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Composition and quality of durum wheat mill streams

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SUMMARY

The durum wheat pilot mill, located in Montpellier, INRA, France, is described. As used it allowed us to obtain 16 different mill streams (six semolina, eight flours, and two tailings) with different milling characteristics (yield, ash content). The various mill streams came from the central endosperm, medium endosperm or from the peripheral parts of the kernel.

Very large differences in colour and cooking quality were found between pasta samples processed from the different mill streams, as well as between the extractability and the viscoelastic characteristics of their gluten. The comparison of pasta samples made from semolinas or from flours showed that those from semolinas had better viscoelastic properties but could have had a tendency to stickiness and surface disintegration when overcooked, while, in contrast, pasta processed from flours lacked elasticity but kept remarkable state of surface. The particle size of the mill streams, however, could not explain such differences.

Marked changes in protein solubility were noticed between mill streams originating from the inner and from the outer endosperm respectively. Peripheral fractions possessed a lower solubility of gliadin-type, low-molecular-weight and high-molecular-weight glutenin-type subunits in reducing solvents or in soaps, along with a higher content in both salt-soluble and very insoluble fractions. In contrast, only minor differences could be detected from gliadins and some more from glutenin-subunits electrophoregrams. The amount of salt-soluble-type proteins and the aggregation state of gluten proteins, in relationship to possible difference in lipids and in mineral element content, could impart histological differences in cooking quality of the different mill streams.

1. INTRODUCTION

The purpose of durum wheat milling is to process the endosperm of the durum wheat kernel into a maximum amount of coarse particles called semolina, and not into flour. Therefore, the process of durum wheat milling is very different from bread wheat milling or from milling of other cereals.

Hereafter the main characteristics of durum wheat milling are presented. Technological quality and biochemical composition of mill streams are discussed.

2. DURUM WHEAT MILLING

The anatomical composition of the durum wheat kernel is:

- pericarp 7–8%
- aleurone layer 5–8%
- endosperm 75–80%
- germ (embryo) 2–4%.

During a regular milling, the pericarp and the aleurone layer yield together the bran streams. Semolina streams (particle granulation: between 150 and 500 microns) are yielded by the endosperm but, besides semolina, the endosperm also yields flour streams (particle granulation: below 150 microns). The major part of the germ is usually removed from the kernel, prior to the milling, at the cleaning stage.

A specific characteristic of wheat milling results from the presence of a crease in the kernel. Because of it, the peripherical parts (that is the pericarp and aleurone layer) cannot be separated by an abrasive approach because it is not possible to reach the bran located inside the crease. Thus, instead of starting from the outside by abrasion and going inwards like in the case of rice or sorghum kernel, the wheat millers have first to open the grain, then to remove stepwise the endosperm from the bran, going roughly from the inside to the outside, using break rolls which produce a crushing as well as a shearing action.

Also since the main, and the more valuable, product from durum wheat is semolina and not flour, the durum wheat mill streams cannot be scratched up and separated from brans by sieving only, as in bread wheat and flour technology. Durum wheat milling must therefore be progressive, involving corrugated rolls and allowing separation of semolina at each step. Then the purification of semolina particles has to be carried out both as a function of their size using sifters and of their density using purifiers. The main differences between durum wheat and bread wheat milling are presented in Fig. 1.

The very important role played by the purifiers (that are not used any longer in bread wheat milling) is one of the most striking between milling of the two types of wheats.

The flow diagram of the durum wheat pilot mill used in this study is presented in Fig. 2.

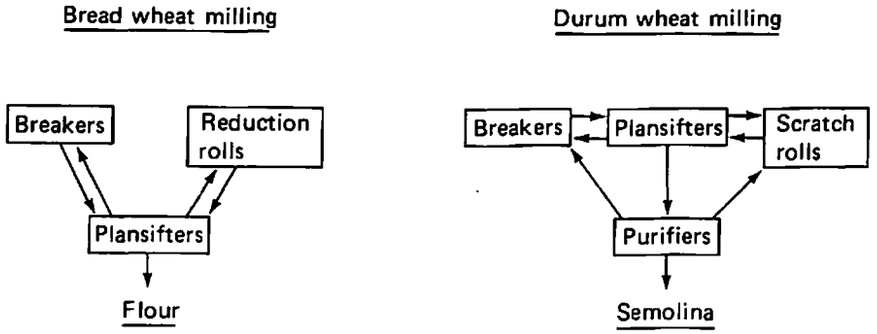


Fig. 1 — Diagram showing the main differences between bread wheat milling and durum wheat milling.

