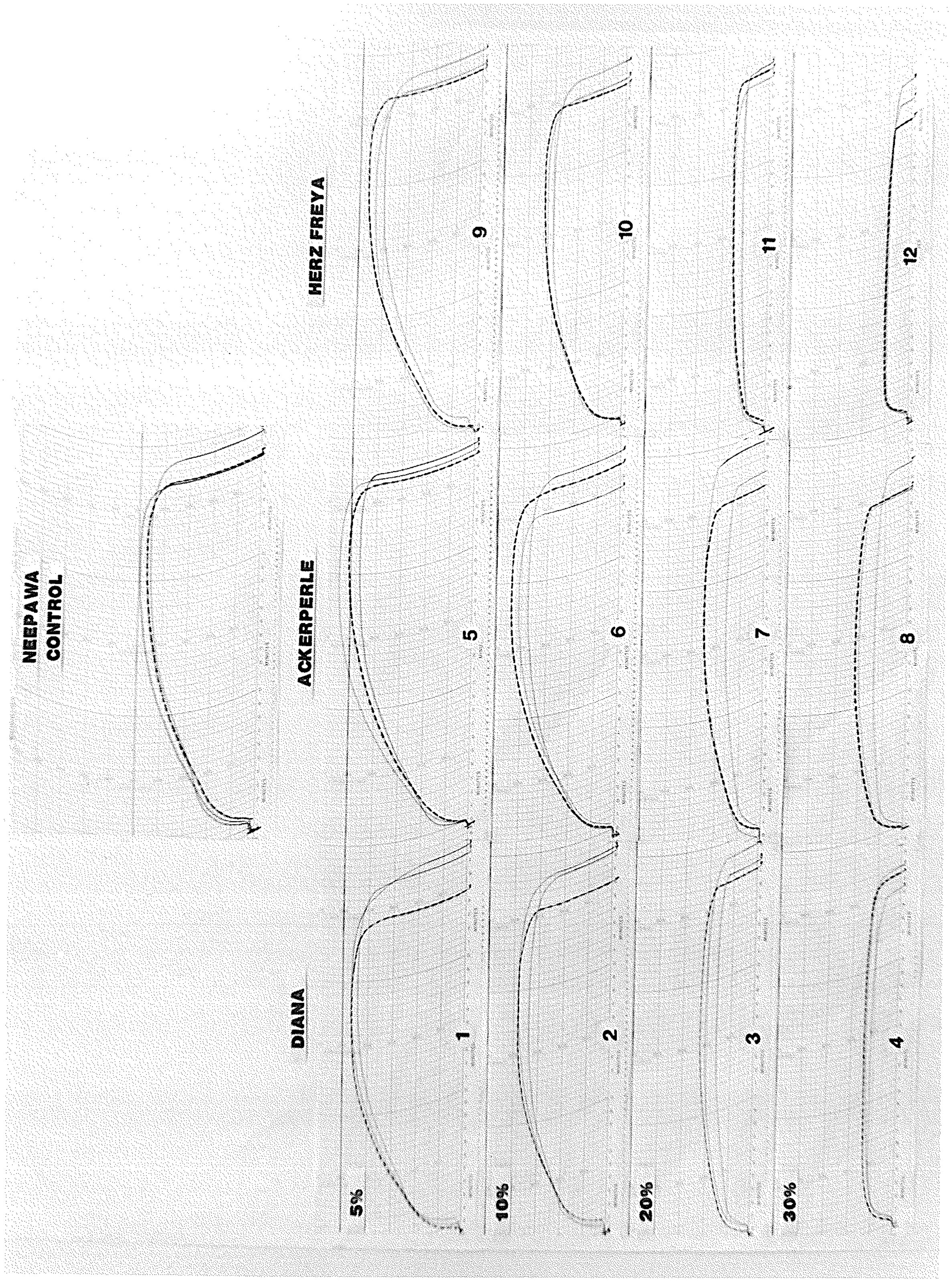

NEEPAWA CONTROL
DIANA
ACKERPERLE
HERZ FREYA
5%
10%
20%
30%
1
2
3
4
5
6
7
8
9
10
11
12
MINUTES

Figure 6. Extensigrams of Fredrick and Fredrick-fababean composite flours.

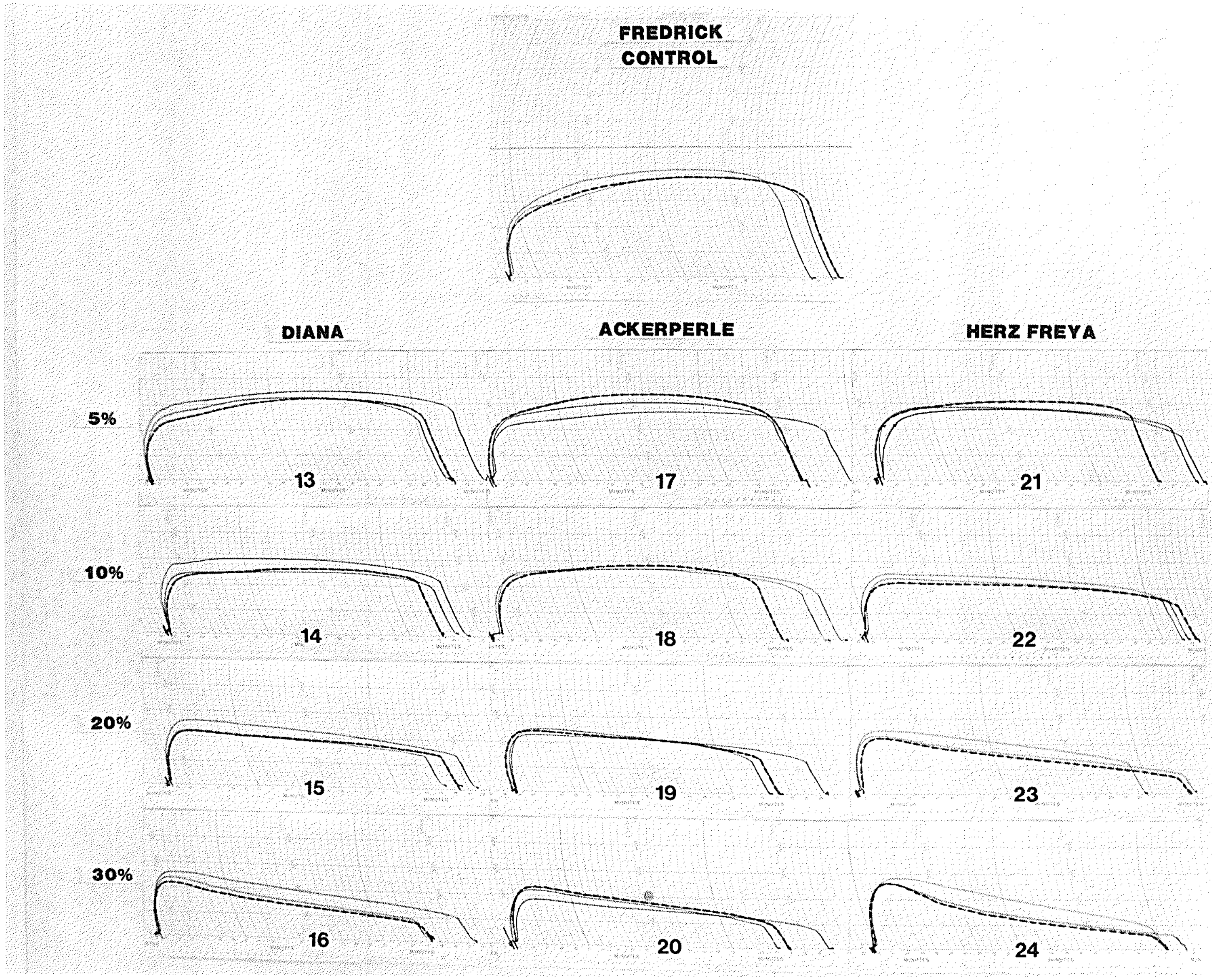
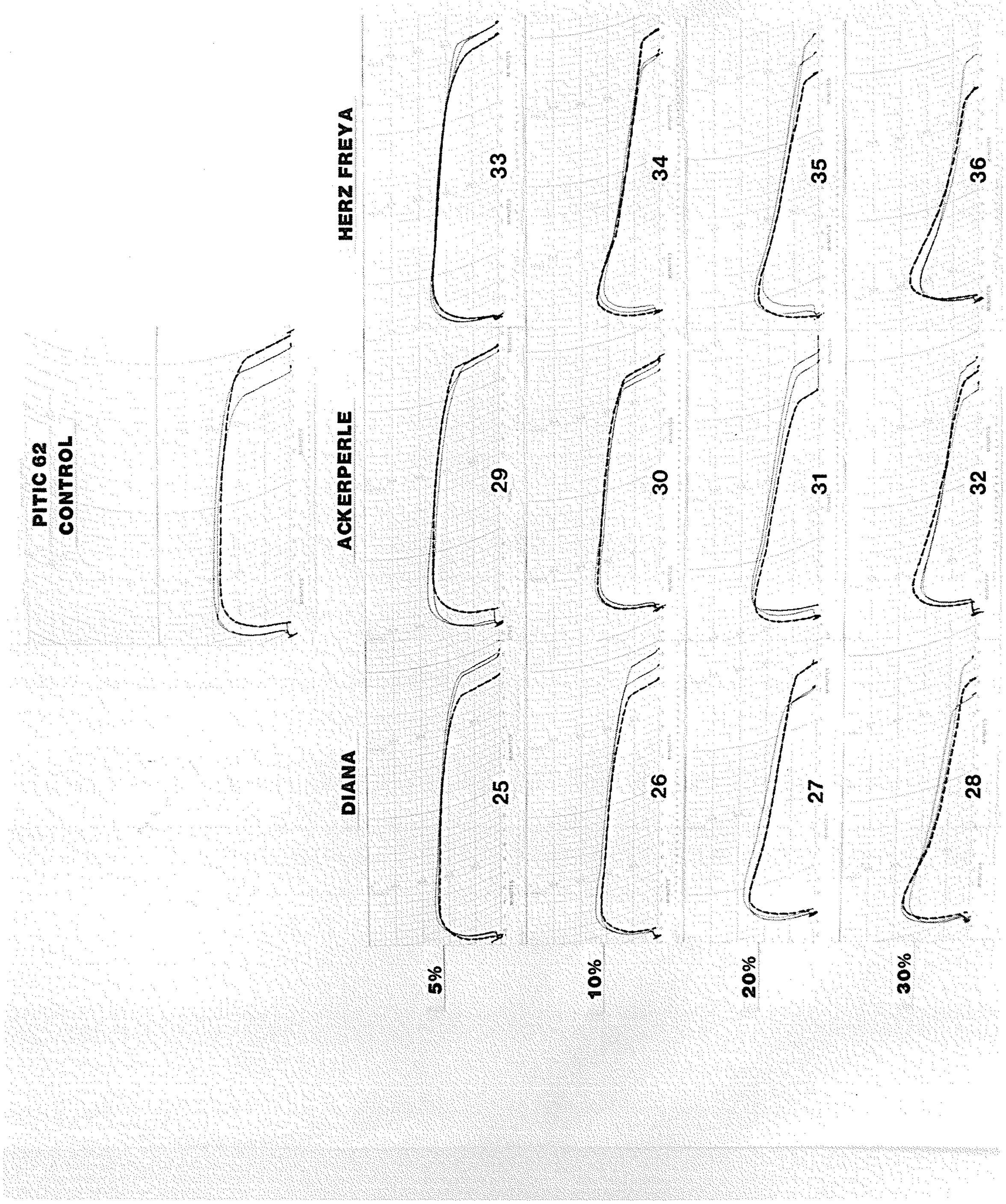

FREDRICK
CONTROL
DIANA
ACKERPERLE
HERZ FREYA
5%
10%
20%
30%
13
17
21
14
18
22
15
19
23
16
20
24

Figure 7. Extensigrams of Pitic 62 and Pitic 62-fababean composite flours.


PITIC 62
CONTROL
DIANA
ACKERPERLE
HERZ FREYA
5%
25
29
33
10%
26
30
34
20%
27
31
35
30%
28
32
36

In extensigram properties, the energy value supplies information on the dough strength of a wheat flour. The larger the energy factor, the greater will be the dough strength of the flour. The energy value for Neepawa (176 cm^2) was higher than those for Fredrick (115 cm^2) and Pitic 62 (71 cm^2). On the other hand, with all three varieties of wheat flour, the energy value decreased as the amount of fababean flour in the blend increased (Tables 13, 14 and 15).

An interesting result was obtained in Neepawa-fababean blends related to dough elasticity (resistance to extension). The elasticity was greater for the 5% fababean blends than for the pure Neepawa flour (Table 13 and Fig. 5). In addition, for the 10% wheat flour substitution, the elasticity was similar to the Neepawa flour unblended. On the other hand, there was a decrease in elasticity of the doughs with 20 and 30% fababean flour. The extensibility remained essentially the same, giving a tendency to decrease as the amount of fababean increased.

In connection with energy, the ratio figure value (relation between elasticity and extensibility) is an important criterion in determining dough behaviour. The smaller the ratio figure value is, the greater will be the tendency of the dough to flow. Notable results were the large ratio figure values for 5 and 10% fababean flour blends at 135 min rest period (Table 13). Similar results were obtained by D'Appolonia (1977). The significant decrease in energy and ratio figure values at higher substitution levels (20 and 30%) indicates that fababean flours have an adverse effect on breadmaking properties of dough as measured by the extensigraph.

