16 Composite Flours

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16.1 Introduction

In the 1960*s* and 1970*s*, composite flours very often found themselves at the focus of attention in European and international cereal research. Most of the studies in this field were supported by the FAO (Food and Agriculture Organization of the United Nations).

In these two decades, bread consumption increased continuously in many of the developing countries. There were three main reasons for this:

- a steadily growing population;
- changes in eating habits;
- an overall increase in income, which meant that a larger proportion of the income could be spent on food.

In most cases the wheat or wheat flour needed for making bread, rolls and pastry goods had to be imported, since the climatic conditions and soil did not permit wheat to be grown locally, or made it very difficult. In these developing countries the imports of wheat had an increasingly adverse effect on the balance of trade. For these reasons the FAO and these developing countries were interested in the possibility of replacing the wheat needed for making baked goods, and also pasta, wholly or partly with flour obtained from home-grown products. Possible sources were tuberous plants rich in starch such as cassava [23], yams, sweet potatoes, protein-rich flours such as soy and peanuts, and other cereals including maize, rice, millet and sorghum. Although it is well known that no other crop can achieve the baking properties of wheat, composite flours became the subject of numerous studies. For the developing countries the use of composite flours had the following advantages:

- a saving of hard currency;
- promotion of high-yielding, native plant species;
- a better supply of protein for human nutrition;
- better overall use of domestic agriculture production (Berghofer, 2000; Bugusu *et al.*, 2001).

The International Association for Cereal Science and Technology also took up this topic at an early stage (Chatelanat, 1973).

16.2 Definition of Composite Flours

Composite flours are quite different from the ready-mixed flours familiar to millers and bakers. Whereas ready-mixed flours contain all the non-perishable constituents of the recipe for a certain baked product, composite flours are only a mixture of different vegetable flours rich in starch or protein, with or without wheat flour, for certain groups of bakery products. This gives rise to the following definition:

"Composite flours are a mixture of flours from tubers rich in starch (e.g. cassava, yam, sweet potato) and/or protein-rich flours (e.g. soy, peanut) and/or cereals (e.g. maize, rice, millet, buckwheat), with or without wheat flour" [24] .

16.3 Composition of Composite Flours

The goal of earlier research with composite flours was to save the largest possible percentage of wheat flour in the production of certain baked products. The extent to which wheat flour could be replaced by other vegetable flours naturally depended on the nature of the products to be baked.

16.3.1 Bread and Small Baked Goods

Trials with composite flours with and without wheat flour were carried out for this purpose. The composite flours containing wheat flour usually consisted of 70% wheat flour, 25% maize/cassava starch and 5% soy flour. But there were tests in which the composite flour contained no wheat flour at all – for example 70% cassava flour or starch and 30% peanut and/or soy flour.

[23] *Cassava* (lat. Manihot esculenta)*; synonyms tapioca, yuca, manioc*

[24] *Given this definition, rye flour could also be considered as part of composite flours with or without wheat. Probably due to tradition and its importance for breadmaking in the northern hemisphere, it has never been considered as such.*

16.3.2 Pastry Goods

In this field the focus of the tests was on producing hard and soft biscuits, with or without the use of wheat flour. As a rule, the composite flour containing wheat consisted of 70 - 80% wheat flour and 20 - 30% soy flour. In cases where no wheat was included, a mixture of 100% sorghum/millet flour or 50% cassava starch, 20% milk powder and 30% soy flour was used.

16.3.3 Pasta

The best quality was achieved with mixed flours consisting of 60% cassava starch, 15% peanut flour and 25% wheat flour, or 30% maize, 40% soy and 30% wheat. But there were tests in which no wheat flour at all was used – only about 80% pre-gelatinized maize flour and 20% soy flour. In Japan, noodles with or from buck-wheat [25] *(soba)* are a traditional food, so nobody considers them to be made from composite flour, which, by definition, is the case.