As it can be seen, this diagram allows us to prepare six different semolina streams (S1, S2, S3, S4, S5 and S6), four flour streams from the break rolls (B2, B3, B4 and B5), and four flour streams from the scratch rolls (D1, D2, D3 and D4). According to earlier studies [1] these various mill streams originate from different anatomical layers of the kernel. The best defined fractions are those coming from the central regions (semolina streams S1 and S3 and flour streams B2, B3 and D1) or from the peripheral regions (semolina streams S5 and S6 and flour streams B5 and D4).

The respective yield of the mill streams and their ash content are given in Table 1.

Although there are variations of these values between cultivars, the average yields in semolina and flour are in the order of 70% and 10% respectively, and similar, therefore, to those that are obtained in industrial conditions. Table 1 also shows that, because of the higher mineral content of outer layers of the grain compared to central endosperm, the ash content is higher in the streams that originate from the peripheral parts. This tendency is true within both series of semolina or flour streams, but within a given histological region, flour particles have a much higher ash content than semolina particles, probably because of a different subcellular origin.

3. TECHNOLOGICAL QUALITY OF MILL STREAMS

Colour is one of the most important aspects of quality in durum wheat products. Colour of mill products or of pasta is usually assessed through yellow index and brown index colorimetric determinations. High yellow index and low brown index indicate higher quality. The colour indexes of the various mill streams of Mondur cultivar are given in Table 2.

The results show that in semolina streams, the yellow index decreases for central to peripheral regions while the flour yellow index remains constant. In both semolina and flour, however, the brown index is much higher in the peripheral streams than in the central ones.

