Full-Fat Soy Flour

WILLIAM PRINGLE, The British Arkady Co. Ltd., Arkady Soya Mills, Old Trafford, Manchester M16 0NJ, England

ABSTRACT

Full-fat soy flours containing ca. 40% protein and 20% oil are described. Manufacturing procedures as well as nutritional and functional qualities are described.

INTRODUCTION

I start this afternoon's session at the bottom of the ladder. You will be taken higher and higher during the course of the afternoon, but I make my confession now, full-fat soy flours contain only 40% protein.

That may be low for a soy product, but it compares favorably with other foods, as may be seen from Table I.

To produce full-fat flour all that is removed from the bean is the outer seed coat or hull. The two cotyledons, which represent ca. 90% bean, then are milled to a fine particle size.

This may sound like a simple process, but the efficient handling of the flour fractions in the mill requires skill and knowledge. Full-fat soy flour is rather sticky, it can quickly build to a thick layer on the internal surfaces of grinders and conveyors, causing breakdowns and blockages. At least in Europe, the production of full-fat soy flour of high quality has become a specialized business (Fig. 1).

PRODUCTION

We use only good quality beans of North American origin, storing them in our own silos at Manchester's docks and in ancillary silos adjacent to the mill. On intake to the latter silos, the beans pass through a dry cleaning process to remove foreign seeds and other undesirable material.

Before milling the beans are washed to remove any adhering dirt and any small stones which may be present. From the washers the beans pass to modern continuous cookers, which are controlled to give accurate, constant heat processing conditions. I will explain why this is so important later.

After drying, or conditioning, the hulls are removed by a specially designed system of roller mills, sieves, and aspirators to produce pure endosperm. This purified product then is ground in high energy impact grinders, producing a stream of flour which is fed to air classifiers. The coarser fraction is returned to the grinders for further processing and the fine flour proceeds to the packing machine.

The flour conforms to the typical analysis shown in Table II. We find these figures remarkably constant when we use North American beans. The range of figures over the last 5 years is shown in Table III.

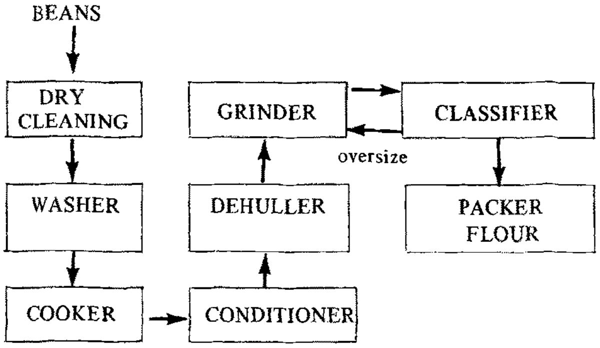

FIG. 1. Soy flour production

So far I have talked about a single soy flour. In practice a range of full-fat flours of the same chemical composition, but with different properties, can be produced depending upon the nature and duration of the cooking process to which the soy has been subjected.

Functional properties, like enzymic activity and absorptive capacity, are influenced by the heating process; and the nutritive value is also critically dependent upon the degree of heat treatment.

From the full spectrum of flours it is possible to make, I would like to describe the two which are commercially most important. They are from the opposite ends of the heat processing spectrum. One has had no heat processing whatsoever, and the second has been subjected to what we consider is the optimum heat processing for maximum nutritive value.

ENZYME ACTIVE SOY FLOUR

This is produced by omitting the cooking stage, consequently the protein is undenatured and has a minimum water solubility of 70%. This flour has all the enzymic activity of the raw bean. Soy flour is a rich source of enzymes containing amylases, lipases, proteinases, urease, and lipoxidase. The lipoxidase enzyme system is of great importance in the use of enzyme active soy in the baking industry. Here it is employed to improve the quality of bread and other yeast raised products.

Two principal effects are noticed. First, there is an improvement in crumb color, which is particularly pronounced when flour which has not been previously chemically bleached is used. The soy lipoxidase enzyme is responsible; it fixes atmospheric oxygen through the formation of hydroperoxides. The oxygen then is utilized to bleach the pigments of the flour. Second, the addition of as little as 0.5-1.0% soy flour (based upon wheat flour wt) will produce a marked improvement in the crumb softness and in the keeping quality of bread. It has been proposed that the improvement in crumb softness also is related to the action of the lipoxidase enzyme, which induces an oxidative improvement in the gluten, the structural protein of the flour.

It is rare to find a bread recipe in England which does not contain full-fat enzyme active soy flour.

HEAT PROCESSED FULL-FAT SOY FLOUR

Our second type of full-fat soy flour undergoes a heating process designed to optimize its nutritive value and also to remove the slightly bitter beany flavor of raw soy flour.