The extensigraph data for the composite flours with the weak wheats, Fredrick and Pitic 62 are given in Tables 14 and 15 and shown in Figures 6 and 7, respectively. The extensigraph properties of these types of blends were analogous to those obtained with Neepawa-fababean flours. However, due to the low initial protein content of the weak wheat flours, there were no significant differences in energy and elasticity values, even at high levels of nonwheat flours, compared to the two controls, Fredrick and Pitic 62.

All the fababean varieties used in this study, showed a similar pattern in relation to extensigraph characteristics. However, as in farinograph results, the variety Ackerperle gave slightly higher extensigraph results than the other fababean varieties, blended with both strong and weak wheat flours.

In general, increasing levels of fababean flours reduced the elasticity and caused the dough to have putty-like properties. The elasticity increased with the strength of the flour. This suggests that a medium-to-strong wheat flour is recommended as a carrier of nongluten protein supplements.

3. Amylograph

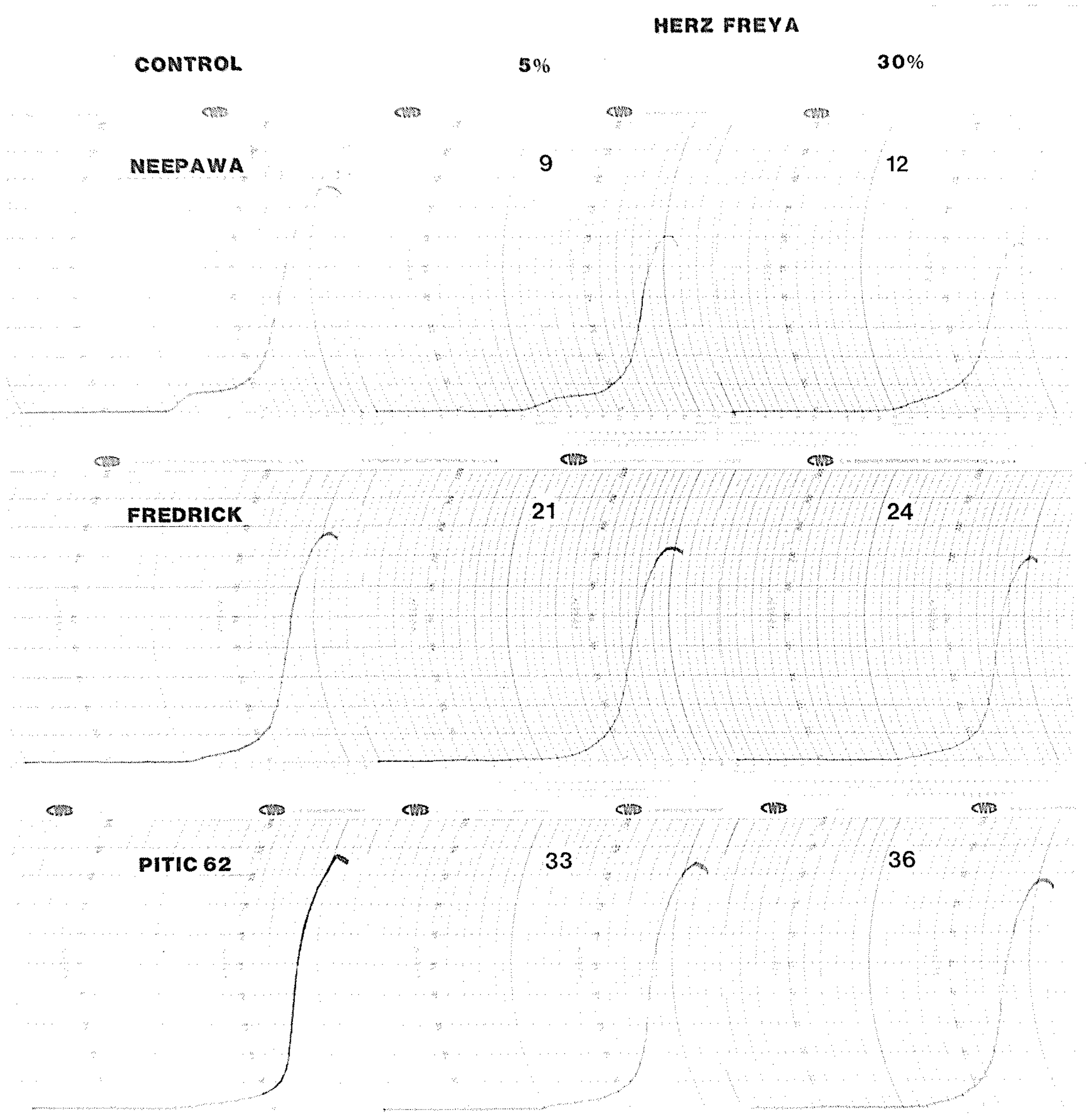
Amylograph viscosities (B.U.) of wheat flours blended with 5 and 30% fababean flour, variety Herz freya, were determined. The results are presented in Table 16 and Figure 8.

The addition of fababean flour to wheat flour produced a slight decrease in amylogram peak viscosity as well as an increase in gelatinization temperature in the strong wheat flour. Similar results were reported by Lorenz *et al* (1979). However, this effect is not proportional to the amount of fababean flour in the composites. These results

TABLE 16. Amylograph data of wheat-fababean flour blends

Sample		Viscosity at peak (B.U.)	Temperature at peak (^oC)
Neepawa %	Herz freya %		
100	0 (control)	770	59
95	5	600	59
70	30	585	61
Fredrick %	Herz freya %		
100	0 (control)	780	61
95	5	730	62
70	30	700	64
Pitic 62 %	Herz freya %		
100	0 (control)	870	60
95	5	845	62
70	30	780	65

Figure 8. Amylograms for wheat flours and their blends with fababean flour.


HERZ FREYA
CONTROL
5%
30%
NEEPAWA
9
12
FREDRICK
21
24
PITIC 62
33
36

indicate that increasing the level of nonwheat flour in the blends, decreased the amount of starch present, resulting in the decreased viscosity. The starch yield in fababean is around 40% which is considerably lower than the 70-80% obtained for wheat flour (Naivikul and D'Appolonia 1979, Cerning *et al* (1975). Also, fababean flour may interfere with the normal gelatinization of the wheat starch.

The amylograph data estimate enzyme activity, predominantly alpha-amylase. It is well known that damaged starch is more rapidly attacked by enzymes. Although damaged starch was not determined, the results obtained indicate that the percentage of damaged starch during the milling process of fababean was negligible, insofar as its effect on the amylograph viscosity is concerned. Naivikul and D'Appolonia (1978) used the same milling method for fababean as was followed in this study and found less damaged fababean starch than for hard red spring wheat.

C. Breadmaking Properties

Baking results for the wheat-fababean composite flours, obtained from comparative baking studies among the straight-dough method [method 10-10; AACC (1969)], the modified (short) straight-dough method and the modified sheeting roll method, are presented in Tables 17, 18 and 19.

The baking absorption was the same for each sample for all three baking methods. This baking absorption was found to improve the dough handling properties and to produce the best baking results. However, the mixing time differed according to the type of wheat, blend of fababean flours, as well as the baking method followed.

The baking absorptions for the controls (wheat flours) were the

TABLE 17. Comparison of loaf volumes in Neepawa and Neepawa-fababean composite flours by different baking methods

Flour		Water absorption		Loaf volume		
		Farinograph (%)	Baking (%)	AACC method cc/100 g flour	Modified AACC method cc/100 g flour	Sheeting method cc/100 g flour
Neepawa (control)		67.2	67.2	835	995	850
Composite flour						
Neepawa (%)	Diana (%)					
95	5	62.3	60.3	560	900	780
90	10	61.8	57.8	485	865	725
80	20	62.2	56.2	360	700	590
70	30	60.2	52.2	305	565	500
Neepawa (%)	Ackerperle (%)					
95	5	62.2	60.2	640	910	775
90	10	61.8	57.8	550	810	720
80	20	61.5	55.5	405	680	605
70	30	58.6	50.6	300	560	495
Neepawa (%)	Herz freya (%)					
95	5	62.6	60.6	645	935	825
90	10	62.0	58.0	560	845	725
80	20	61.2	55.2	415	700	560
70	30	58.5	50.5	300	550	480

TABLE 18. Comparison of loaf volumes in Fredrick and Fredrick-fababean composite flours by different baking methods

Flour		Water absorption		Flour volume		
		Farinograph (%)	Baking (%)	AACC method cc/100 g flour	Modified AACC method cc/100 g flour	Sheeting method cc/100 g flour
Fredrick (control)		50.6	50.6	410	610	720
Composite flour						
Fredrick (%)	Diana (%)					
95	5	51.0	50.0	300	585	640
90	10	51.9	49.9	290	535	570
80	20	51.3	49.3	235	415	380
70	30	50.5	47.5	210	335	275
Fredrick (%)	Ackerperle (%)					
95	5	51.2	52.2	315	590	680
90	10	51.8	50.8	265	535	550
80	20	50.5	48.5	250	450	380
70	30	49.6	45.6	220	365	295
Fredrick (%)	Herz freya (%)					
95	5	51.4	52.4	330	595	680
90	10	51.7	50.7	280	550	525
80	20	50.5	48.5	250	420	345
70	30	49.2	45.3	200	330	270

TABLE 19. Comparison of loaf volumes in Pitic 62 and Pitic 62-fababean composite flours by different baking methods

Flour		Water absorption		Loaf volume		
		Farinograph (%)	Baking (%)	AACC method cc/100 g flour	Modified AACC method cc/100 g flour	Sheeting method cc/100 g flour
Pitic 62 (control)		54.0	54.0	320	500	570
Composite flour						
Pitic 62 (%)	Diana (%)					
95	5	54.4	52.4	250	425	425
90	10	54.4	51.4	240	350	360
80	20	53.1	50.1	215	270	290
70	30	51.8	47.8	190	235	240
Pitic 62 (%)	Ackerperle (%)					
95	5	55.5	55.5	275	480	545
90	10	54.2	53.2	235	420	430
80	20	52.4	50.4	215	340	320
70	30	51.4	48.4	205	275	265
Pitic 62 (%)	Herz freya (%)					
95	5	54.5	55.5	255	490	500
90	10	54.5	54.5	255	450	420
80	20	52.3	51.3	220	340	310
70	30	51.0	48.0	195	280	250

same as the farinograph absorptions. Baking absorption for the Neepawa-fababean blends (Table 17) decreased with increasing amounts of the fababean flour. A similar finding was reported by McConnell *et al* (1974) and Fleming and Sosulski (1977). The baking absorption pattern was similar for all three fababean varieties. On the other hand, for the weak wheat - fababean flour blends, baking absorption increased with increasing amounts of fababean up to a level of 10% and then decreased slightly at the higher levels. Similar results were obtained by Lorenz *et al* (1979). The results reported in this thesis suggest that baking absorption depends on the type and strength of the wheat.

1. Straight-dough Method (AACC)

The straight-dough baking method [method 10-10; AACC (1969)] was used in baking all the wheat-fababean composite flours. The results are presented in Tables 17, 18 and 19. All samples were optimized for baking absorption. A 2 min mixing time in a GRL mixer (130 r.p.m.) was used to mix the ingredients and develop the dough. The dough was then rounded by hand folding (20 times) and placed in a fermentation cabinet for 180 min.

Sheeting and moulding was satisfactory for composites containing up to 20% fababean flours blended with Neepawa flour, and up to 10% fababean flours blended with Fredrick or Pitic 62 flours. Doughs containing 20% and 30% of the fababean flours were quite sticky and difficult to handle. With most of the composite flour blends, this stickiness could be overcome and dough handling improved by careful selection of the baking absorption.

Bread crumb color and crust color became darker with increasing amounts of fababean flour. These results indicated that the baking temperature and baking time were probably excessive for baking these types of composite flours.

Bread baked by the AACC straight-dough method with the strong wheat Neepawa and the weak wheats Fredrick and Pitic 62 and blended with the fababean variety Ackerperle, are shown in Figures 9, 10 and 11. Bread volume for Neepawa was quite acceptable (835 cc), while the results for Fredrick (410 cc) and Pitic 62 (320) were unacceptable with this method. The AACC straight-dough baking method was found to be inadequate for the weak wheats. Bread baked with Neepawa and 5% and 10% fababean flours produced acceptable loaf volumes (over 550 cc). However, at the 20% nonwheat flour level, there was a decrease in loaf volume, as well as a change in crumb structure. As expected, composite flours with the weak wheat flours, showed poorer breadmaking results, even with 5% fababean flours. The loaf volumes obtained were less than 330 cc and 275 cc for Fredrick-fababean flour blends and Pitic 62-fababean flour blends, respectively. Similar baking results were obtained for all three fababean varieties.

2. Modified (Short) Straight-dough Method

Baking formulas and/or procedures are usually modified when composite flours are baked. Some of the modifications include the use of relatively strong wheat flours, improvers and shorter fermentation time. The baking results for a modified (short) straight-dough method are presented in Tables 17, 18 and 19. A shorter 2-hr fermentation time, optimized mixing time depending upon the type of wheat flour, and 20 ppm potassium bromate, were used in the baking formula.

