Durum Wheat, semolina and pasta quality characteristics for an Italian food company

Landi A.

in

Di Fonzo N. (ed.), Kaan F. (ed.), Nachit M. (ed.).
Durum wheat quality in the Mediterranean region

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 22

1995
pages 33-42

Durum wheat, semolina and pasta quality characteristics for an Italian food company

A. LANDI
BARILLA G. e R. F.lli
SOCIETA PER AZIONI
PARMA
ITALY

SUMMARY - Barilla, the first company in Europe and in the world in the production of semolina pasta, presented lists of the most important parameters for the definition of wheat, semolina and pasta quality, and the analytical methods for their determination. Further, the description of the technologies in modern mills, the influence of milling operations on semolina quality, the most advanced technologies in the pasta drying process and their influence on pasta quality were also presented. Finally, the nutritional characteristics of pasta and their contribution to the modern diet were discussed.

Key words: Durum wheat, quality, semolina, egg pasta, pasta drying technology.

***RESUME -** "Caractéristiques de qualité du blé dur, de la semoule et des pâtes pour une société alimentaire italienne". Barilla, la première société en Europe et dans le monde pour la production de pâtes de blé dur, dresse une liste des plus importants paramètres pour la définition de la qualité des blés, des semoules et des pâtes, et des méthodes analytiques pour les déterminer. Ensuite elle décrit les technologies des moulins modernes, l'influence de la mouture sur la qualité des semoules, les technologies les plus avancées dans les processus de séchage des pâtes et leur influence sur la qualité du produit fini. Enfin, l'auteur illustre les caractéristiques nutritionnelles des pâtes et leur contribution à l'alimentation moderne.*

***Mots-clés :** Blé dur, qualité, pâtes de semoule, pâtes aux oeufs, technologie de séchage des pâtes.*

Introduction

Barilla is the world's leading producer of pastas: semolina pasta, egg pasta and pasta with meat, cheese and vegetable fillings. The company has been in the pasta industry for more than eighty years and saw its major growth in the nineteen fifties and sixties. 1970 marked a high point for the company with the construction of a pasta production plant at Parma, Italy, capable of producing 1,200 tons per day, the largest facility of its kind in the world. In 1992, Barilla, together with its associates Voiello, Braibanti, Rio (Spain) and Misko (Greece), produced 540,000 tons of pasta, divided as follows: (i) 490,000 tons of dry semolina pasta; (ii) 41,000 tons of dry semolina egg pasta; (iii) 6,000 tons of dry semolina egg pasta with meat, vegetable and cheese fillings; (iv) 3,000 tons of fresh semolina egg pasta with meat, vegetable and cheese fillings.

Barilla is the market leader in Italy, with a 35% market share for semolina pasta and a 40% share in the egg pasta sector; the company already has more than 10% of the fresh pasta market even though it only entered this sector two years ago. Barilla produces pasta in 9 factories: 7 in Italy, one in Spain and one in Greece.

Barilla is also a large milling company, directly processing durum wheat to meet its own requirements. The company is the owner of 4 mills and the sole manager of a further mill and these facilities have a daily turnout of 1,560 tons. In 1992 Barilla purchased 480,000 tons of durum wheat. In the same year, in order to make up its requirements, the company purchased 180,000 tons of semolina on the market. On the durum wheat market therefore, Barilla consumes approximately 700,000 tons: 600,000 tons from Italy; 50,000 tons from North America; and 85,000 tons from France, Greece and Spain.

The cultivation of durum wheat originally started in some countries of the Mediterranean basin. Cultivation subsequently spread to North America and today the United States and Canada are one of the major producers. In the last forty years there has been a gradual expansion in durum wheat cultivation in the Southern-Eastern and North-Western areas of the Mediterranean. These historical movements have enabled the development of wheat varieties suited to colder, more humid climates. Table 1 shows the production of the world's major producers.

Table 1. World production of durum wheat (millions tons)

Country	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94 forecast
EEC	7,5	7,0	6,5	7,4	10,6	8,1	6,4
Italy	4,4	3,9	3,5	3,8	4,6	4,0	3,7
France	1,4	1,2	1,4	1,9	2,5	1,9	1,0
Greece	1,2	1,4	0,9	1,0	2,2	1,0	0,9
Spain	0,3	0,3	0,5	0,5	1,1	1,1	0,7
Others	0,2	0,2	0,1	0,2	0,2	0,1	0,1
Canada	4,0	2,0	4,1	4,3	4,6	3,1	2,9
USA	2,5	1,2	2,5	3,3	2,8	2,6	2,2
Turkey	6,0	4,0	5,5	5,5	5,0	4,0	4,2
South America	0,1	0,1	0,1	0,1	0,1	0,1	0,1
North Africa	3,1	2,4	3,0	3,1	4,8	3,3	3,4
Others	5,5	5,8	5,3	5,4	5,8	5,7	5,7