TABLE I

Protein Content of Soy Flour and Other Foods

	Percent protein
Full-fat soy flour	40
Whole eggs	12
Cheese	25
Lean beef	22
Fish	20

TABLE II

Soy Flour Typical Chemical Analysis

	Percentage
Protein (N x 6.25)	40.5
Oil (including 2% lecithin)	20.5
Moisture	6.6
Fiber	2.3
Ash	4.5
Carbohydrate (by difference)	25.6
	100.0

In its raw state soy flour contains a variety of antinutritive factors, including trypsin inhibitors and soybean hemagglutinin. These components of the bean have been the subject of a great deal of scientific scrutiny in recent years; and, when reading the voluminous literature, it is easy to overreact and start worrying. Let us be sure today not to get the subject out of context. In brief, raw soybeans, in common with many other plant materials, contain antinutritive factors; but, by the correct application of heat, soy products become an excellent nutritious feed and foodstuff.

The cooking process is carefully regulated to ensure the best possible protein nutritive value. Too short an exposure to heat will not inactivate all the antinutritive factors. Whereas if it is too prolonged, the soy flour will brown; and there will be a loss in availability of amino acids, in particular lysine.

We pass our soy in a continuous stream traveling at constant speed through a cooker working at above atmospheric pressure.

If the required temperature within the cooker cannot be maintained, because of a failure in the heating system, pressure sensitive devices detect the changed conditions, instantly shutting off the feed and activating an alarm system.

Another important element of process control is a meter which continuously monitors the moisture of beans going to the mill after the conditioning (or drying) process. Experience has shown that unless beans go to the grinders at the right moisture content, the whole of the milling process will run at low efficiency.

Laboratory quality control is used to ensure that the mill process controls are operating in a satisfactory manner and, for certain customers, to provide certificates of analysis covering a consignment. Regular checks are carried out on the following.

Particle Size

For this we use an Alpine Air Sieve to speed the process. Our specification is less than 5% retained on a 200 mesh sieve (this is ca. equal to a particle size of 74μ).

Fiber Content

The amount of fiber in the flour is a measure of the efficiency of the separation of the hulls from the endosperm. Pure endosperm contains ca. 2.0% fiber. The hull contains 50% fiber. We expect our fiber figure to be 2.0-2.3%, that is we expect no more than 10% outer seed coat to end up in the flour.

TABLE III

Range of Analyses of Soy Flour

	Range (last 5 years)	Average
Protein	38.5-43.0	40.7
Oil	19.1-23.0	20.6
Moisture	4.6- 7.7	6.6

TABLE IV

Approximate Fatty Acid Composition of Soy Oil and Butter

Composition	Soy	Butter
	Percentage	
Saturated	18	61
Monounsaturated	23	36
Polyunsaturated	59	3

Microbiology

It is possible to attain extremely high microbiological standards with the heat processed flour, provided regular cleaning and maintenance procedures are adopted in the mill. Our standards are: total count less than 10,000/g, coliforms absent in 1 g, and thermophilic organisms to the standards of the American National Canners Association. In practice we frequently have total counts of less than 1500 (this is using milk agar medium and after 48 hr incubation at 37 C).

Efficiency of Heat Processing

Several techniques are available to check on the efficiency of heat processing. These are described below.

Nitrogen solubility index: Heat denatures the protein of the flour and renders it less soluble in water. As a matter of routine, we carry out determinations of the nitrogen solubility index (NSI), which is a measure of the protein in solution compared to the total protein, and is expressed as a percentage. We expect our flour to be in the range of 15-20%.

Urease determination: The raw soybean is rich in the enzyme urease, which produces ammonia from urea but with increasing levels of heat treatment the enzyme loses activity. The standard method for urease given in the *American Association of Cereal Chemists Methods* depends upon measuring the change in pH resulting from the formation of ammonia when soy flour is incubated with a buffered urea solution. We have adapted this method for use as a quick screening test utilizing a chemical indicator of pH change, bromothymol blue, rather than a pH meter. This method is simple and reliable.