Figure 9. Bread from Neepawa and Neepawa-fababean (var. Ackerperle) composite flours baked by the AACC straight-dough method.

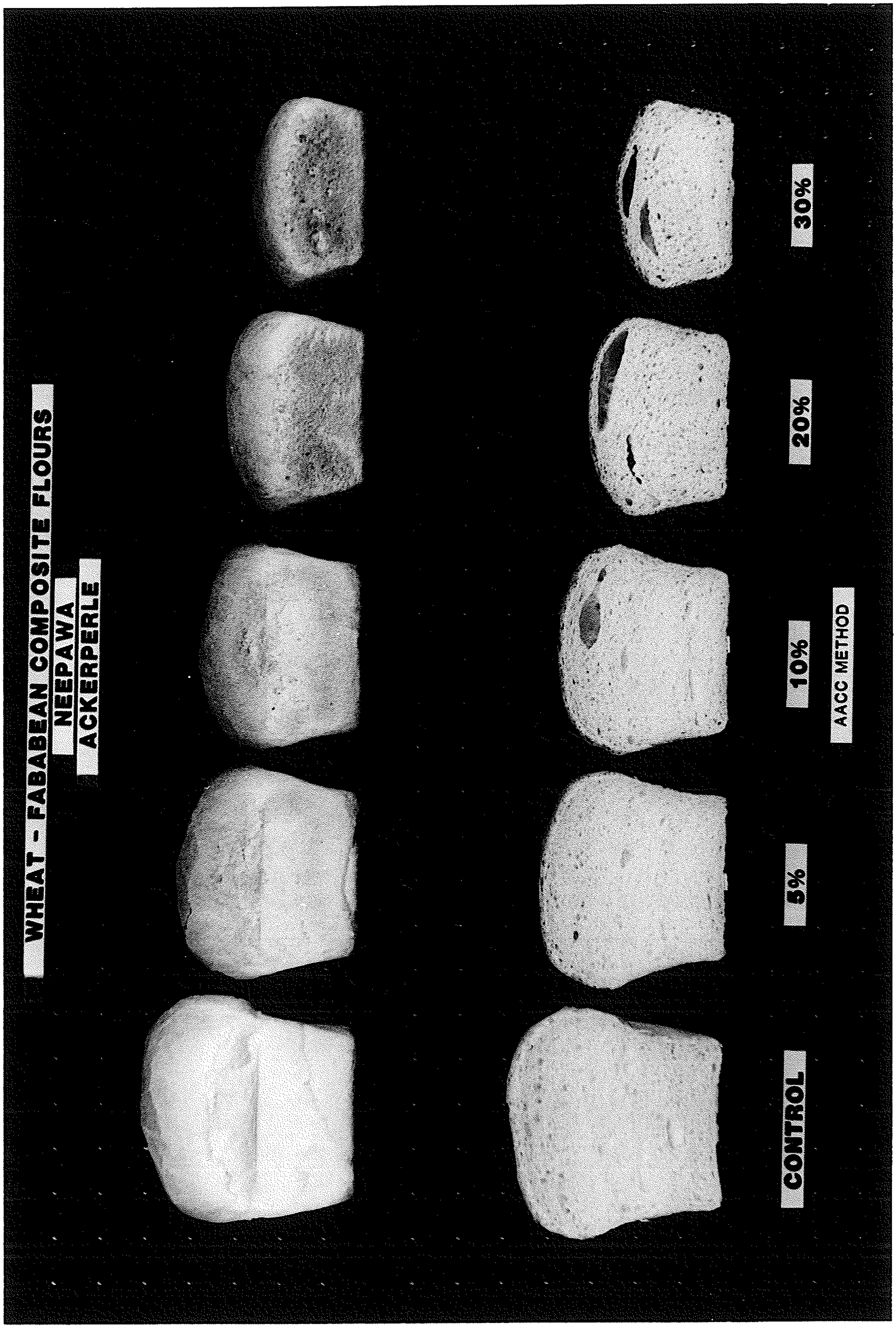

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
ACKERPERLE
CONTROL
5%
10%
20%
30%
AACC METHOD

Figure 10. Bread from Fredrick and Fredrick-fababean (var. Ackerperle) composite flours baked by the AACC straight-dough method.

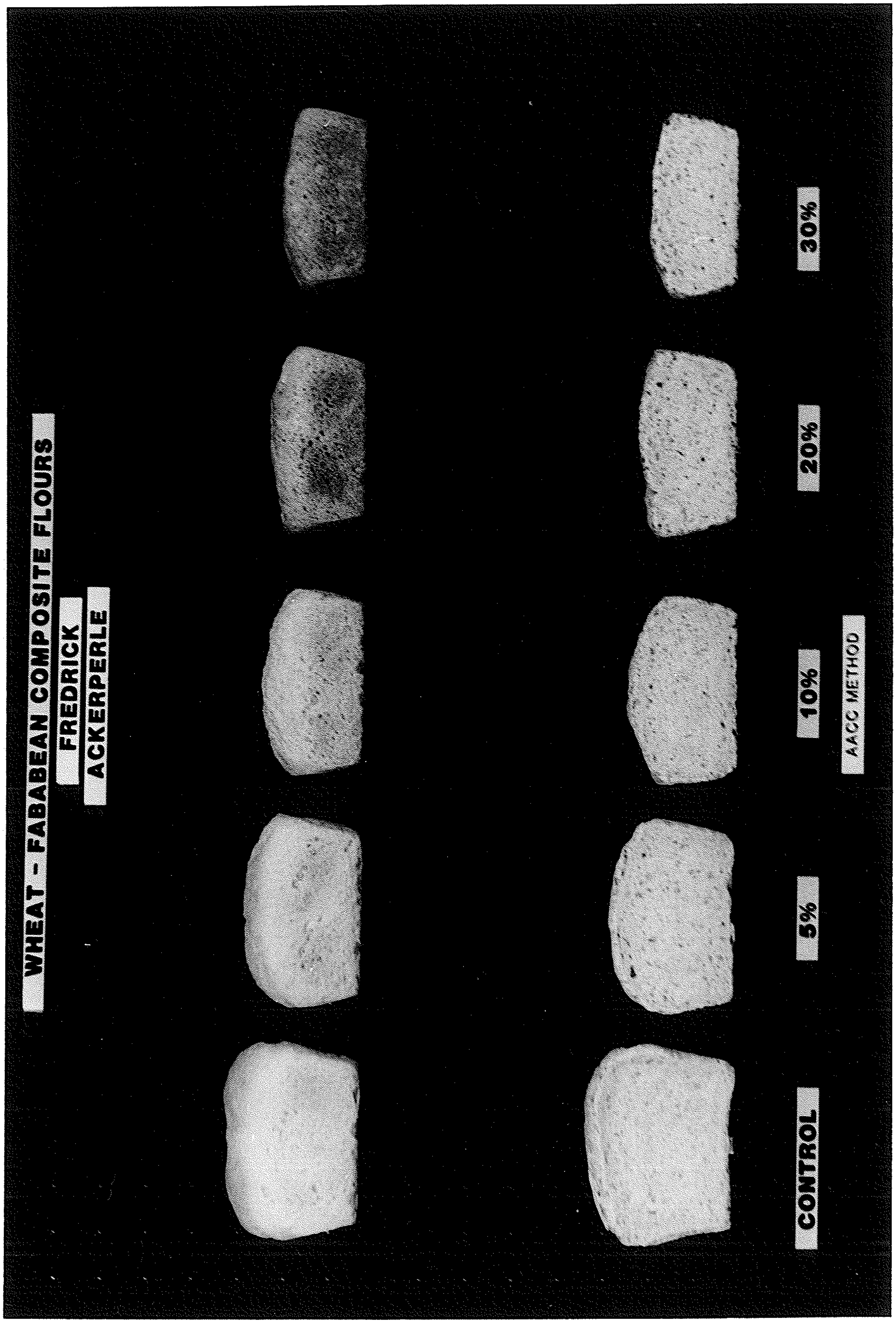
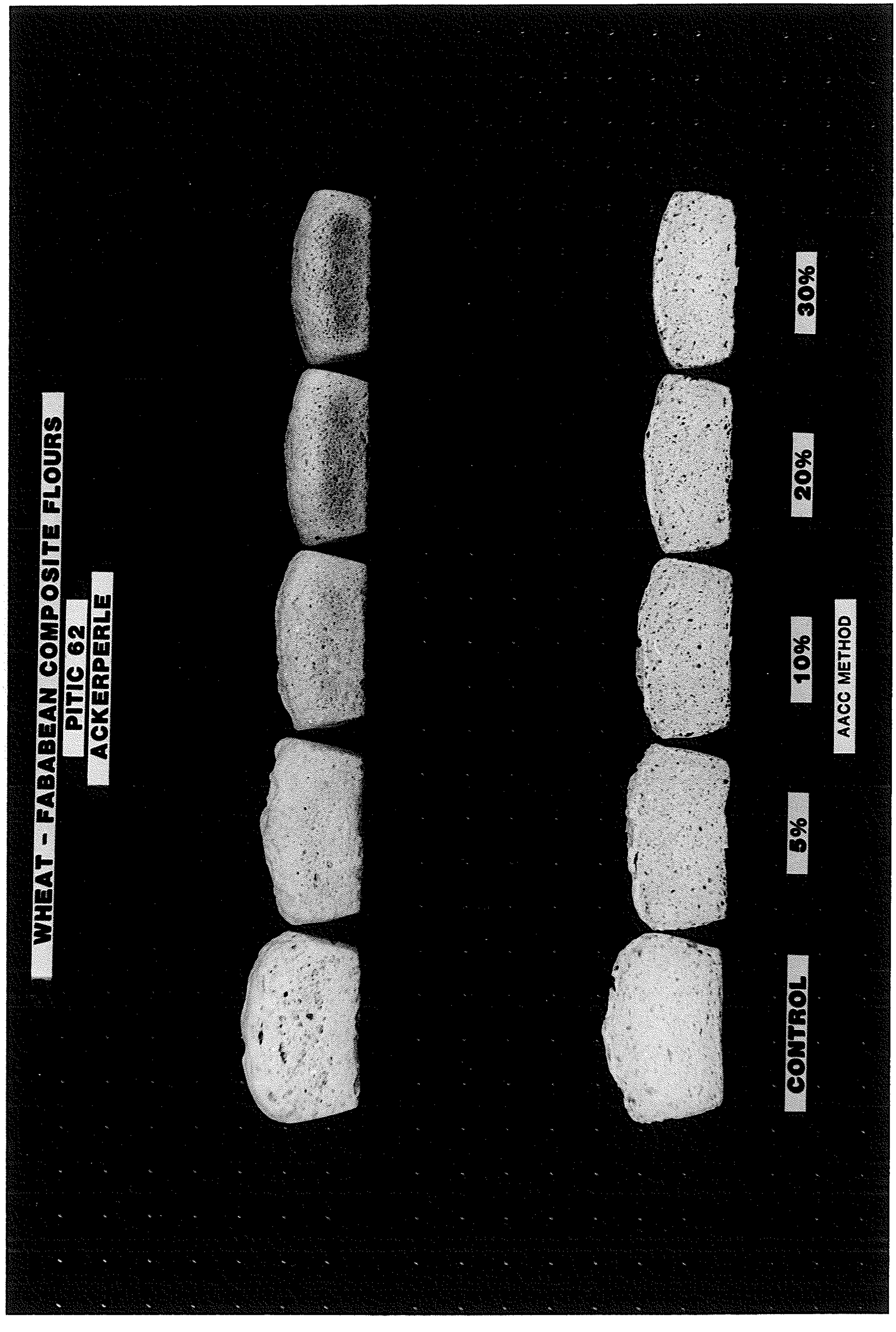

WHEAT - FABABEAN COMPOSITE FLOURS
FREDRICK
ACKERPERLE
CONTROL
5%
10%
20%
30%
AACC METHOD

Figure 11. Bread from Pitic 62 and Pitic 62-fababean (var. Ackerperle) composite flours baked by the AACC straight-dough method.


WHEAT - FABABEAN COMPOSITE FLOURS
PITIC 62
ACKERPERLE
CONTROL
5%
10%
20%
30%
AACC METHOD

For Neepawa and its fababean blends, 2 min mixing was not enough time to develop the dough even though the dough was rounded up by folding (20 times). Therefore, longer mixing times were required with strong wheat-fababean flours (4 min) than those with weak wheat-fababean flours (2 min). In preliminary experiments, fababean flours blended with Fredrick and Pitic 62 showed no differences in overall baking quality when 1.5 or 1.75 min mixing time was used. However, baking quality was greatly affected (mainly volume and crumb appearance) with more than 2 min mixing time.

As the percentage of fababean flour increased, bread volume decreased, crust color became darker, and the grain became coarser. In addition, the higher the amount of fababean flour in the blend, the thicker the crust and the harder the crumb. This was expected because of the significant detrimental effect on loaf volume at those levels. Similar changes in bread quality have also been observed by McConnell *et al* (1974), Patel and Johnson (1975), Fleming and Sosulski (1977), and Lorenz *et al* (1979).

Examination of the microstructure of wheat flour doughs and bread has been helpful in determining the changes that occur in physical structure at various stages of bread preparation. Fleming and Sosulski (1978) used light microscopy and scanning electron microscopy to evaluate bread fortified with fababean protein. They found that fababean protein disrupted the well defined protein-starch complex observed in wheat flour bread. Breads baked with fababean proteins resulted in smaller pores and ruptured cell structure.