Concerning protein content, the highest values are found in the

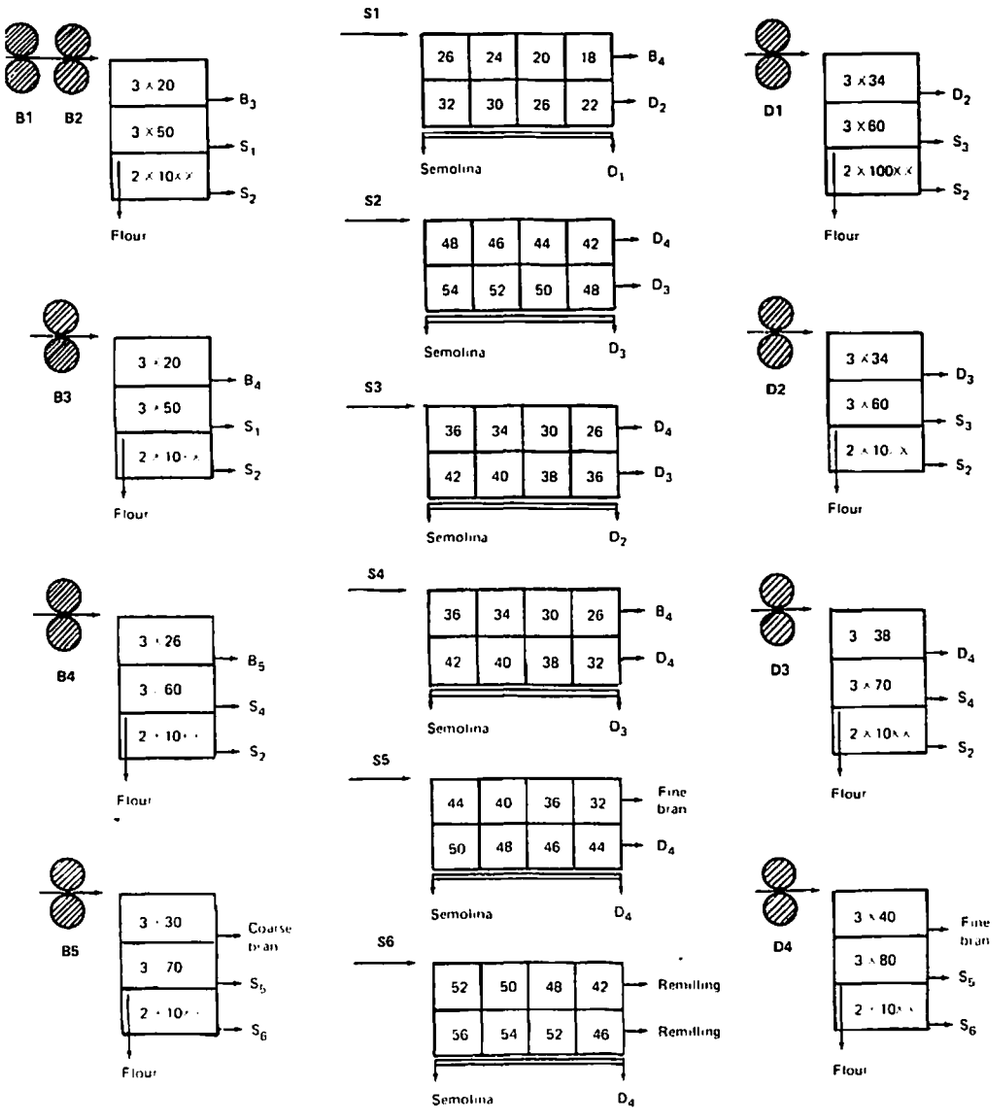


Fig. 2 — Flow diagram of the pilot durum wheat mill used in the Laboratoire de Technologie des Céréales, INRA, Montpellier.

peripheral streams and the lowest in the central ones (Table 3). A similar result can be noticed with semolina gluten content but, interestingly, the flours behave differently: peripheral flours, in spite of their high protein content, have much lower gluten content than flours that originate from central or intermediate regions of the kernel.

Viscoelastic properties of glutens extracted from the various mill streams have been studied (Table 4).

From both semolina and flours, gluten firmness clearly increases from

Table 1 — Yield and ash content of the mill streams

	Semolina streams					Break flours					Scratch rolls flours			
	S1	S2	S3	S4	S5	S6	B2	B3	B4	B5	D1	D2	D3	D4
Yield % db	6.3	18.3	21.0	13.9	1.6	8.6	0.9	1.0	1.1	1.5	0.7	0.8	1.3	4.3
Ash content % db	0.79	0.95	0.67	0.85	1.14	1.34	1.68	1.75	2.19	2.73	1.77	2.22	2.35	2.96

Table 2 — Colouration index of the various mill streams

		Yellow index (b)	Brown index (100-L)
Central parts	Semolina	37.1	17.5
	Flour	32.7	24.0
Intermediate parts	Semolina	36.1	19.1
	Flour	32.1	26.5
Peripheral parts	Semolina	31.9	23.6
	Flour	32.9	31.3

Table 3 — Protein content and gluten content of the mill streams

		Protein (% DB)	Gluten (% DB)
Central parts	Semolina	10.1	12.3
	Flour	11.1	12.9
Intermediate parts	Semolina	11.3	14.8
	Flour	12.4	12.5
Peripheral parts	Semolina	12.5	16.3
	Flour	14.5	7.1

Table 4 — Viscoelastic properties of gluten of the various mills streams.

		Firmness (mm)	Recovery (mm)
Central parts	Semolina	2.42	1.67
	Flour	2.81	1.82
Intermediate parts	Semolina	2.73	1.64
	Flour	3.21	1.64
Peripheral parts	Semolina	2.97	1.52
	Flour	3.55	1.29

central to peripheral fractions. It is especially high in the case of intermediates (3.21 mm) and central (3.55 mm) flours. Interestingly, gluten recovery has an opposite behaviour: it is higher in central streams than in peripheral ones for both semolina and flours.

Table 5 summarizes the cooking quality results obtained on pasta

Table 5 — The cooking quality of pasta made of different mill products

	State of surface	Viscoelasticity
Semolina	4.75	6.1
Flour	7.25	2.9
Ground semolina	3.00	5.4

processed from the different mill streams. Viscoelastic score is much higher with the semolina-made pasta than with the flour-made ones, while state of surface score is higher with pasta made from flour. Neither of these differences are likely to depend on granulometric characteristics of mill products since pasta made from previously re-ground semolina to get the mean particle size of flours, have similar viscoelastic and state of surface scores than the original semolina-made pasta (Table 5).

Such differences in technological quality of these mill streams according to their anatomical origin, as well as differences noticed between semolinas and flours obtained from the same region of the kernel, suggest differences in their biochemical composition.

4. BIOCHEMICAL COMPOSITION OF MILL STREAMS

Proteins were extracted from the various mill streams either by sequential extraction using different solvents, according to Landry [3], or in distilled water in the presence of different amounts of Na-tetradecanoate soap. Subsequently, the extracted protein fractions were electrophoresed in an SDS-PAGE system according to Kobrehel [2].