16.3.4 Technical Problems at the Bakery

The use of composite flours with or without wheat gives rise to technical problems in the production of baked goods. From the baker's point of view the most important component of wheat flour is the protein of the gluten, that plays a decisive role in dough formation, gas retention and the structure of the crumb. If flour mixtures containing little or no wheat are used, certain tricks have to be employed to achieve a properly leavened product in the end. In 1954 Rotsch, and in 1961 Jongh, pointed out that better dough structures and also better leavening of the bread can be achieved by using substances such as pre-gelatinized flour and/or emulsifiers when working with composite flours with or without wheat. Besides monoglycerides (0.5 - 1.0%), calcium and sodium stearoyl lactylate (CSL and SSL) were used successfully at a dose of 0.5 - 1.0% (flour basis). Carboxymethyl cellulose, alginate, guar, carob gum and also pre-gelatinized potato starch were used as binding agents.
The limit for the addition of cassava/ maize/ rice to wheat flour for bread and small baked products is at least 50 - 80% wheat flour. The percentage depends on the baking quality of the imported wheat flour concerned. In the case of biscuits it is possible to replace wheat flour completely.

16.4 Examples of Recipes for Various Baked Goods Made from Composite Flours

The following are a few typical examples of the numerous recipes published in the 1960*s* and 1970*s*.

16.4.1 Bread and Small Baked Products

Tab. 72 contains a recipe for bread and small baked products based on 70% wheat flour. The flour mixture is supplemented with 25% maize or cassava starch or flour and 5% soy flour. The emulsifier used is CSL in the amount of 0.5% of the total flour. Of course there are recommended recipes in which no flour at all was used. Tab. 73 is a formulation for bread / small baked products based on cassava starch/flour and deoiled soy flour. In this case the emulsifier used was glyceryl monostearate at a dose of 1% of the total amount of flour (Bugusu *et al.*, 2001; Anon., 2000).

Tab. 72: Recipe for bread /small baked products with 70% wheat flour

Component	%
Wheat flour	70
Maize and/or cassava starch/flour	25
Soy flour	5
Sugar	4
Yeast	2
Salt	2
CSL	0.5
Water	50-60

[25] *Buckwheat,* Fagopyrum sagittatum *Gilib. Synonyms: brank, beechwheat, Indian wheat, French. wheat, Saracen corn. Native of Central Asia, now cultivated in China and other Asian countries, Europe and in the U.S. Not a cereal but a knot grass, relative of rhubarb. The dark brown seed enclosing the starchy kernel has a three-sided form, with sharp angles, resembling the triangular Beech-nut, hence the name of the plant, Buckwheat, a corruption of* Boek-weit *(Dutch), meaning "Beech-wheat".*

Tab. 73: Recipe for bread /small baked products without wheat flour

Component	%
Cassava starch/flour	80
Deoiled soy flour	20
Yeast	2
Salt	2
Sugar	2
Glyceryl monostearate	1
Water	55-65

16.4.2 Pastry Goods

Most of the practical trials in the pastry goods sector were carried out with biscuits, since biscuits usually have a long shelf-life. Tab. 74 shows a biscuit recipe with 70% wheat flour and 30% soy flour. The remaining ingredients are the same as in normal biscuit recipes. The emulsifier used was calcium stearoyl lactylate Tab. 75 shows another biscuit recipe without wheat, based this time on 80% sorghum flour and 20% soy flour. At 32% the proportion of sugar is somewhat higher than in Tab. 74, where 25% sugar is used. The emulsifier was again CSL (Jongh, 1961).

16.4.3 Nutritional Value

Do bread types made from composite flours have greater nutritional value than wheat bread? Special nutritional studies were carried out parallel to the development of various types of bread made from composite flours.

Tab. 74: Biscuit recipe with 70% wheat flour

Component	%
Wheat flour	70
Soy flour	30
Baking fat	20
Sugar	25
Syrup	4
Salt	1
Baking powder	2
CSL	1

The trials conducted by Kim and de Ruiter (1968, 1973) from TNO Wageningen, Netherlands, may be considered a typical example. They compared

- conventional white Dutch bread (100% wheat flour)
- cassava (80%) – soy (20%) bread, and
- cassava (80%) – peanut (20%) bread

in feed trials with rats. Among other things they recorded the net protein utilization (NPU), digestibility (D) and the protein efficiency ratio (PER). From the NPU and D, the biological value (BV) was calculated. Tab. 76 shows the most important results. The NPU and D values of the cassava-peanut bread correlated well with the normal white Dutch bread. The cassava-soy bread was superior to the other two bread types due to the better protein quality of the soybean as compared to peanuts and wheat. The PER value was also highest for the cassava-soy bread; as a result, the rats fed with this bread were the heaviest. This leads to the conclusion that the protein quality of bread made from composite flours is superior to that of conventional Dutch white bread. The best values were achieved by the cassava-soy bread.

