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SUMMARY - The durum wheat milling process has specific characteristics. Some conditions influence semolina yield (i.e. good semolina yield ratio and quality): (i) genetic and physiologic properties of *Triticum durum* crop; (ii) physico-chemical characteristics of grain; (iii) qualities of milling products: semolina; (iv) economic conditions; (v) environment and working hygienic conditions. In line with these items the kind of milling processes will change, even though there are common sections. The durum wheat milling process could be defined as: "Grain, with very hard texture, is cleaned severely, tempered in three steps, milled gradually into large particles of similar size, and finally cleaned of seed coats".

Key words: Durum milling, clean diagram, grinding diagram, tempering, technological quality, new processes.

RESUME *- "Processus de mouture du blé dur". La mouture de blé dur a des caractéristiques spécifiques. Certaines conditions ont une influence dans l'extraction des semoules, selon la proportion de semoules de qualité et le blé dur utilisé : (i) les caractéristiques génétiques et physiologiques de Triticum durum; (ii) les propriétés physiques et chimiques du blé; (iii) les qualités technologiques des produits de mouture : semoules; (iv) les conditions économiques; (v) les facteurs de l'environnement et les conditions hygiéniques du travail. En accord avec ces conditions requises la mouture changera selon les semouleries et les utilisations finales, bien qu'il y ait sections et processus communs. Le processus de mouture de blé dur pourrait être défini comme suit : "Le grain, avec une texture d'amande peu friable, est nettoyé avec beaucoup d'attention, ensuite préparé pour la mouture après mouillage pendant trois étapes et les repos correspondants et en dernier lieu broyé peu à peu en grandes particules de dimensions similaires qui sont séparées des enveloppes par différentes opérations".*

Mots-clés : *Mouture du blé dur, diagramme de nettoyage, diagramme de broyage, mouillage, qualité technologique, nouveaux processus.*

Introduction

Durum wheat is a very important crop in the Mediterranean region, but its uses are very variable. Thus, while in European countries it is almost completely used in the elaboration of pasta products, in the Middle East and North Africa it is used equally for breadmaking process and for pasta, couscous, bulgur and other various uses (Bozzini, 1988). With regard to these uses, durum wheat must have different technological properties and several transformation processes.

Objective of milling and technological quality of durum wheat

Two are the main objectives of commercial milling of durum wheat: (i) to reach the highest mill yield; and (ii) to satisfy the needs and requirements of the customers. Consequently, an ideal durum wheat should have good technological qualities and yield adequate semolina when milled. Although customers need semolina with specific qualities to be used in different processes (for pasta, couscous, bread and bulgur products), there are common properties or technological qualities that wheat must have. On the other hand, some technological properties of semolina can be affected by the milling process. All properties of wheat and semolina defines the "technological quality of durum wheat and semolina", also known as "durum wheat milling value" and "pasta value" respectively (Abecassis *et al.*, 1990).

The durum wheat milling value is determined by the amount of extracted semolina with good technological properties. This ratio could be influenced by some of following features:

(i) Moisture content of grain must be the lowest possible.

(ii) Impurities and foreign seeds have negative incidence on yield.

(iii) Due to the long shape, hard texture and low moisture of the durum wheat kernel it is broken during the harvest; these broken kernels are not easy to recover during cleaning process.

(iv) Small grains are not valid for milling due to the low endosperm/seed coat proportion.

(v) The size of all grains must be always similar.

(vi) Sprouted grains could yield pastas with bad cooking qualities.

(vii) Hard texture is a genetic characteristic related to the compactness of endosperm and the presence of starch protein strong links. The absence of a protein, named 15K protein, on the surface of the starch granules of durum wheat (Greenwell and Schofield, 1986) could be responsible for its harder texture. The break of endosperm would be easier across the starch granules yielding semolinas, whose size should be in the range between 300-400 µm to satisfy industry demand (Fig. 1).