4.1 Sequential extractions

Table 6 shows the results of a sequential extraction of proteins from a central semolina (S1), a peripheral semolina (S6), a central flour (B2) and a peripheral flour (B5).

Compared to central endosperm, peripheral parts contain much higher contents of salt-soluble fractions (32% in semolina S6 instead of 21% in semolina S1) and much lower contents of ethanol-soluble (gliadin-I) fractions (20% instead of 30%), and ethanol + ME-soluble (gliadin-II) fractions (13.5% instead of 24.5%), while the two subsequent glutenin fractions have higher concentrations in peripheral parts. In addition, within a given histological region, the protein composition is essentially similar between a

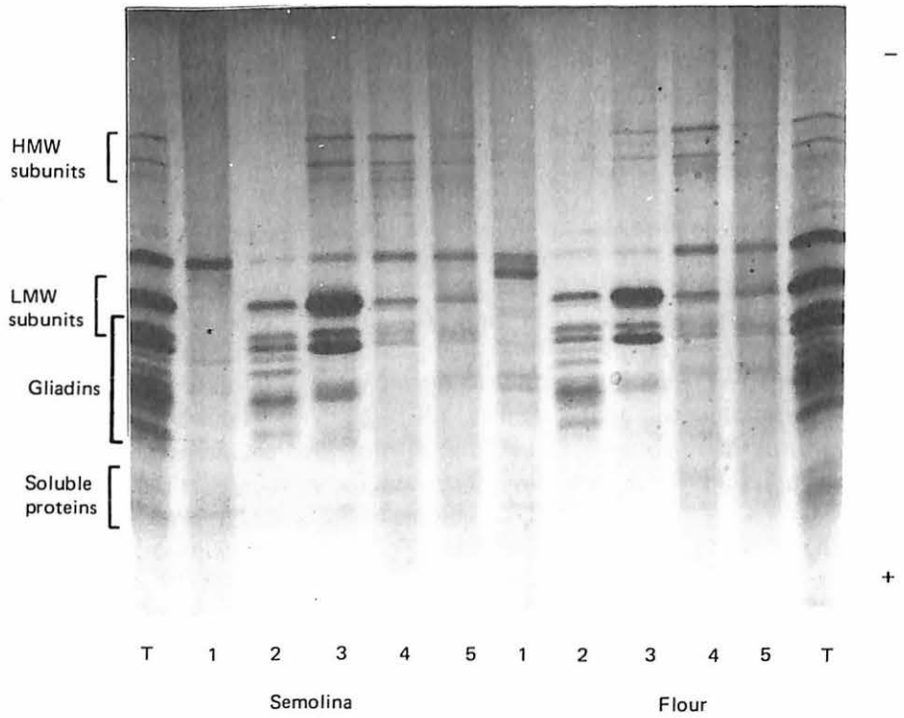
Table 6 Durum wheat milling streams: sequential extraction of proteins (% of total proteins)

	Solvent	NaCl 0.5 M	Et-OH 70% v/v	ET-OH 70% 2-ME†	AC-OH+ 2-ME	SDS+‡ 2-ME	Insoluble residue
	Fraction		Gliadin I	Gliadin II	Glutenin I	Glutenin II	
Central	Semolina	21	30.0	24.5	7.0	9.0	8.5
	Flour	26	27.0	20.0	7.5	12.0	7.5
Peripheral	Semolina	32	20.0	13.5	12.5	13.5	8.5
	Flour	33	20.5	13.5	10.5	15.5	7.0

† 2-ME = 2-mercapto-ethanol
‡ SDS = sodium dodecyl sulphate

semolina and a flour except for a slightly higher content in salt-soluble fractions in flours.

These results are confirmed with further details on SDS-PAGE electrophoregrams of the corresponding protein fractions (Fig. 3).