Changes in internal bread structure were observed in this study.

The fababean flours accounted for some of the deteriorations in bread quality (depressed loaf volume and irregular crumb structure).

Bread crumb color became slightly darker with increasing amounts of fababean flour in the blends, even though the oven temperature was reduced to 210°C. However, at levels of up to 20% of wheat flour substitution, crumb color was acceptable considering that these breads will have to be regarded as speciality breads. According to Bertram (1953), the brown crust and crumb color is due to the Maillard reaction which occurs between free carbohydrates and amino acid residues in the presence of heat and low moisture levels. Fleming and Sosulski (1977) reduced the intensity of browning by lowering the temperature of baking, and by eliminating the malt extract or sugar from the formula. However, they found that these alterations caused further deterioration in loaf volume.

The modified (short) straight-dough method used in this study gave higher loaf volumes compared to the AACC straight-dough method. A 50% increase in the loaf volume of the Neepawa-fababean blends and more than 60% in Fredrick or Pitic 62-fababean blends, even at the highest fababean percentage (30%), were obtained by the modified straight-dough method (Tables 17, 18 and 19).

Attempts were made to compare the baking results obtained by the AACC straight-dough method and the modified straight-dough method. Bread baked with the modified straight-dough method with Neepawa, Fredrick and Pitic 62 and their blends with fababean variety Ackerperle, are presented in Figures 12, 13 and 14. The external and internal bread characteristics improved with the modified straight-dough baking method.

Figure 12. Bread from Neepawa and Neepawa-fababean (var. Ackerperle) composite flours baked by the modified (short) straight-dough method.

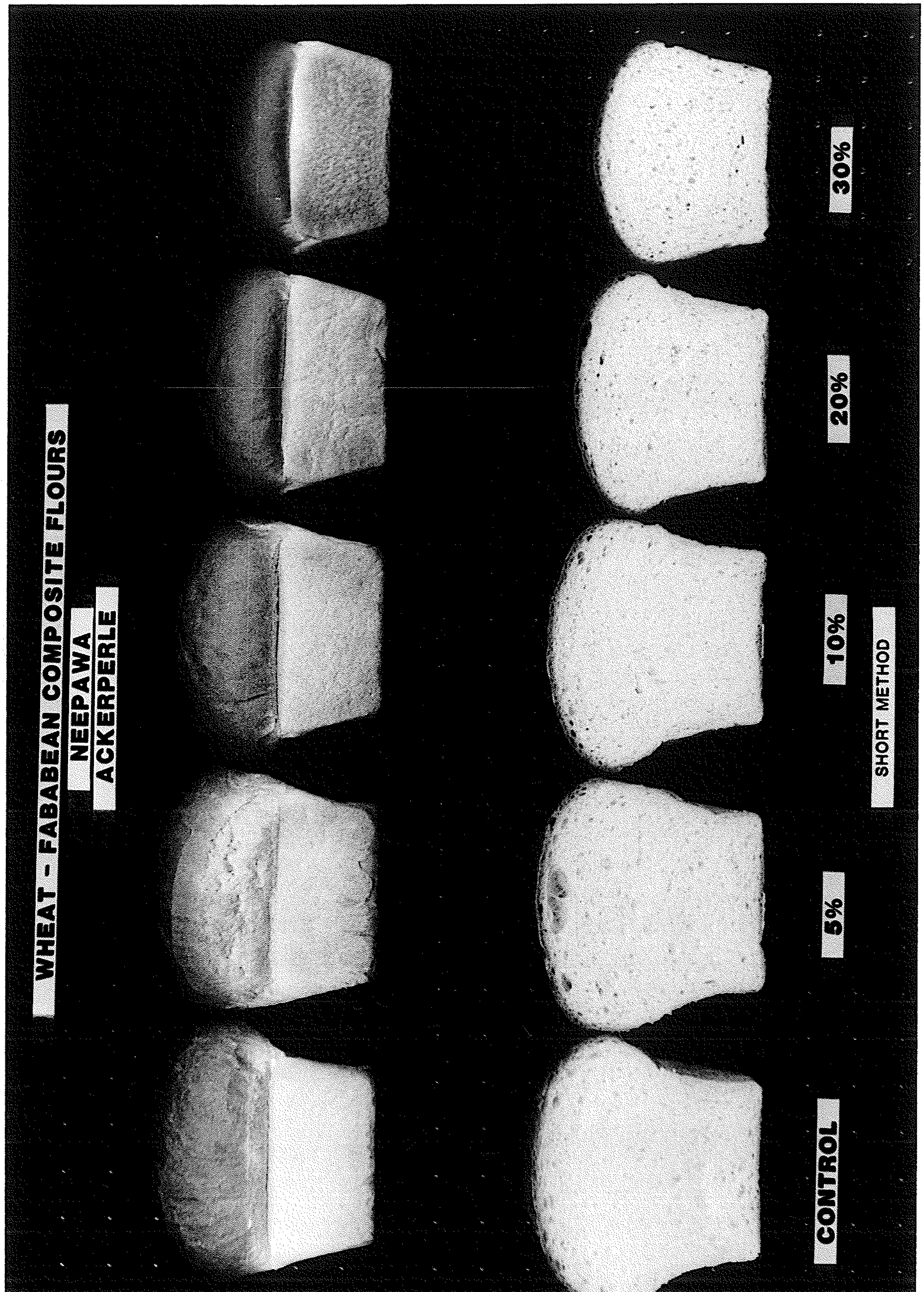

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
ACKERPERLE
CONTROL
5%
10%
20%
30%
SHORT METHOD

Figure 13. Bread from Fredrick and Fredrick-fababean (var. Ackerperle) composite flours baked by the modified (short) straight-dough method.

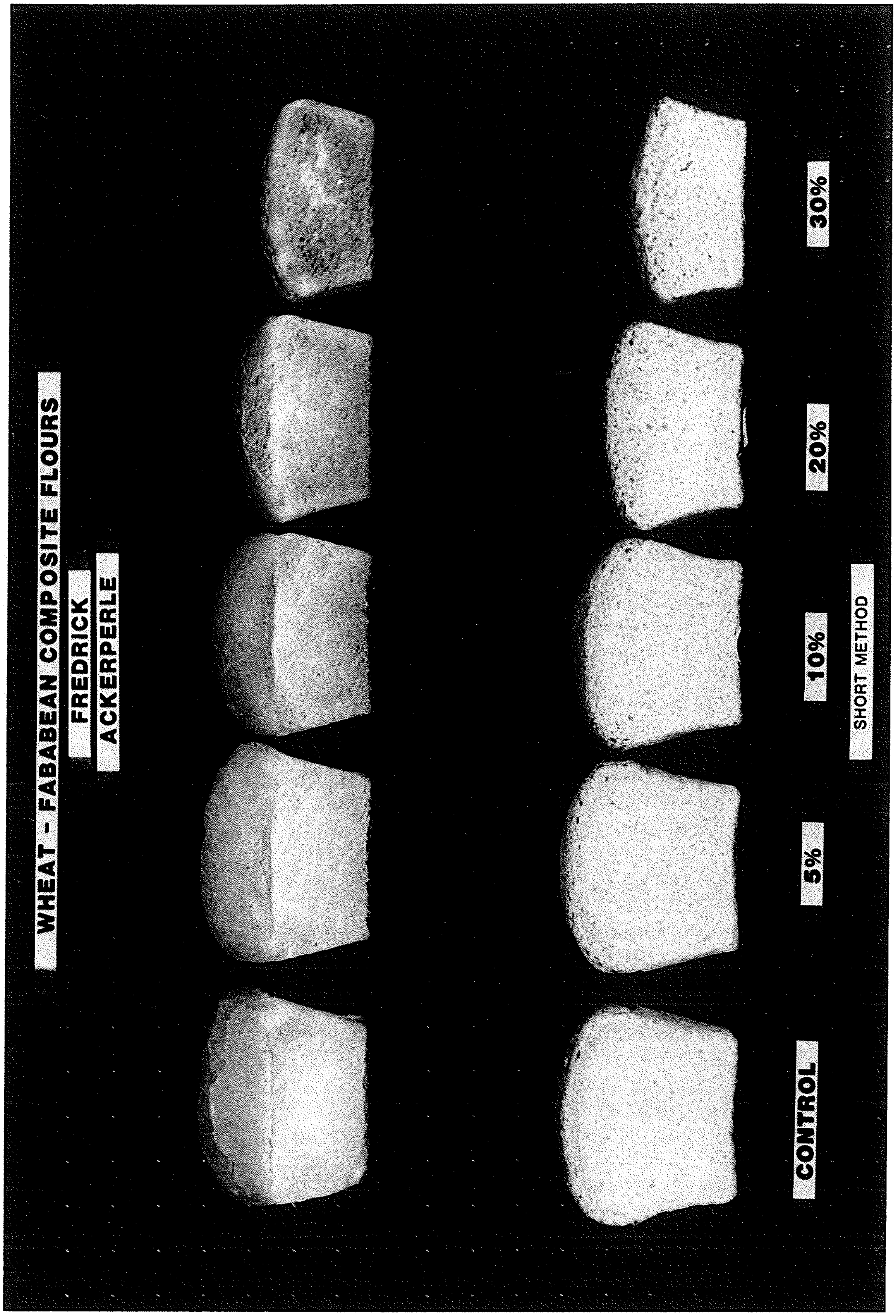
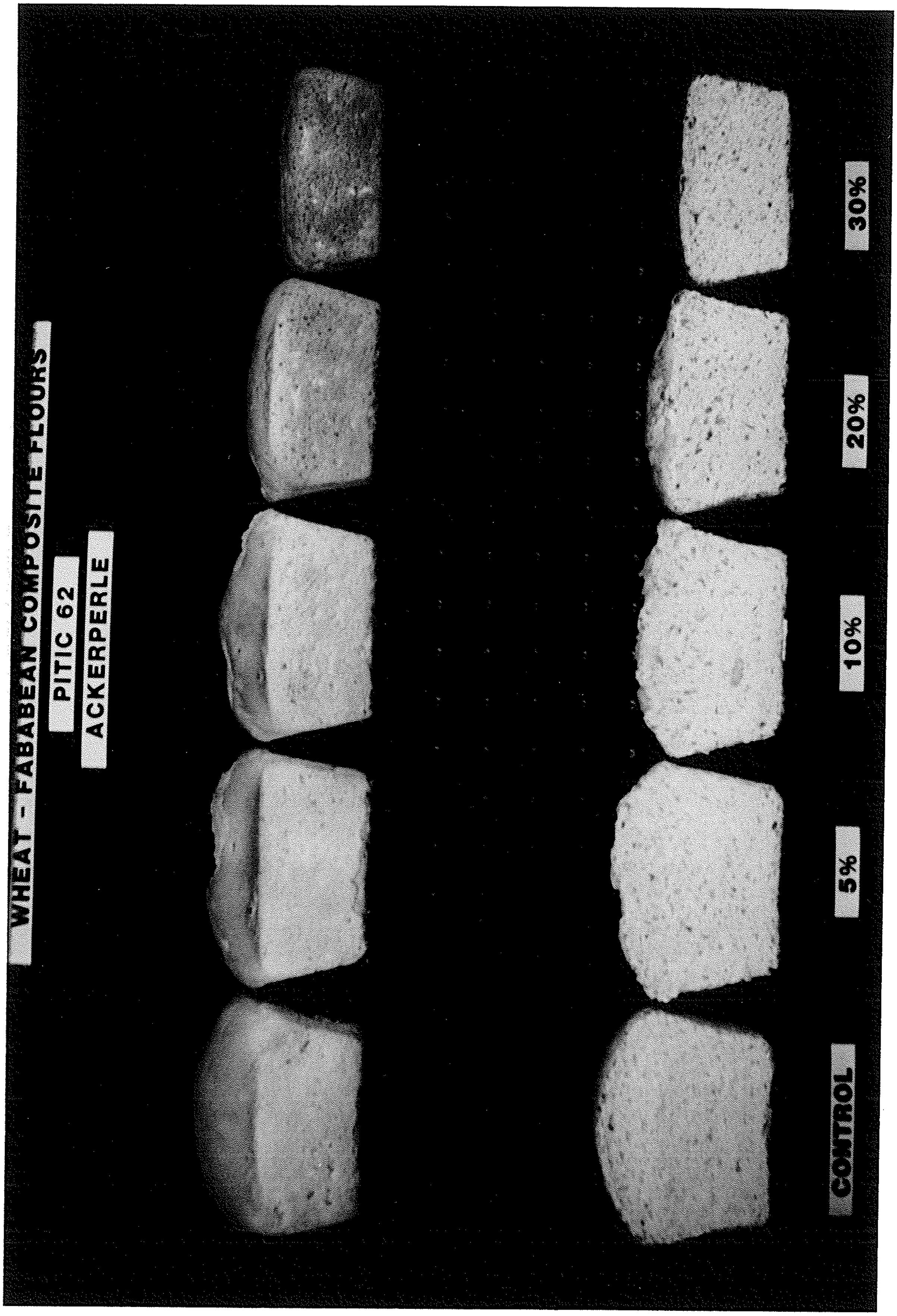

WHEAT - FABABEAN COMPOSITE FLOURS
FREDRICK
ACKERPERLE
CONTROL
5%
10%
20%
30%
SHORT METHOD

Figure 14. Bread from Pitic 62 and Pitic 62-fababean (var. Ackerperle) composite flours baked by the modified (short) straight-dough method.