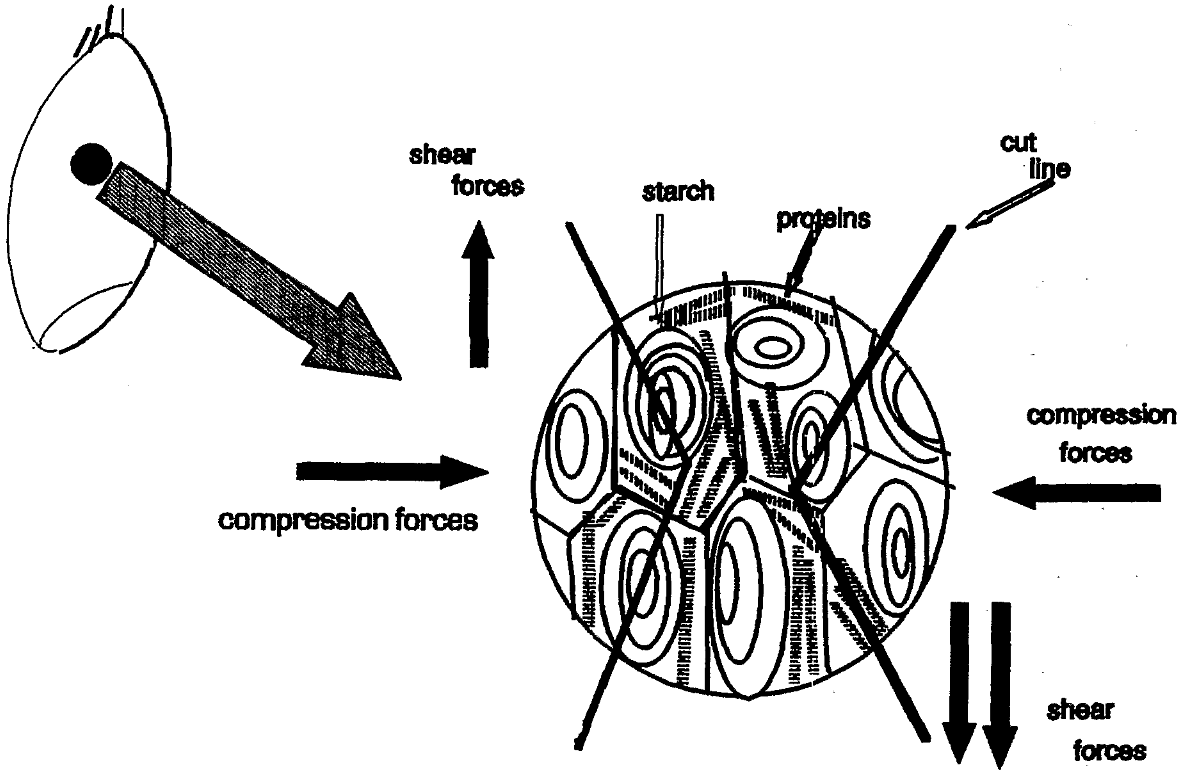

Fig. 1. The endosperm is broken mainly across the starch granules. The arrows represent the forces that act on the endosperm during the grinding.

(viii) As proposed by Dionigi (1962) and Henson and Waines (1983), there is a strong correlation between nitrogen availability in the soil, the transfer of nitrogen products from leaves and stems to kernel and the amount of endosperm protein. When light interacts with protein rich and compact endosperm it is diffracted, giving it a vitreous aspect; whereas protein poor endosperm reflects light, reaching a white appearance. Consequently, vitreous aspect and hard texture are strongly associated and correlate with high yield of semolina.

(ix) A large and protuberant germ allows a good milling, because it is removed while the grain is cleaned. The germ can not only contaminate and darken the semolina but also its lipoxigenase can oxidize carotenoids, changing the yellow colour of the product.

(x) When the seed coat and endosperm are morphologically detached, the purification of semolina is very easy.

(xi) The brown colour of grain is usually related with semolinas of good yellow colour.

(xii) The ash content is, perhaps, the most important characteristic, because it is regulated in several countries. It has been demonstrated that the ash content is associated with a larger extraction. But it is demonstrated that the ash content depends not only on efficiency of the milling process but also on the type of wheat. Moreover, ash content is also irregularly distributed into the kernel (Abecassis and Feillet, 1985). In fact, the gradient of ash abundance between endosperm and peripheral parts of grain is twice higher in bread wheat than in durum wheat (Abecassis, 1991).