Protein nutritive value: However, urease absence is only a rough indication of adequate heat processing, and doubts have been expressed on how closely it relates to the quality criterion we really are trying to establish–protein nutritive value. We do not feel that a daily determination of protein efficiency ratio (PER) on our product is justified. Breeding all those rats just to slaughter and weigh them would be an awful waste of their time, not to mention our time and our soy. The most significant antinutritive factor is the trypsin inhibitor, and we feel that, if this is reduced to a very low level, we probably have optimized the protein nutritional value of the soy flour. For some time now we have carried out regular trypsin inhibitor determinations. The method involves measuring the activity of trypsin on a synthetic substrate, benzoyl-arginine ethyl ester (BAEE), in the presence of the soy sample. As the reaction proceeds, the

TABLE V

NPU of Different Protein Sources[a]

Sources	NPU
Egg	100
Beef	80
Milk	75
Full-fat, heat processed soy flour	74
Wheat gluten	40
Peas	40

[a]NPU = Net protein utilization.

rate of production of acid is measured; hence, we can arrive at the extent of trypsin inhibition. We hope to reduce the trypsin inhibitor activity in our processed soy flour to less than 0.5% activity in the raw bean.

While discussing soy flour quality I would like to make a point on the keeping quality of full-fat flours. Our full-fat soy flour will keep in excellent condition for long periods. We happily quote a shelf-life of 12 months, given normal, cool, dry storage conditions.

At first sight it is surprising that the highly unsaturated soy oil should not show some deterioration in this time, but we believe that, despite the fineness of grinding, our milling technique has not destroyed the natural cellular structure (the spherosomes which are ca. 0.2-0.5μ in diameter) which contain the soy oil in the endosperm. The natural antioxidants, lecithin and the tocopherols are also present, and these undoubtedly aid the stabilization process.

USES

Time allows for only brief mention of the many uses of the heat processed flour. It has considerable application as a natural emulsifier and stabilizer in many food systems. It is used widely in cake making, thus sparing more expensive ingredients, like egg, fat, and milk. It also stabilizes the structure and gives a softer, moister crumb to the cake and greatly extends its useful shelf-life.

As I have indicated earlier, the excellent nutritive value of optimally processed soy flour is important in many sections of the food industry. Any firm which sells food based upon its nutritive value is interested in soy products. Baby foods, slimming foods, health foods, all contain soy products; and, of course, full-fat soy flour is ideal for many specialized applications in the animal food industry, where young animals are given a high protein, high energy diet for maximum growth.

Soy flour is chiefly of interest because of its protein nutritive value, but we should not neglect the fact that it is quite a good source of vitamins and minerals and an excellent source of a stabilized vegetable oil with a high content of polyunsaturated fatty acids. Table IV shows a comparison between soy oil and butter. Ca. 52% polyunsaturated acid content is linoleic and 7% linolenic. Again this is a useful attribute in the preparation of specialized foods which might interest people on a low cholesterol diet.

The carbohydrate fraction of soy flour still contains some mysteries. Aspinall and his colleagues have identified, but have not completely characterized, three complex polysaccharides, an arabinogalactan, an arabinan, and an acidic polysaccharide resembling the pectic substances found in other plants. These complicated carbohydrates account for more than half of the total carbohydrate content; the remainder is made up of simpler well characterized sugars, sucrose, raffinose, and stachyose. Full-fat flour contains 6.6% sucrose, 1.0% raffinose, and 4.4% stachyose.

Experimental work has shown that only ca. 40% soy flour carbohydrate can be metabolized by monogastric animals. If one takes this into consideration, then the metabolizable energy of full-fat soy is ca. 380 kcal/100 g.

Finally, since this is a protein Conference, I return to the 40% protein in our full-fat flour, protein of high digestibility and excellent value. Net protein utilization (NPU) determinations carried out on our heat processed flour give figures of 74. For comparative purposes, Table V shows the NPU value of some other food proteins.

The NPU (standardized) is that proportion of nitrogen intake which is retained, i.e. $\frac{\text{nitrogen retained}}{\text{nitrogen intake}}$ (with the protein fed at or below maintenance levels). It is the product of biological value and digestibility.

I have deliberately not shown a table giving the essential amino acid composition of soy protein and compared it with whole egg or FAO reference patterns. If I had we would all have drawn the conclusion that soy protein is deficient in the sulphur containing amino acids, cystine and methionine. Mention soy protein to a dietitian, and this is his first comment; but the same dietitian includes milk in everything as a first class protein, never mentioning that the same deficiency is equally apparent in milk!

There is a great danger in always stressing the negative aspects, and at times it seems as if the industry has an obsession about methionine deficiency. The positive aspect of the situation is that an average adult man weighing 65 k could meet his daily protein requirements from 38.4 g protein, NPU value 100 (this is based upon the FAO/WHO Report 301 on protein requirements, which gives a requirement of 0.59 g protein/kg body wt). If the same man consumed only soy protein, NPU value 74, then his requirements should be met from 52.5 g–less than 2 oz./day. Most of us eat at least twice as much protein as this every day.

It really is incumbent on those of us in the soy industry to make sure that there is no misunderstanding on this point. Properly processed soy protein has an equivalent nutritional value to cows' milk. We should make sure the dietitians know.