History, tradition and quality requirements make durum wheat ideally suited for the production of pasta. In the years immediately following the Second World War, the need to meet food shortages and the state of development of agriculture lead to the production of large quantities of pasta made from bread wheat flour. The traditional cereal production of the nineteen fifties returned durum wheat to its rightful place even to the extent that some countries (Italy, France and Greece) legally established that pasta could only be made with durum wheat and that the use of other undeclared cereals in pasta production constituted fraud. Other countries, such as Spain, the United States and Canada do not have such laws but by tradition and choice almost exclusively consume pasta made with durum wheat.

This is mainly due to the fact that only durum wheat has all the necessary qualities required to make pasta. This will continue to be the case despite the recent decision of the Luxembourg courts. Although, the EEC has authorized the sale throughout the Common Market of pastas which conform to the legislation of member countries in which the sale of pastas made from bread wheat flour. However, the consumer choice will continue to decide about the better quality product.

Barilla's consumer strategy has always emphasized quality and service. All raw materials are therefore subject to constant research to define quality parameters and to ensure that finished products meet the quality standards specified by the company.

Quality characteristics of pasta

The qualities that pasta must have in order to meet the criteria and expectations of Italian consumers are as follows: (i) a uniform, amber-yellow colour without shades of grey or red; (ii) a clean surface appearance without brown, black or white spots or other signs indicating faulty milling; (iii) when cooked, pasta must not be glutinous on the surface i.e. stick together, but should have good ribbing and resistance to mastication; (iv) a pleasant aroma and taste typical to pasta; (v) practically zero contamination from chemical pesticides and preservatives.

All these characteristics can be measured using instruments, organoleptic and taste tests and constitute the basic requirements for a quality Italian pasta. To produce pastas with these characteristics requires: (i) raw materials with the characteristics needed to guarantee the final quality required; (ii) suitable, modern technologies for processing raw materials; (iii) production and human resource management systems focused on quality and systems which therefore involve personnel at all levels in the attainment of quality objectives. At Barilla this system is known as Integrated Production Process Management. Developed at the end of the eighties this system now directly involves 2,500 persons employed in the company's various facilities.

Years of research have shown that pasta resistance to cooking stems mainly from three factors: (i) a high protein content, or rather, a high content of total nitrogenous substances; (ii) high gluten strength and elasticity; (iii) a pasta drying cycle at temperatures above 80°C so that semolina starches undergo changes which prevent their release from the structure; this prevents the formation of a sticky surface.

In 1980, our Research Department developed a mathematical formula based on multiple correlation. The formula is significant and reliable in 95% of cases and enables our personnel to predict the cooked quality, or Pasta Value, of durum wheat and semolina as a function of their protein and gluten contents:

$$\text{Pasta Value} = K + 2GLU + 0.04W + 8.5P/L - 2(P/L)^2$$

where:

Pasta Value	was based on a scale from 0 to 100 points; a good quality pasta is one which scores more than 80 points.
2GLU	amount of dry gluten per 100 parts, extracted from the semolina by milling durum wheat in a pilot or industrial mill; this factor can be substituted by the amount of dry protein in dry matter (expressed as nitrogen x 5.70) of the semolina multiplied by a coefficient of 1.85.
0.04W	typical Chopin alveogram value.
$8.5P/L - 2(P/L)^2$	typical Chopin alveogram value strength.
K	numerical factor whose value depends on the temperature of the drying cycle used in pasta production; for example, in drying cycles at 80-85°C this factor is 42 ± 2 and for a 85-90°C drying cycle K is 47 ± 2.

In order to clarify this concept for judging wheat quality. Examples of numerical values for high and medium quality wheats are given as follows:

	High quality	Medium quality
protein %/dry matter (N x 5.70)	>15.00	13.00-15.00
gluten %/dry matter	>14.00	12.00-14.00
W alveogram	>250	150-250
P/L alveogram	1.5-2.5	0.5-1.5

Given that protein substances play a leading role in defining quality, considerable research is going on to identify those protein structures that are particularly linked to cooking quality. It seems virtually certain that some groups of gliadin and glutenin proteins are more important than others on this point. Current research is attempting to identify and quantify these groups and this could make it possible for geneticists to improve durum wheat quality by introducing these protein groups using proven bio-engineering techniques. This could produce new varieties of durum wheat with very high pasta values.