(xiii) The protein content is related to weight and pasta values as well as pasta aspects (specks, colour, fissures, surface texture) and cooking qualities (firmness, stickiness, cooking strength, colour, flavour, aroma), however these points will not be discussed in this paper.

Milling process

The procedure more widely used in the world is based on the opening of grain and the recovering, step by step, of the endosperm, going gradually from the inner to the outer part of grain.

The main steps of the overall process are shown in Fig. 2. The II and III phases, cleaning and milling, are defined as "diagrams" (Bizzarri and Morelli, 1988). The different ways that wheat and its products follow, depend on the final use of semolina. The yield of the process is usually about 65-72%.

Cleaning and conditioning of wheat

Firstly, wheat is receptioned, analyzed and precleaned. Afterwards it is classified and stored according to the following parameters: endosperm texture, vitreous appearance, protein, ash and moisture contents. The precleaning process eliminates most of the larger impurities (sand, leaves, stones, wet stems, etc.), so that, the grain is best stored and preserved. Wheat release and flow from bins and silos must be controlled to guarantee specific characteristics of mixture previously defined. This flow must also be fitted to cleaning, tempering and milling capacities.

Cleaning is a very important phase whose control represents a main objective. During the cleaning process, several impurities and foreign seeds are eliminated according to the shape, dimension, density and weight. The cleaning must be effective because the dimension of semolina particles is as large as some impurities, and these could be mixed with semolina.

The cleaning process is adapted to the type of wheat. The number of cleaning machines and their positions change according to the mill and the wheat origin, depending on the kind and amount of its impurities.

The flow process chart of standard first cleaning (Fig. 3), includes the following machines:

(i) Weigher and magnetic apparatus.

(ii) Sieving machine with aspiration channel to separate all the impurities of different dimensions from wheat.

(iii) Concentrator to select a heavy fraction (70%) and a light fraction (30%) containing ergot. The heavy fraction is directed towards a destoner to remove stones in order to protect the corrugation of the rolls and to obtain perfectly cleaned semolina with low ash content; this step also avoids the damage to presses used to produce pasta. The light fraction is transported to a specific gravity separator which removes ergot. The healthy grains that flow from the specific gravity separator are directed to a scourer where the outer layers are cleaned and some germs are removed. The grains the pass through a cockle cylinder, a recockle cylinder and a spiral separator to recover round particles and grains.