16.5 Composite Flours in Different Continents

The ingredients used in composite flours must take account of the raw materials available in the country concerned. The objective is to save as much expensive imported wheat as possible when making bakery products.

Tab. 75: Biscuit recipe without wheat flour

Component	%
Sorghum flour	80
Soy flour	20
Baking fat	21
Sugar	32
Inv ert sugar	2
Salt	1
Baking powder	1,5
CSL	1

Tab. 76: Nutritional evaluation of various bread types made from wheat and composite flour

Product	Protein[a],%	NPU[b]	D[c]	BV[d]	PER[e]
White Dutch bread	10.2	48	94	51	2.50
Cassava/soy	10.3	60	92	65	1.26
Cassava/peanut	12.4	49	91	54	0.86

[a] *wet basis*
[b] *net protein utilization*
[c] *digestibility*
[d] *biological value*
[e] *protein efficiency ratio*

16.5.1 South America

In the late 1960s, tests were carried out in Brazil in which 75% wheat flour was mixed with the relevant amounts of potato, maize or cassava flour. The baking tests were conducted on the basis of the Chorleywood bread process. The same flours were used as raw materials for biscuits, but the proportion of wheat flour was reduced to 50%. There is no evidence that these experiments have been put to practical use. A limiting factor is that the use of potassium bromate for treating wheat flours is prohibited (Berghofer, 2000); however, flour improvers containing enzymes are now available as an effective substitute.

16.5.2 Africa

Most of the trials with composite flours have been carried out in this continent because of Africa's continually growing population. Reports are available from Senegal, Niger and Sudan (Berghofer, 2000). In the bread sector the task here was to produce typical French bread with composite flour. The proportion of wheat flour in the different mixtures varied greatly, the maximum being 70%. Because of the difficulty of keeping bread fresh, a great many experiments were carried with composite flours in biscuit production. Biscuits keep longer, and it is no problem to bake them at a central facility and transport them over long distances (Jongh, 1961). So far there are no reports that bread and biscuits have been produced from composite flours to any appreciable extent in an African country. In spite of the lower price, the population is often disinclined to buy such bread because of its unfamiliar flavour and its chewing properties, which differ from those of ordinary white bread. Moreover, there are persistent rumours that many institutions profit financially from imports of wheat, and this would not be the case if locally-grown raw materials were used.

On 1 January 2005 Nigeria enacted a directive that makes the addition of 10% cassava flour to wheat flour mandatory in order to support the local cassava crop and reduce exports of hard currency. Unfortunately, cassava has always been a staple food of the very poor. Since the local growers of cassava roots can by no means satisfy the theoretical demand of the flour mills, at least a temporary shortage with price increases is likely. Moreover, the available cassava flour qualities differ greatly, for example in colour, taste and cyano-glycoside content. So it is still not certain whether this initiative will soon result in the long-term use of cassava flour in wheat flour.

16.5.3 Europe and North America

These two continents produce sufficient quantities of bread cereals, so theoretically they have no need to market and use composite flours at all. But constantly widening ranges of bread and small baked goods and the emergence of certain types of bread as "functional food" have led to an interest in mixtures of wheat flour with other agricultural raw materials (Abdel-Kader, 2000; De Ruiter and Kim, 1969).

Composite flours are an ideal partner in programmes to combat coeliac disease. In making up composite flours it is important to ensure that they contain no wheat, rye, triticale, barley or oats at all. Instead, they may contain products derived from rice, millet or buckwheat, maize or wheat starch, cassava flour and starch, potato starch or soy grits; milk and egg products and also vegetable swelling substances may be used additionally. Even in normal bread production, more and more vegetable substances that are not bread cereals are now being used (e.g. multi-grain bread, oilseed bread).