WHEAT - FABABEAN COMPOSITE FLOURS
PITIC 62
ACKERPERLE
CONTROL
5%
10%
20%
30%

This was most notable with the weak wheat composite flours. Bread quality was quite acceptable up to 20% of fababean flour blended with Neepawa, and up to 10% nonwheat flour blended with Fredrick and/or Pitic 62.

As in the case of the AACC straight-dough method, there were no significant differences among the three fababean varieties. However, the variety Ackerperle gave a slightly higher bread volume and better internal crumb characteristics compared to the other two fababean varieties.

3. Modified Sheeting Roll Method

A no-time dough baking process has certain advantages over a conventional baking process that requires a long bulk fermentation time. Its primary advantage is that the quality of the flour required to produce bread can be lower than that required by the conventional processes. This feature makes the method attractive for the production of bread from composite flours (Pringle *et al* 1969). Preliminary baking experiments using the sheeting method developed by McConnell *et al* (1974) were found to be unsatisfactory for the weak wheat -fababean blends. Therefore, a modified sheeting method was developed. Baking results obtained by this method are presented in Tables 17, 18 and 19.

The baking absorption for all samples was the same as used with the modified straight-dough method. However, the mixing time was shorter. The best results were obtained by mixing Neepawa and its fababean blends for 2 min, and a mixing period of 1.5 min for Fredrick or Pitic 62-fababean blends.

With all the wheat-fababean flours investigated, the quality of the bread deteriorated gradually as the amount of the fababean flour in the composite increased. Satisfactory bread was obtained for composite flours containing up to 20% fababean flour and 80% Neepawa. The data for a strong wheat-fababean blends obtained in this study are comparable to the data published by McConnell *et al* (1974). With the weak wheats, acceptable bread was obtained for composite flours containing up to 10% fababean flour, even though these doughs were sheeted only 21 times instead of the 30 times for Neepawa and its fababean blends.

Several modifications using different mixing speeds, salt concentration and oxidant levels in the sheeting roll method were attempted in order to determine if these changes would result in any improved effects on the bread characteristics of the composite samples. Optimal mixing results were obtained with the GRL mixer run at a low speed (69 r.p.m.). Loaf volumes of the bread were not affected at this speed. Furthermore, there was a slight improvement in the crumb grain. The addition of 2% salt (NaCl) as suggested by D'Appolonia (1977), resulted in an excessively fine grain. Therefore, 1% salt concentration was used in further experimentation. Optimum oxidant levels were found to be 75 ppm ascorbic acid plus 15 ppm potassium bromate, which compares well with the findings of Axford *et al* (1963).

Breads baked by the modified sheeting roll method with the strong wheat Neepawa and the weak wheats Fredrick and Pitic 62 and their blends with the fababean variety Ackerperle, are shown in Figures 15, 16 and 17. This modified sheeting roll baking method gave bread with lower loaf volumes than those obtained by the modified straight-dough method with only Neepawa and its fababean flour blends (Figure 15). Improved bread quality was obtained with the weak wheats and their blends using this baking method (Figures 16 and 17). These results indicate that Neepawa

Figure 15. Bread from Neepawa and Neepawa-fababean (var. Ackerperle) composite flours baked by the modified sheeting roll method.

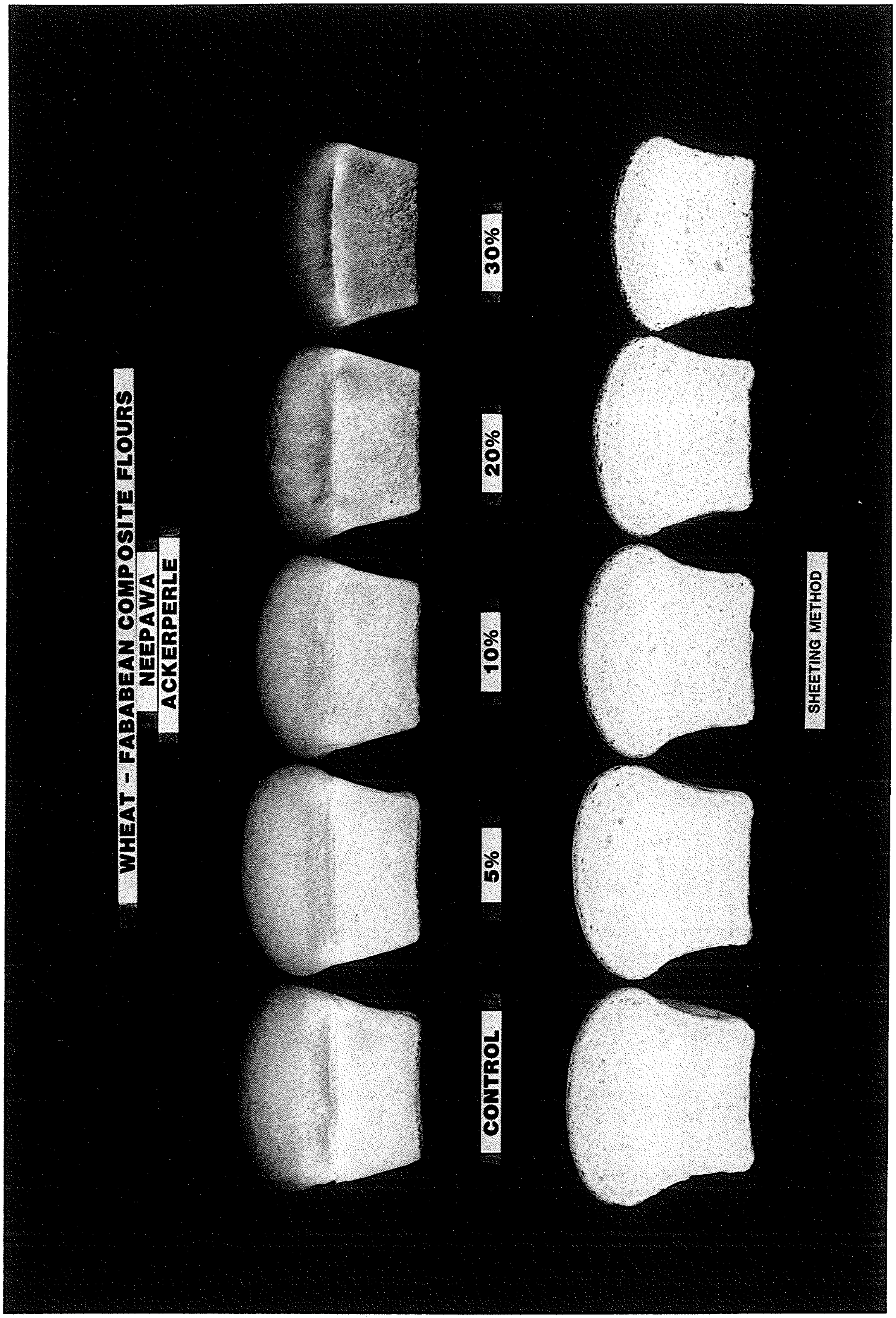

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
ACKERPERLE
CONTROL
5%
10%
20%
30%
SHEETING METHOD

Figure 16. Bread from Fredrick and Fredrick-fababean (var. Ackerperle) composite flours baked by the modified sheeting roll method.

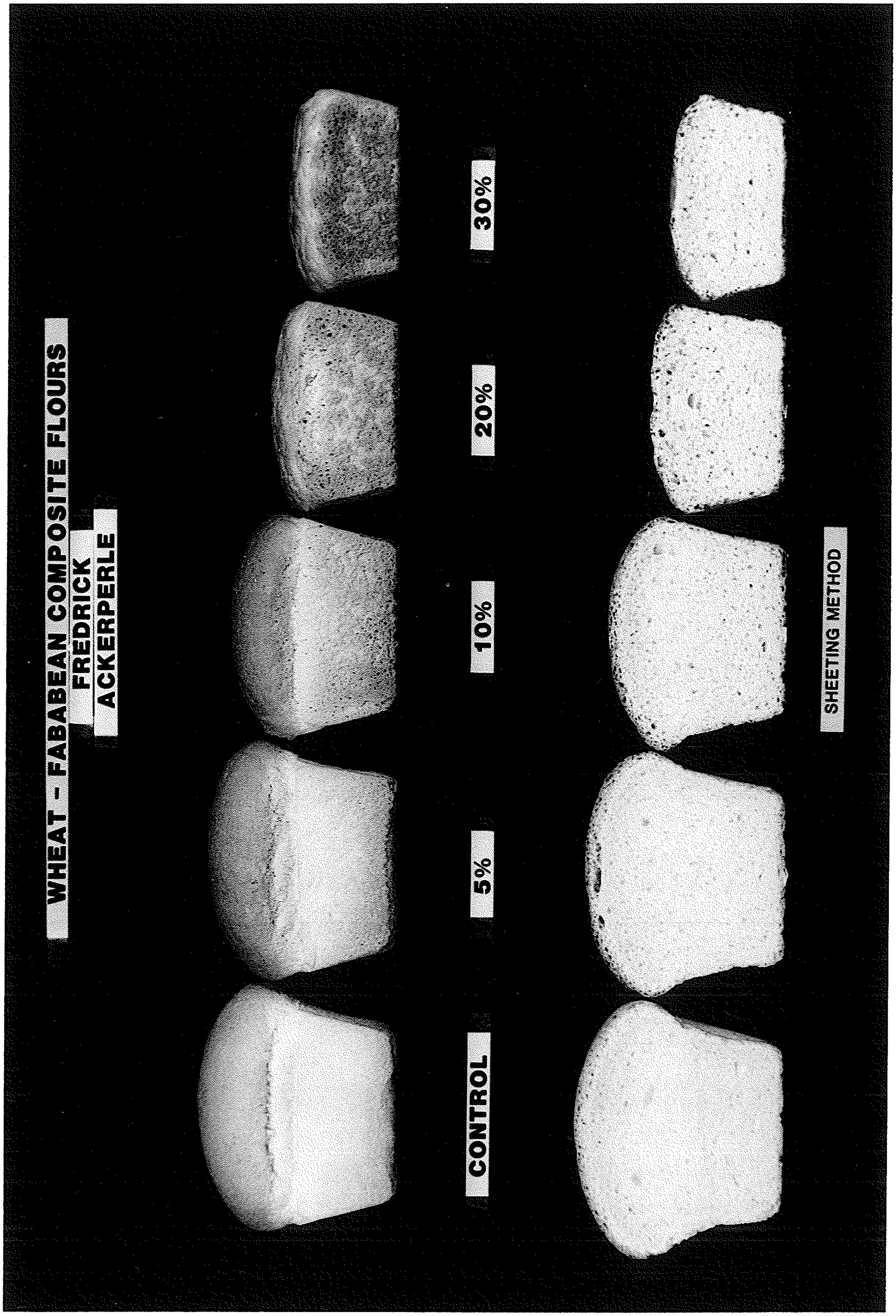
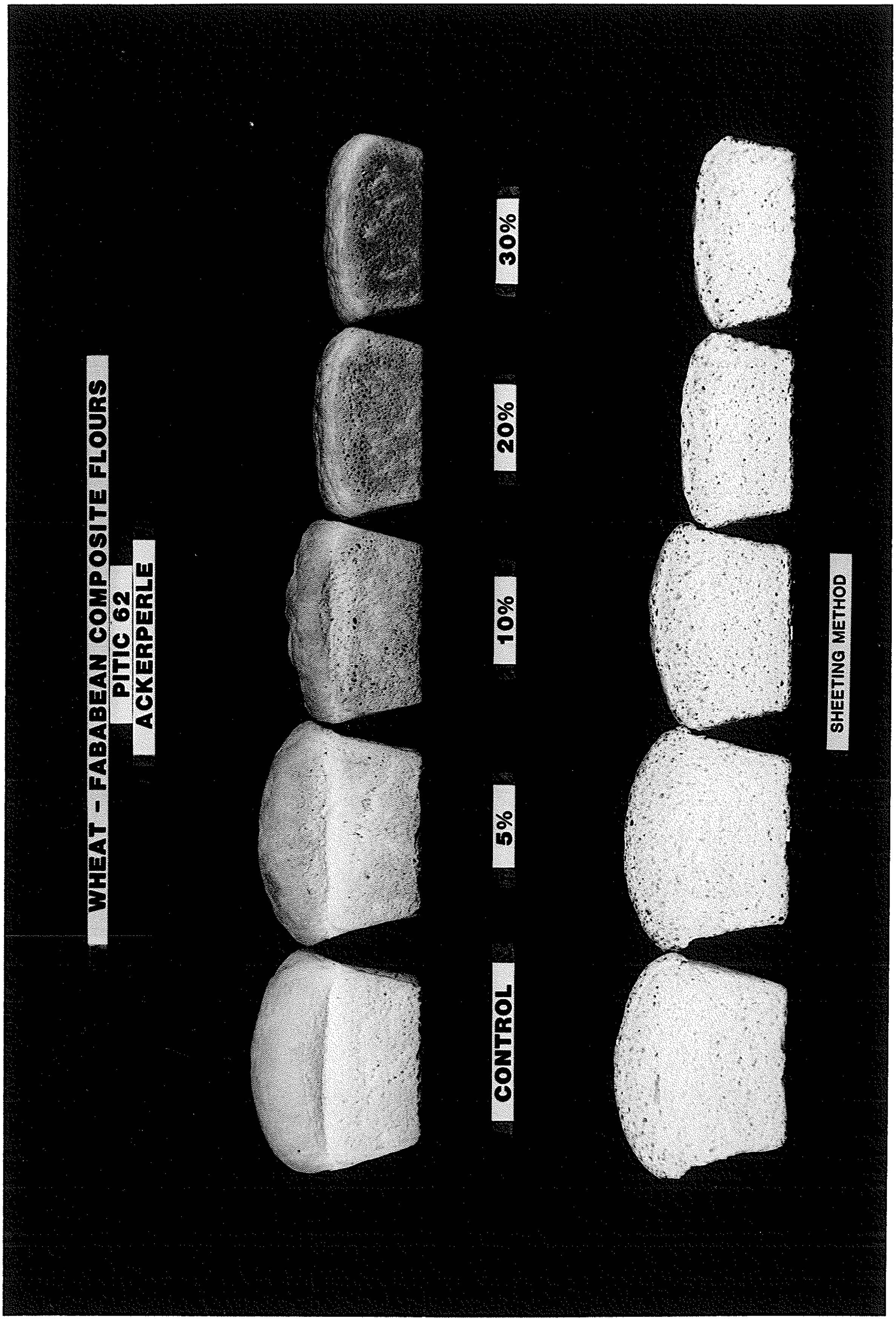

WHEAT – FABABEAN COMPOSITE FLOURS
FREDRICK
ACKERPERLE
CONTROL
5%
10%
20%
30%
SHEETING METHOD

Figure 17. Bread from Pitic 62 and Pitic 62-fababean (var. Ackerperle) composite flours baked by the modified sheeting roll method.