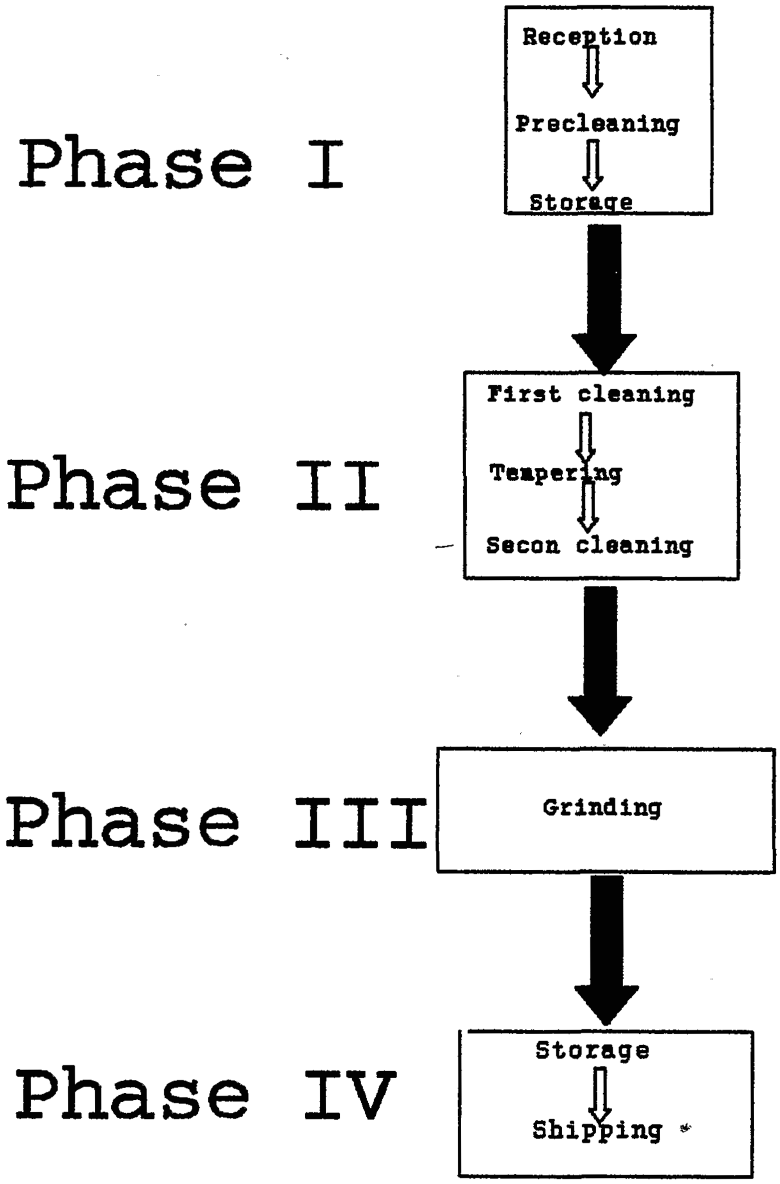

Fig. 2. Phases of general process to transform durum wheats.

(iv) The broken kernels which can reach 3%, are difficult to recover on the helicoidal separators and they flow together with vetch seed and other round particles. A specific gravity separator is used to remove the former.

The wheat conditioning for milling consists of two processes: damping and tempering. The water is added and has to penetrate into the grain. The goal is to modify endosperm and seed coat textures to yield large semolina and bran without endosperm, with minimal power consumption.

The amount of added water and the tempering time depend on initial moisture, temperature and endosperm structure-texture. As the end moisture is 16-17.5% and the initial moisture 7-8%, the water should be added in two steps, a first one to modify endosperm and a second step to prepare the seed coat before the break. The whole time of tempering is approximately 9-10 hours (first step 4 h, second step 5 h, third step 30 min). This type of damping and tempering gives an ideal distribution of water into durum wheat. Water addition is controlled by automatic systems; the flow of wheat is fitted by means of smaller bins. The tempering takes place when the wet grains are stored into specific bins.