Fig. 100: Pan bread from composite flour treated with flour improving agents.
All samples treated with ascorbic acid, azodicarbonamide and α-amylase.
(A) 90/10 wheat/cassava (%) + 0.3 % Mulgaprot (mono- and diglycerides co-emulsified with lecithin);
(B) 100 % wheat;
(C) 80/20 wheat cassava + 0.5 % Mulgaprot + 0.1 % DATEM + enzyme mix;
(D) 70/30 wheat cassava + 0.8 % Mulgaprot + 0.16 % DATEM + enzyme mix

16.5.4 Asia

Traditionally, rice and tapioca have been cultivated as carbohydrate sources. Today, in particular India and China are also growing wheat in considerable amounts for human consumption, and all other Asian countries are importing large quantities of wheat. Nevertheless, the traditional crops are sometimes subsidized by the government in order to reduce the demand for hard currency. Therefore, flour from tapioca (tapioca starch) is used to replace wheat flour in some applications, mainly in pastry, if it can contribute to cost reduction.

16.6 Treatment of Composite Flours

158 When bakery products are made from composite flour, their overall quality (odour and flavour, chewing properties, appearance, shelf-life) should be as similar as possible to those of products made from wheat. To achieve this, the wheat flour contained in the composite flour must be suitably treated. The familiar flour improvers potassium bromate and ascorbic acid have proved very satisfactory for this purpose. The amount added must be adjusted to the quality of the wheat flour. As a rule it is between 20 and 50 ppm.

Modern enzyme preparations are also capable of compensating for the loss in volume resulting from the composite flour as compared to pure wheat flour. Hemicellulases and also lipases can be used as well as amylases. Fig. 100 shows the effects of flour improvers on the appearance of pan bread made from a composite flour consisting of wheat flour and up to 30 % cassava flour.

The technical problem for the baker is usually poor dough formation in the mixing and kneading process. Pre-gelatinized starches and certain emulsifiers have proved useful here. Numerous tests have been carried out on the use of emulsifiers (Khalil *et al.*, 2000). Especially in the case of mixtures containing only a small proportion of wheat flour, glyceryl monostearate (1%, flour basis) as an emulsion (GMS:water = 9:1) has proved useful when added during preparation of the dough. Tab. 77 gives an overview of the improvements that are possible in respect of volume when certain emulsifiers and pre-gelatinized starches are used in bread production. Oxidative flour treatment with 25 ppm ascorbic acid was also used in these tests.

Apart from oxidative treatment f.i. with potassium bromate and ascorbic acid, it is also important to use sufficient amounts of water-binding substances such as pre-gelatinized products and to ensure that the wheat flour has optimum baking properties in accordance

Tab. 77: Influence of flour treatment and pre-gelatinized starch on loaf volume of composite flour from cassava starch and wheat flour (50/50 %)

Additive	Dosage, %	Volume, mL/kg flour
No additive		2,600
Gelatinized maize starch	10	3,700
Soy lecithin	4	3,900
Glyceryl monostearate	1	4,300
Calcium stearoyl lactylate	0.8	4,200

with its percentage of the mixture. In addition to monoglycerides, other emulsifiers – CSL and SSL – have proved very satisfactory.

More examples for improvement of baking properties of composite flours are provided by chapter 18.13.4, page 278.

16.7 Rheology of Dough

In nearly all countries the wheat and rye flours used in baking are tested for the rheological properties of the dough. The aim is to achieve the rheological optimum of each dough in the production process. But the extensive literature available makes it plain that doughs made with composite flours cannot be evaluated and classified by the usual rheological methods. Nor does the literature give any indication that specially adjusted rheological methods have been used for evaluating doughs made from composite flours.

16.8 Outlook

In recent years, too, research into optimizing composite flours has continued internationally. There are publications on the use of bean meal in Egyptian *baladi* bread (Abdel-Kader, 2000) and the addition of zein to a mixture of wheat and millet flour (Bugusu *et al.*, 2001). There are numerous research studies on the subject of improving dough rheology (Khalil *et al.*, 2000, Sharma *et al.*, 1999) and the use of pseudo-cereals (Kuhn and Götz, 1999). But so far the composite flours have not achieved a noticeable commercial breakthrough in any country. Success is only to be expected if all the sensory attributes of baked products or pasta made from composite flours differ only slightly from those of the products with which they are compared.

16.9 References

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