WHEAT - FABABEAN COMPOSITE FLOURS
PITIC 62
ACKERPERLE
CONTROL
5%
10%
20%
30%
SHEETING METHOD

and its fababean blends were too strong for this baking method. In addition, the internal bread characteristics improved with this method for all baked wheat composites.

4. Modified Sheeting Method With Emplex

Dough conditioners improve the bread quality of composite flours. Therefore, sodium stearoyl-2-lactylate (SSL, Emplex), a dough conditioner, was used in the baking studies. Addition of Emplex generally produced an improvement in crumb grain and crumb color. Initial experiments using Neepawa and Fredrick flours with different concentrations of Emplex, indicated that this dough conditioner at a 1% level in the baking formula produced optimal baking results (loaf volume and bread structure). When more than 1% Emplex concentration was added to the baking formula, the grain became excessively fine and compact (Figures 18 and 19).

Figure 20 shows the effect with Emplex at the 1% level and without Emplex on the loaf volume of a strong flour (Neepawa) and of a weak flour (Fredrick) blended with fababean flour (var. Ackerperle), respectively. Emplex increased the loaf volume and bread quality for both varieties. As the proportion of fababean flour in the composite flour increased, there was a gradual decrease in loaf volume with and without Emplex. The baking results for the Neepawa-fababean blends and Fredrick-fababean blends with and without Emplex are presented in Figures 21, 22, 23 and 24. As can be seen in these figures, the texture gradually deteriorated, the grain became coarser and the color became darker with increasing proportion of fababean flours. However, Emplex produced an overall improvement in texture and color, compared to bread baked without Emplex.

Figure 18. Bread from wheat flour (var. Neepawa) with different concentrations of Emplex by the modified sheeting roll method.

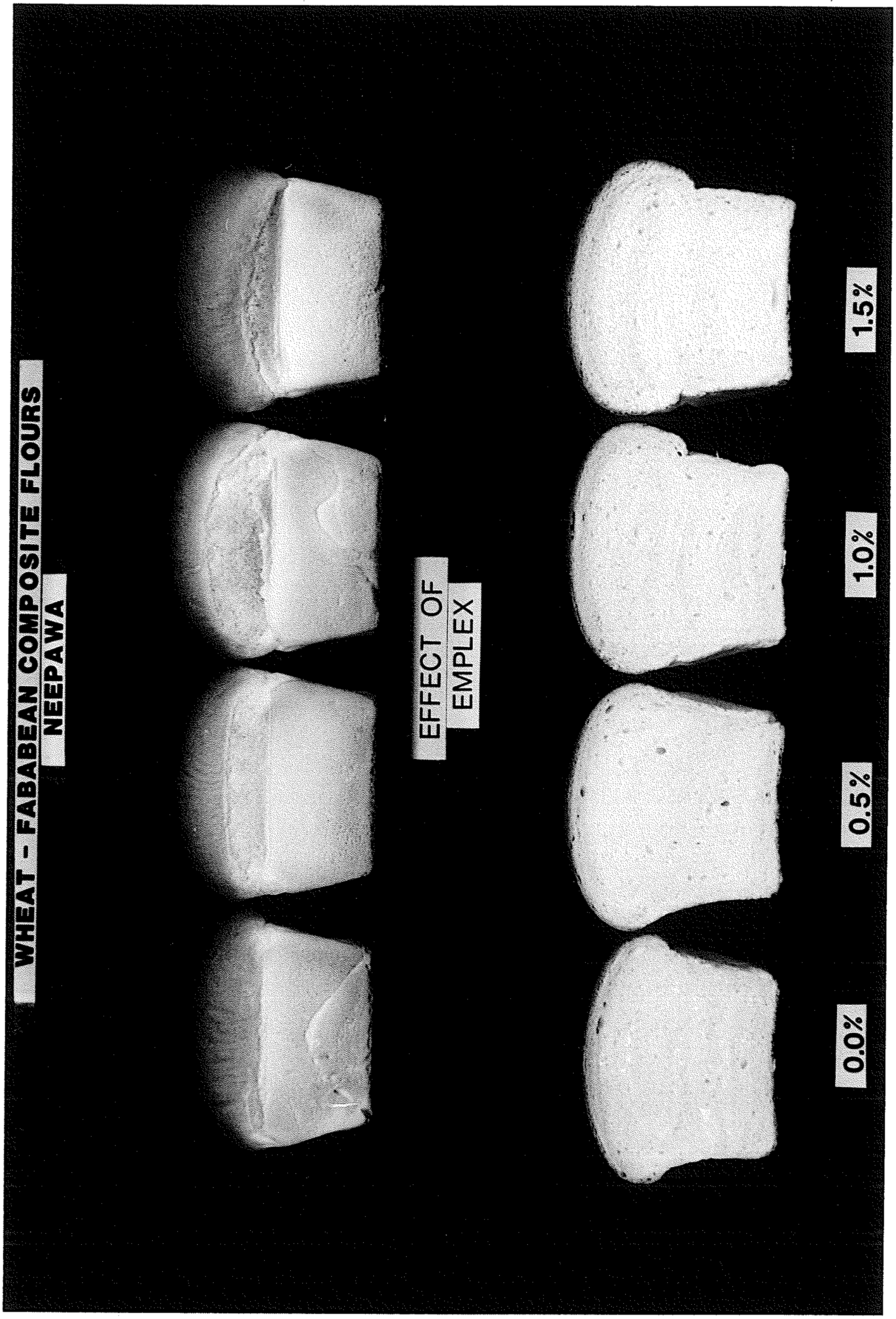

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
EFFECT OF
EMPLEX
0.0%
0.5%
1.0%
1.5%

Figure 19. Bread from wheat flour (var. Fredrick) with different concentrations of Emplex by the modified sheeting roll method.

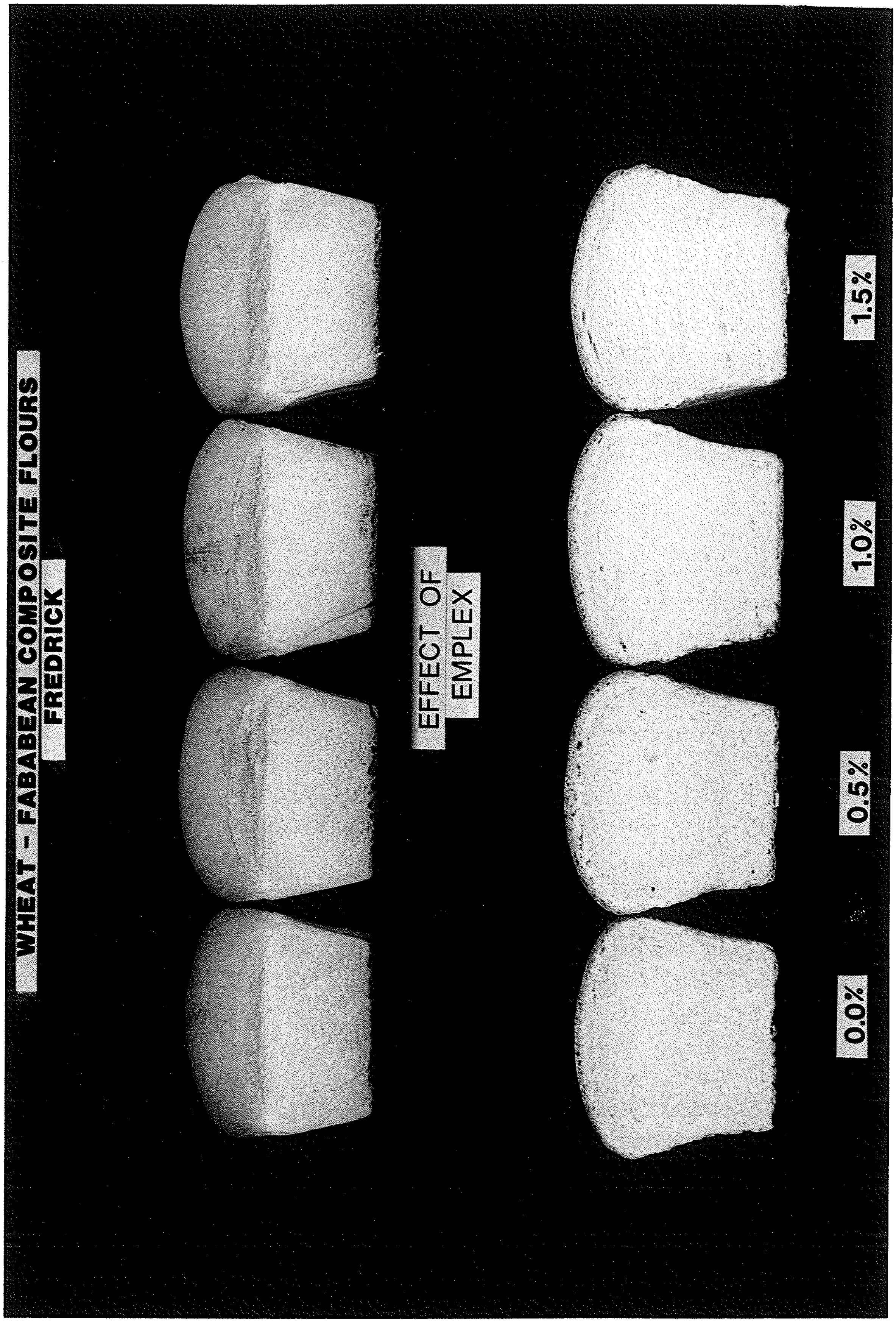

WHEAT - FABABEAN COMPOSITE FLOURS
FREDRICK
EFFECT OF
EMPLEX
0.0%
0.5%
1.0%
1.5%

Figure 20. Relationship between loaf volume and composition of the wheat-fababean composite flour with Emplex (1%) and without Emplex.