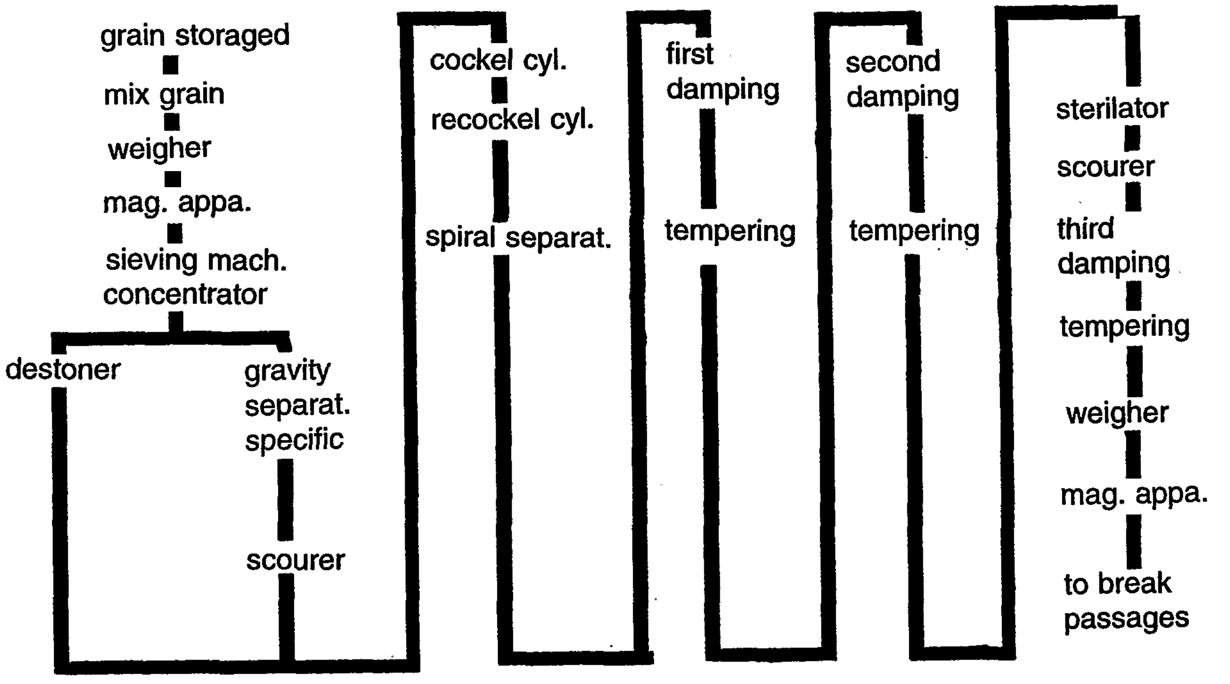

Fig. 3. First cleaning, damping, tempering and second cleaning of durum wheat conditioning to milling.

Milling

The conventional milling should be gradual. Fig. 4 shows the main flows of products. First of all, the prepared grain passes between the corrugated rolls (breaking passage). The mixture of products of various sizes have to be sorted in the plansifter. Afterwards, products are selected in the purifiers in several qualities according to their size.

The first pure semolinas can be obtained here. The purer semolinas are further classified by size; the fine semolinas are stored directly and the gross semolinas are channelled to reduction passages, where they are reduced to regular semolina. The semolina with adherent seed coats are directed to the last breaking passages or to detach passage with corrugated rolls; this passage has the purpose of obtaining the semolina free of seed coats. Following several size and quality selections they yield purer semolina. Some diagrams have special reduction passages to transform the semolina with a lot of proportion of attached bran.

The mechanical conditions as well as the disposition and number of machines and passages change according to the process. The break passage must work to produce minimal flours and the largest semolinas to facilitate the work of purifiers. The number of break passages are six, subdivided into coarse and fine from the fourth break. The diagram is completed with six corrugated detaching passages, eighteen purifiers and three or four reduction passages (Fig. 5).

The technical characteristics are specific to produce good semolinas (Instituto de Molinería e Industrias Cerealistas, 1983; Abecassis, 1991): (i) main positions sharp to sharp of corrugates; some times are used to B1 and B2, the position back to back; (ii) lesser diameter rolls to reduce the milling place; (iii) ratios between the speed of rolls of 1:2 to decrease the shear effect; (iv) the sharp angles of corrugates are 25-30° and the back angles are 60-65°; (v) little load to avoid strong press on the products; (vi) the number of corrugates/cm is: in breaking passages 3.5-9.6, in detaching passages 7-10.5 and in reduction passages 8.5-9.5; (vii) the slopes of corrugates are 8-12% for breaking, 10-12% for detaching and 12% for reduction passages, respectively.