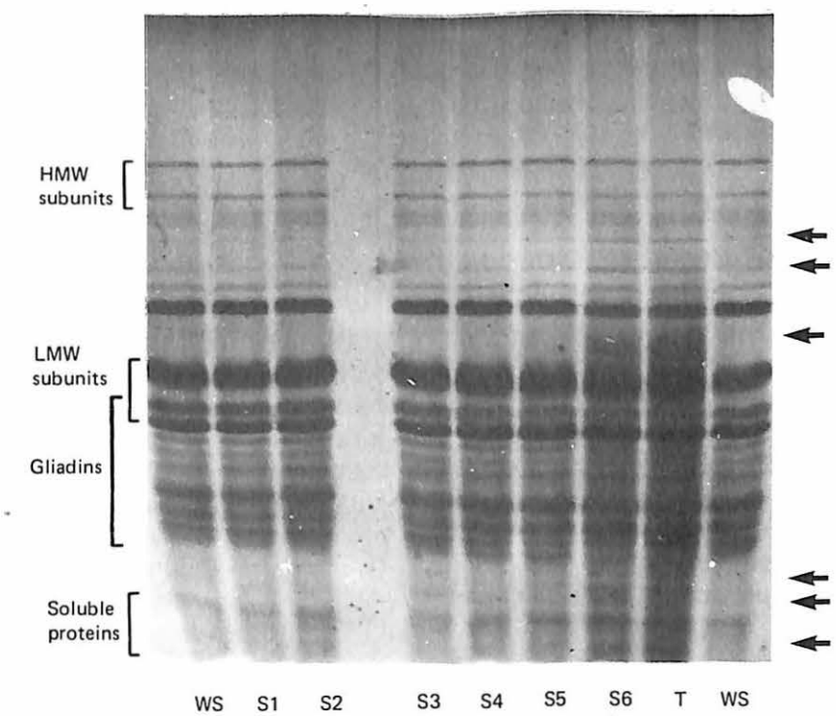
T: Total reduced proteins
1: Salt-soluble proteins (NaCl 0.5 M)
2: Gliadin-I (Ethanol 70 %)
3: Gliadin-II (Ethanol 70 % + ME 0.6 %)
4: Glutenin-I (Acetic acid + ME 0.6 %)
5: Glutenin-II (SDS 1.5 % + ME 0.6 %)

Fig. 3 — Durum wheat milling streams — electrophoretic (SDS-PAGE) characterization of the main proteic fractions.

Gliadin-I fractions have a typical gliadin pattern with major bands in the 35000 to 50000 daltons, while gliadin-II (ethanol + ME-soluble) fractions contain in addition strong low-molecular-weight glutenin subunits in the 45000 to 50000 daltons, plus, in some cases, some high-molecular-weight subunits typical of glutenins. It is especially important to notice that gliadin-II of internal parts of the kernel always contain HMW subunits, whatever

the stream (semolina or flour) and whatever the variety which is considered. Conversely, gliadin-II from peripheral parts never contain HMW subunits, these being extracted in the following (acetic acid + ME) extraction step only. This tends to indicate a higher aggregation level of these subunits in peripheral parts of the durum wheat kernel.

The electrophoretic (SDS-PAGE) composition of the total reduced proteins shows little difference as is shown in Fig. 4. The patterns of the



WS – Whole semolina
S1 – to S6 semolina stram number
T – tailings

Fig. 4 — Durum wheat milling streams — electrophoretic (SDS-PAGE) characterization of total reduced proteins.

various mill streams are essentially the same as the one of whole semolina. The only minor differences that can be noticed are the presence of some more intense high-molecular-weight subunits and of more concentrated medium and fast moving zones in the fractions of outer endosperm. The latter could be related to the higher content in salt-soluble fractions.

4.2 Soap extractions

When proteins are solubilized in distilled water in the presence of various amounts of Na-tetradecanoate, important differences can be noticed between the mill streams. An electrophoretic (SDS-PAGE) comparison of the extracted proteins is shown in Fig. 5.

It turns out that HMW subunits are solubilized at lower soap concentration in the case of semolina S3 than in the case of semolina S6, and that similar solubility characteristics appear for some gliadin-type or LMW glutenin subunits. Also, qualitative differences have been noticed which concern mostly the fast-moving components. When a central fraction, like S3, is compared to a peripheral fraction, like D4, the differences become much more important as illustrated on Fig. 6 where the proteins of both samples have been solubilized with 80 mg of Na-tetradecanoate per gram of semolina or flour.

5. CONCLUSIONS

Considerable differences in quality exist between different mill streams. These differences concern pasta colour as well as pasta cooking quality. Semolina gives pasta with good viscoelastic properties but with a tendency to surface disintegration when overcooked. Conversely, pasta processed from flours lacked elasticity but kept a remarkable aspect of surface and these differences cannot be related to the particle size of the products.