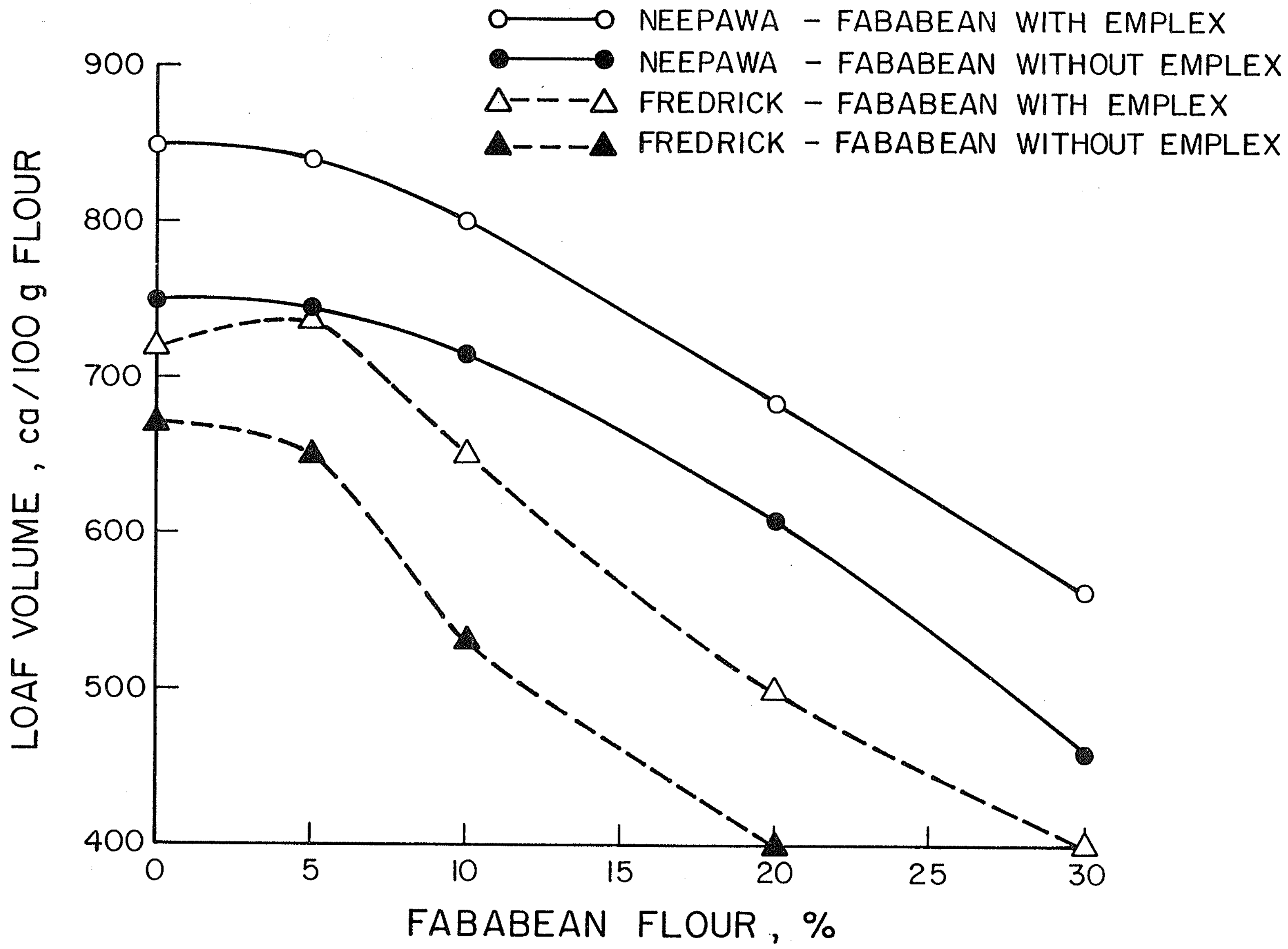

○—○ NEEPAWA - FABABEAN WITH EMPLEX
●—● NEEPAWA - FABABEAN WITHOUT EMPLEX
△- - -△ FREDRICK - FABABEAN WITH EMPLEX
▲- - -▲ FREDRICK - FABABEAN WITHOUT EMPLEX
LOAF VOLUME , cc/100 g FLOUR
900
800
700
600
500
400
0
5
10
15
20
25
30
FABABEAN FLOUR , %

Figure 21. Characteristics of bread made with Neepawa-fababean (var. Ackerperle) composite flours without Emplex by the modified sheeting roll method.

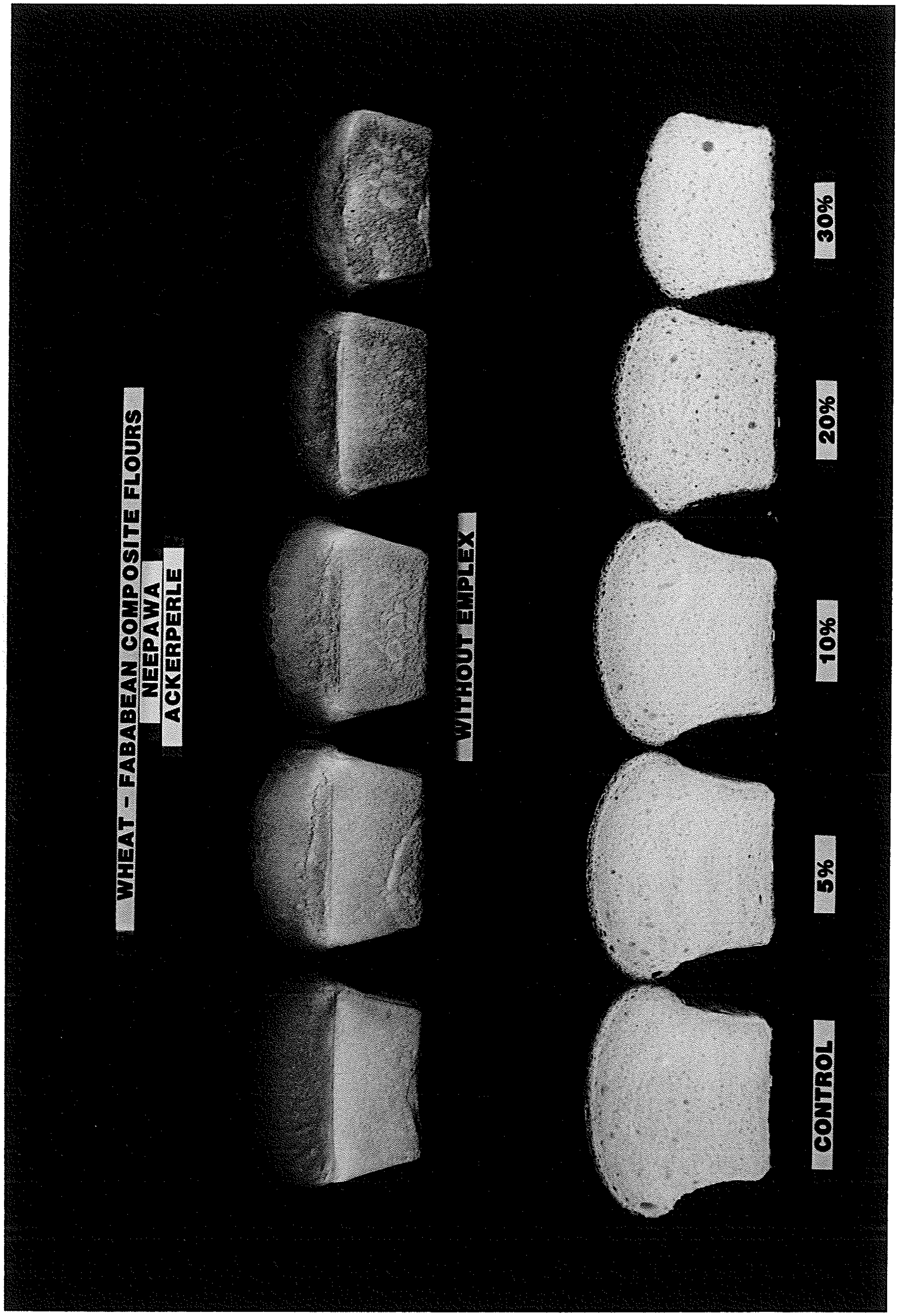

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
ACKERPERLE
WITHOUT EMPLEX
CONTROL
5%
10%
20%
30%

Figure 22. Characteristics of bread made with Neepawa-fababean (var. Ackerperle) composite flours with Emplex (1%) by the modified sheeting roll method.

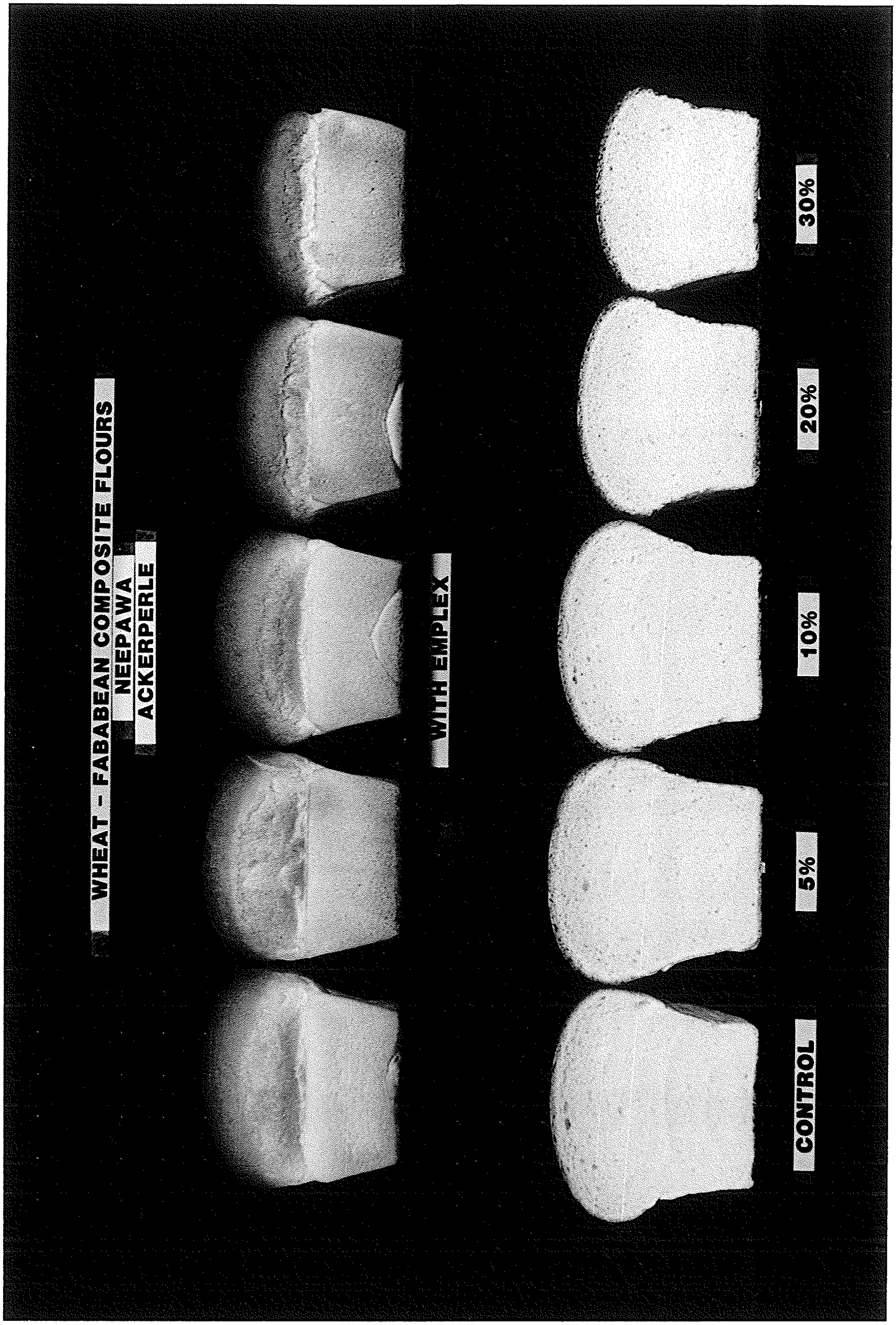

WHEAT - FABABEAN COMPOSITE FLOURS
NEEPAWA
ACKERPERLE
WITH EMPLEX
CONTROL
5%
10%
20%
30%

Figure 23. Characteristics of bread made with Fredrick-fababean (var. Ackerperle) composite flours without Emplex by the modified sheeting roll method.