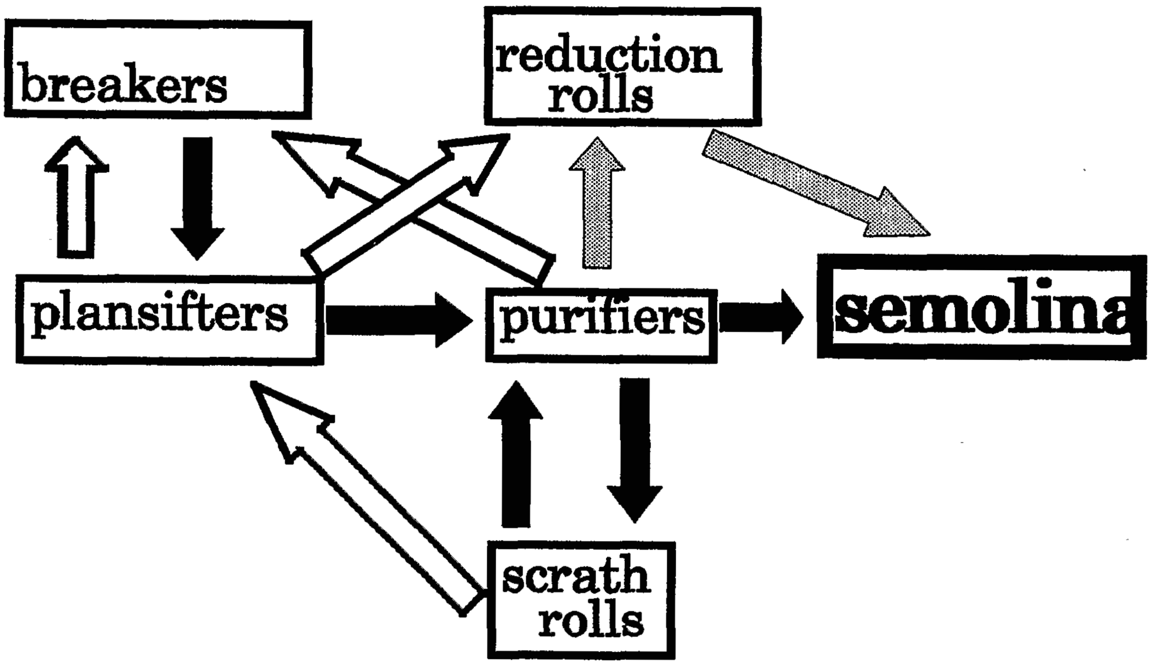

Fig. 4. Schematic graphic of principal products flow of milling.

The passages, plansifters and purifiers have specific values that determine the characteristics of grinding diagram (Instituto de Molinería e Industrias Cerealistas, 1983): (i) specific lengths of rolls: breakings 4.5-10 mm 100 kg^{-1} 24 h^{-1}; detaching 3-8 mm 100 kg^{-1} 24 h^{-1}; reductions 0.8-2.5 mm 100 kg^{-1} 24 h^{-1}; semolina reductions 1-2.5 mm 100 kg^{-1} 24 h^{-1}; (ii) specific sifting surface: 0.07-0.085 m^2 100 kg^{-1} 24 h^{-1}; (iii) specific size of purifiers sieve: 5.5-8 mm 100 kg^{-1} 24 h^{-1}.

To obtain gross semolina for producing couscous, the diagram is modified in order to classify by means of purifiers and detached passages, step by step, the gross semolinas (1300-500 µm) which are obtained in breaks rolls.

As the semolina is attacked by several insects, the milling process must be completely hygienic. The semolinas cannot pass across the sterilizer because flour would be produced under those conditions. In these cases, the semolina can only be stored for a short time. Semolina flows from the bins without using any extraction mechanism, because its size avoids compacting and makes it unnecessary.

In some North African countries durum wheat is milled by bread wheat or mix diagrams. The little mills with milling stones are also very used.

Quality control

The milling process must be controlled by laboratory and statistical analysis of wheat, intermediate and finished products, as well as of the milling work methodology.