It is assumed that the various quantitative and qualitative differences in the protein solubility and electrophoretic composition may be the origin, at least partly, of the differences in technological quality between the different mill streams.

For example, peripheral fractions possess a lower solubility in gliadin-type, LMW- and HMW-type glutenin subunits in reducing solvents or in soaps, along with a higher content in both salt-soluble and very insoluble fractions. Therefore, a more aggregated state of gluten proteins seem to characterize mill streams that originate from outer endosperm, which could explain higher gluten firmness and higher state of surface score of cooked pasta. The solubility behaviour could, however, be related to other components present in higher concentration in outer endosperm such as lipids and mineral elements.

On the other hand, the quality differences that have been noticed between different mill streams (semolinas or flours) coming from a given histological layer remain unexplained. More basic (biochemical and subcellular) investigations are necessary to elucidate this question.

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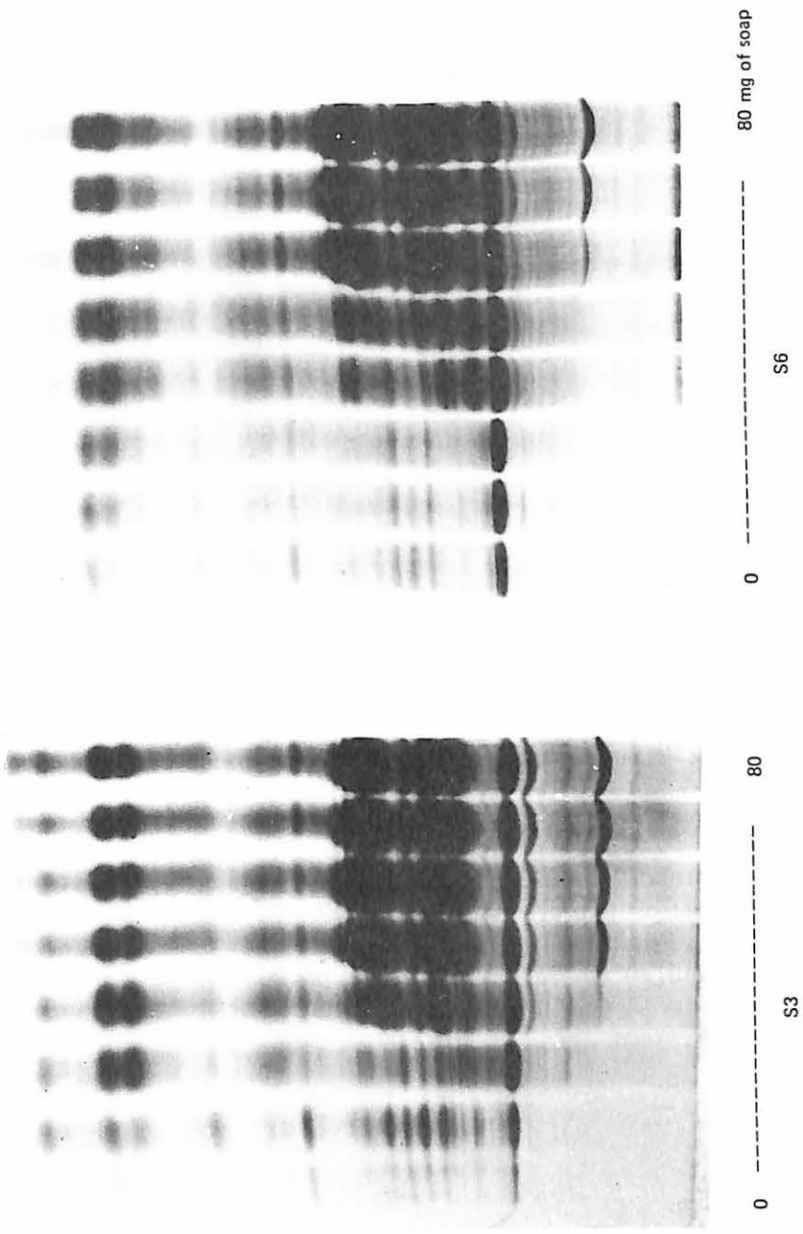

Fig. 5 — Compensation of semolina streams (S3 and S6) proteins solubilized with increasing amounts of soap (SDS-PAGE electrophoresis).

Fig. 6 — Composition of semolina (S3) and flour (D4) proteins solubilized with soap (SDS-PAGE electrophoresis).

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