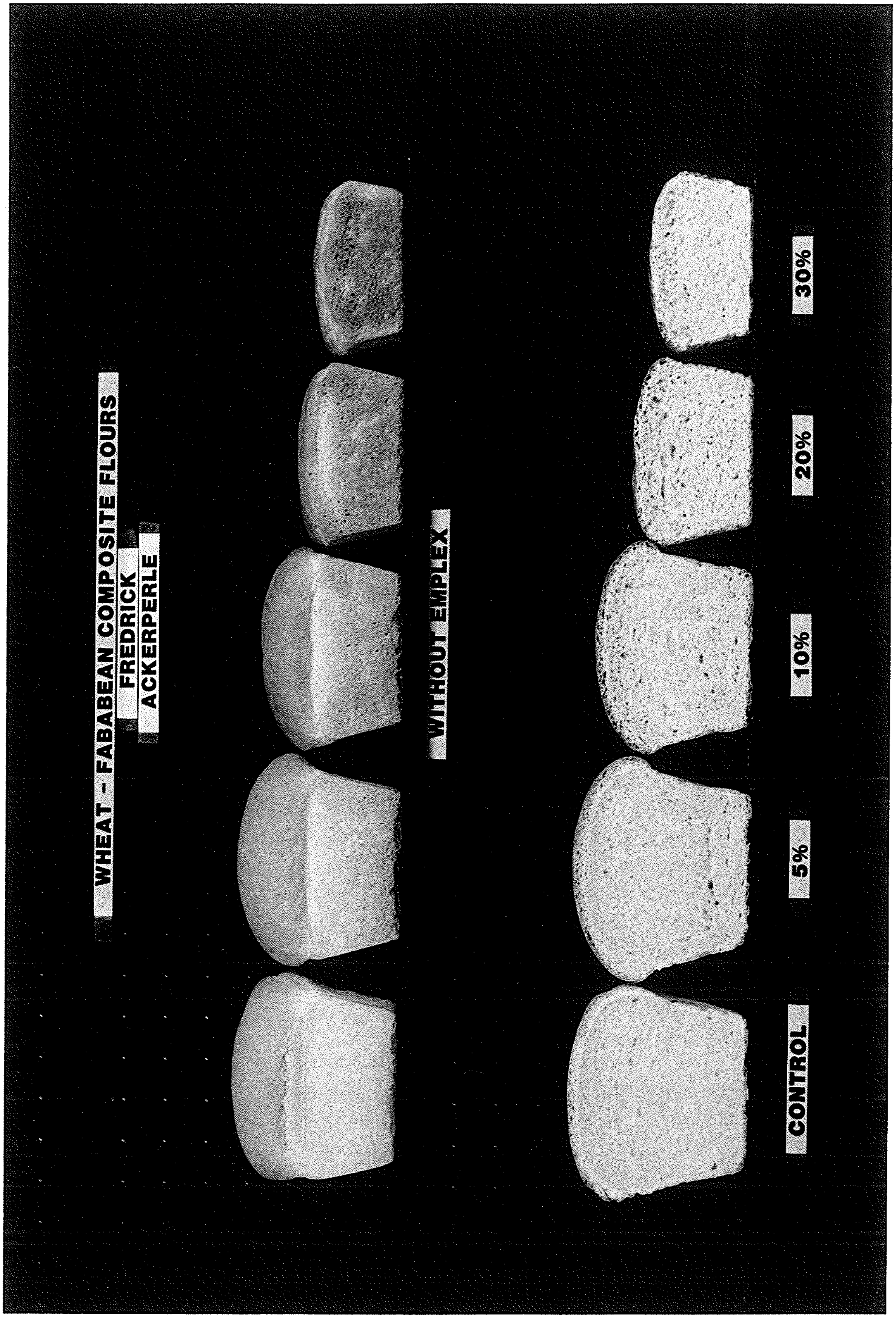
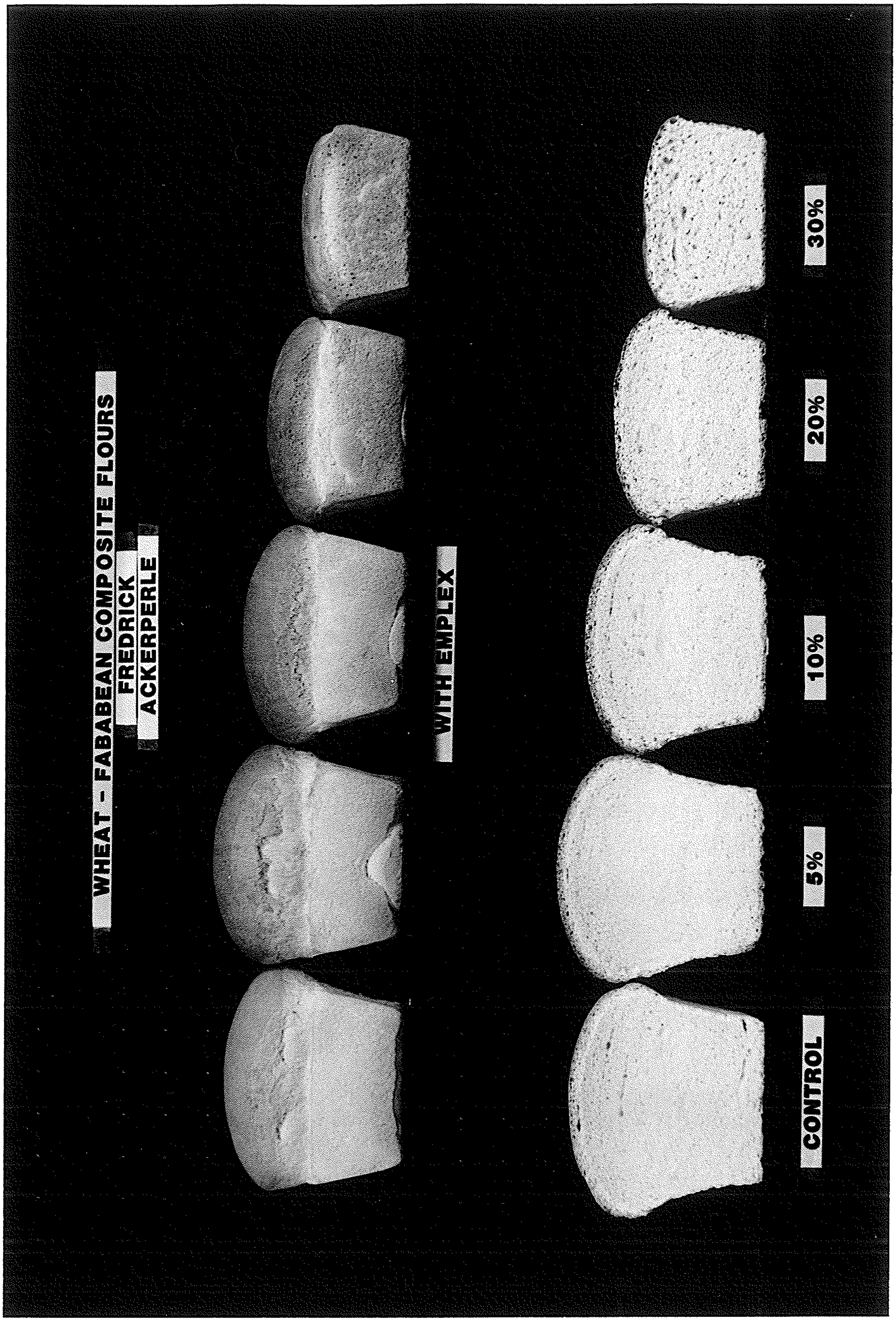

WHEAT - FABABEAN COMPOSITE FLOURS
FREDRICK
ACKERPERLE
WITHOUT EMPLEX
CONTROL
5%
10%
20%
30%

Figure 24. Characteristics of bread made with Fredrick-fababean (var. Ackerperle) composite flours with Emplex (1%) by the modified sheeting roll method.


WHEAT - FABABEAN COMPOSITE FLOURS
FREDRICK
ACKERPERLE
WITH EMPLEX
CONTROL
5%
10%
20%
30%

Although taste panel tests were not done, loaves of bread containing up to 20% of fababean flours were distributed among several graduate students in the Department of Plant Science, University of Manitoba. The majority of the students could not detect any taste difference in the bread produced with fababean flour compared to wheat controls.

VI. GENERAL DISCUSSION

The main objective of this thesis was to study the effects of various levels of fababean flours from three different varieties on the breadmaking properties of one strong and two weak wheat flours. This type of information is basic to the utilization of fababean flour in composite flours for producing bread.

Selected wheat flours and fababean flours were used for this investigation. Where possible, the results obtained were compared with results reported in the literature for similar or other types of wheat and fababean flours. The information presented in this thesis should be useful in relation to optimal utilization of fababean flour in composite flours for bread production.

Base materials and all composites were analyzed for proximate composition. The starting materials, wheat flours and fababean flours, gave values of moisture, protein and ash contents that are typical for such flours. The moisture content of fababean flours was similar for all three varieties, but lower compared to the wheat flours. The ash and protein contents were higher in fababean flours than wheat flours. Generally, the proximate composition of all the composite flours studied could be determined from the analytical values of the constituents, flours and the known flour composition.

It is widely known and accepted that the protein (content as well as quality) and Zeleny Sedimentation value of wheat flour are directly related. Both are good indices of breadmaking quality. The Zeleny Sedimentation test is a useful method for estimating the strength of the wheat; therefore, this sedimentation value is influenced both by the quality and the quantity of the gluten. As expected, the strong wheat flour used in this study (Neepawa) had the highest sedimentation value (53 ml), followed by Fredrick (28 ml) and Pitic 62 (16 ml).

In relation to wheat-fababean composite flours, the addition of increasing proportions of fababean flour to wheat flour caused a decrease in Zeleny Sedimentation value, even though the protein content of the composite flours increased. This indicates that fababean proteins do not have the same functionality in the Zeleny Sedimentation test as wheat proteins. These results suggest first; that fababean dilutes wheat flour protein, which is relevant to baking quality, and second; that fababean proteins do not have the breadmaking quality of wheat gluten proteins. This was subsequently confirmed by baking tests.

Dough mixing and rheological measurements related to breadmaking quality were performed on all composite flours studied. Fababean flours produced a gradual change (with increasing proportion of fababean flour) in rheological properties of the dough as measured with the farinograph and extensigraph. Results indicated that doughs containing up to 20% fababean flour with a strong wheat and up to 10% with a weak wheat, would require minor processing changes for bread utilization.

Fababean flours had a negligible effect on amylograph results. The slight decrease in amylograph peak viscosity and farinograph (water) absorption could be attributed to the lower water binding capacity of fababean proteins compared with that of wheat flour. The farinograph results suggest that fababean proteins interfere with dough (gluten) development during mixing. This effect is analogous to the negative effect in the Zeleny Sedimentation test.

Three baking methods were compared and used to measure the baking quality of all the composite flours: the straight-dough method, the modified straight-dough method and the modified sheeting roll method. Poor quality bread was produced with the straight-dough method. With the modified straight-dough method and the modified sheeting roll method, baking results showed that high levels of fababean flour resulted in a decrease in loaf volume and a parallel deterioration in bread quality. However, it was possible to obtain acceptable bread using these two methods. The baking results indicated that the modified straight-dough method should be used with a strong wheat flour in composite flours baking. On the other hand, with a weak wheat flour in composite flours baking with fababean flour, the modified sheeting roll method produced higher quality bread compared to the modified straight-dough method. However, the maximum fababean flour blended with weak wheat should be no more than 10%. For the three fababean varieties, no significant differences among them were detected during baking. However, the results suggest that the variety Ackerperle produced slightly better bread when it was blended with wheat flour.

This study showed that it is possible to make bread from composite flours containing relatively high proportions (up to 20%) of fababean flour blended with a strong wheat flour such as Neepawa, and up to 10% of fababean flour blended with a weak wheat flour such as Fredrick. With Pitic 62, a very weak wheat variety, the baking results obtained by the modified sheeting roll method were quite acceptable.

The study suggests that increasing levels of fababean flour exerts deleterious effects on the breadmaking quality of wheat flour. Variations in standard dough handling procedures could be anticipated from the observed effects in the farinograph, extensigraph and Zeleny Sedimentation test. The use of Emplex as a dough conditioner improved dough handling properties, bread quality, and crumb structure.

It is anticipated that the data presented in this thesis will be helpful in assessing and/or enhancing the utilization potential of fababean flour in composite flours for bread production in countries that have a supply of legumes but lack wheat. However, the extent to which fababean flour will be used in composite flours for successful bread production will depend on consumer acceptance of the bread. Consumer acceptance will, in turn, be related to the quality of bread. Therefore, the ultimate success of fababean in bread production is totally dependent on baking investigations which should include panel tasting and consumer preferance studies in those countries that wish to incorporate fababean flour in composite flours for bread production.

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APPENDIX

Modified Straight-dough Baking Method

Optimum mixing time, water absorption, bromate levels and salt concentrations were determined by experimentation for the modified straight-dough method and are presented in Table 20.

Modified Sheeting Roll Baking Method

Optimum mixer, type of malt, salt concentration, passes through the sheeting rolls, mixing time and Emplex concentration were determined by experimentation for the modified sheeting roll method and are presented in Table 21.

TABLE 20. Bread data for Neepawa, Pitic 62, Neepawa-Ackerperle and Pitic 62-Ackerperle bababean blends baked from doughs by modifying the AACC straight-dough baking procedure

Salt/$KBrO_3$/mixing/baking absorption	Neepawa	Pitic 62	Neepawa-Ackerperle[1]				Pitic 62-Ackerperle			
			95-5	90-10	80-20	70-30	95-5	90-10	80-20	70-30
Treatment	Loaf volume cc	Loaf volume cc	Loaf volume cc				Loaf volume cc			
1% salt, 10 ppm $KBrO_3$	880	360								
1% salt, 20 ppm $KBrO_3$		390								
2% salt, 10 ppm $KBrO_3$		425								
2% salt, 20 ppm $KBrO_3$	900[2] (980)[3]									
1.25 min mixing										280
1.50 min mixing									350	
1.75 min mixing								420		
2.00 min mixing	885[4] (890)[3]	500	830	745	630	530	500	420	350	275
2.50 min mixing		430								
4.00 min mixing	935[4] (980)[3]		925	830	685	565				
Optimum baking abosorption								370		
2% less farinograph absorption								360		
3% less farinograph absorption								350[5]		
4% less farinograph absorption								330		

[1] Optimum baking absorption.

[2] 4% less farinograph absorption.

[3] Equal to farinograph abosorption.

[4] 2% less farinograph absorption.

[5] Best handling results (lowest stickiness).

TABLE 21. Bread data for Neepawa, Fredrick, Neepawa-Ackerperle and Fredrick-Ackerperle fababean blends baked from doughs by modifying the sheeting roll baking procedure

Mixer/malt/salt/sheeting number/ mixing time/Emplex	Neepawa	Fredrick	Neepawa-Ackerperle				Fredrick-Ackerperle			
			95-5	90-10	80-20	70-30	95-5	90-10	80-20	70-30
Treatment	Loaf volume cc	Loaf volume cc	Loaf volume cc				Loaf volume cc			
Domestic mixer (2 min)	820									
GRL mixer (2 min, 69 rpm)	830									
Malt syrup	820	705								
Malt powder	800	690								
1% salt, malt syrup		750								
2% salt, malt syrup		720								
1% salt, malt powder		710								
2% salt, malt powder		705								
15 passes through sheeting rolls	680									
10 passes through sheeting rolls	790	680								
7 passes through sheeting rolls		750								
1.50 min mixing		585	750							
2.00 min mixing	850	540	775							
2.50 min mixing	830		760							
Without Emplex[1]	750	670	745	715	610	460	650	530	400	320
With Emplex (1%)[1]	850	720	840	800	685	565	740	650	500	400

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[1] 10 passes through sheeting rolls (each division).