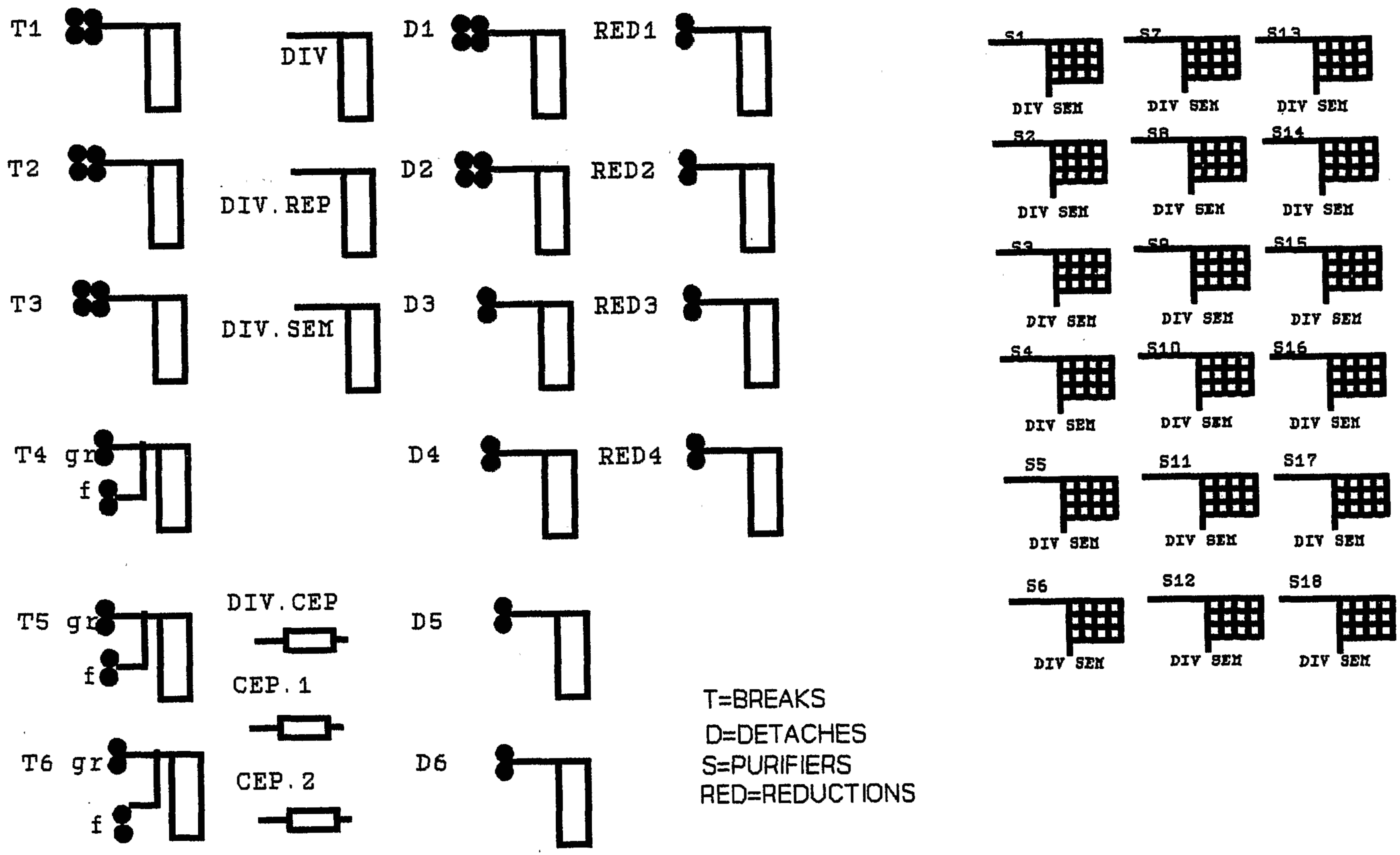

Fig. 5. Schematic grinding flow diagram of durum wheat.

Conclusions and perspectives

Milling of durum wheat is a special and expensive procedure due to the required high quality of durum wheat, and the long, laborious and specific transformation process. The future actions must consider these facts and be focused to satisfy the needs of pasta industries and the taste of consumers

The slow, although constant, increase of consumption of durum wheat forces to optimize and to improve the results. Some technological aspects of durum wheats (irregular ash content, relatively great amount of impurities, uncertain hard texture and vitreousness aspect, strong interaction seed coat-endosperm, morphology of outer layer, protein content and quality) must be better controlled.

With regard to milling process properly, there are old and new needs, such as the yield improvement, or the obtaining of smaller semolina. Some new, experimental and innovative milling processes are now developing (Satake, 1990; Tkac, 1992). With small differences, they are based on a grain preprocess phase that consist in the debranning of grain by sequential friction and abrasion passages using modified rice polishers. The endosperm is then after grided. It seems that these new processes offer a milling yield advantage, but a disadvantage is that they require a lot of power for preprocessing. The application to durum wheats is in a early phase.

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