It is well known that the amber-yellow colour of semolina is due to the presence in wheat of natural pigments from the carotenoid and xanthophyll families. As these pigments increase, the yellow colour detected by the human eye becomes brighter and more vivid. At the same time, it is also known that semolinas with a high pigment content do not always produce very yellow pasta. This is because carotenoids and xanthophylls have components which are affected by several oxidizing enzymes. From this we can conclude that it is important to have a durum wheat with a low content of the enzymes exercising this negative action.

Two instrumental methods for measuring the colour of semolina and pasta are used: (i) extraction of carotenoid and xanthophyll pigments and measurement of these using transmitted-light colorimetry; (ii) direct measurement of the yellow index of semolina and pasta using reflected-light colorimetry.

The real numeric values of colour for high and medium quality semolina should make the concept clearer:

Pigment content	High quality	Medium quality
β-carotene (ppm/dry matter)	>5	3-5
Yellow index	>23.5	19.0-23.5

The presence of brown coloured bran specks and other foreign bodies of various colours, mainly red and black, can be measured by counting the number of points or specks per square decimeter of semolina surface, with the aid of a magnifying glass and a constant light source. The appearance data for high and medium quality pasta are as follows:

	High quality	Medium quality
No. black spots/dm^2	<10	10-20
No. red and brown spots/dm^2	<100	100-150

The hygienic parameters used to measure the presence of contaminants caused by the use of chemical pesticides and preservatives and the lack of hygiene in the treatment of raw materials should be considered. Strict laws and professional ethics operate to keep the levels of such contamination to the minimum and to prevent the improper or excessive use of pesticides and preservatives. Barilla is planning to tackle this problem by the introduction of techniques for stocking wheats and semolinas using methods such as cooling to below 10-15°C to prevent the proliferation of infestations and fermentation. Hygiene also concerns the presence of dirt, insect fragments, bird and rodent residues, all measured using the internationally recognised *filth test.* Our acceptance limits are as follows:

No. insect fragments per 100 g of semolina	<15
No. of rodent hairs and bird feathers	none
Animal droppings	none
Other types of dirt	none

Obviously, there are other chemical and physical factors defining the quality of durum wheat semolina. These include: granulometry; presence of common wheat derivatives; micro-organisms; and the presence of chemical and non-chemical additives.

Characteristics of the varieties

Furthermore, on the characterization varieties have well-defined protein structures, known technically as *patterns* and which act as an identity card for each variety. Each variety has its own particular properties and characteristics: early or late maturing; yields; resistance to disease; the shape of the ear; yellow pigment content; and gluten quality. Cultivation methods and climate cause variations in protein content, hectolitre weight, mineral content, humidity and the number of non vitreous grains. You will understand therefore that it is difficult to indicate a single variety that will guarantee a particular quality level. The following list is therefore only a guide to those varieties that could be defined as being high quality durum wheat:

(i) In Italy, the following, widely grown varieties are particularly valued for their Pasta Value: "Appio", "Grazia", "Plinio" and "Simeto". "Brindur" and "Cosmodur" are also now becoming available. This year Italy has also seen the emergence of varieties, such as "Brindur" and "Zenit", valued for their colour.

(ii) In France, there are only a few varieties with a high Pasta Value. These include: "Arcour", "Ardente" and "Neodur". France does however grow a large number of high pigmentation varieties such as "Primadur", "Ambral" and "Neodur".

(iii) Greece does not cultivate durum wheat by variety and it is therefore difficult to make a list. 85% of cultivation is with uncertified seed, probably of the "Mexicali" variety. This has an average Pasta Value and colour index. In Greece, Barilla has interests linked to the local Misko pasta factory and is therefore launching a programme to cultivate high quality varieties suited to the agricultural and climatic characteristics of the area.

(iv) In Spain, only the "Don Pedro" variety has both a suitable Pasta Value and colour index; "Gallareta" has a good colour rating.

Milling process

On to the milling process, in the last forty years it has undergone minor technological changes but during the same period the basic criteria for producing a quality semolina have been considerably modified. Milling in itself is not a process which generates quality in the sense that it cannot in any way improve or add to the inherent qualities of a wheat. Milling does, however, tend to destroy wheat quality especially when it is carried out incorrectly. Milling can influence the following quality parameters of semolina:

(i) Appearance and purity: the presence or otherwise of foreign matter and brown or dark coloured bran specks can be caused by careless milling and can produce dirty semolina.

(ii) Hygiene: insufficient plant cleaning before milling starts and careless cleaning procedures during milling can mean that various organic substances (insect fragments, rodent hairs, feathers and droppings) remain in the plant and are ground together with the wheat.

(iii) Gluten properties: milling which generates excessive heat can degrade the mechanical characteristics of gluten. Milling which is made with an excessive friction can tear protein components and destroy the gluten.

(iv) Pigment content: pigment is destroyed by milling action which is too violent.

The milling process itself is in turn influenced by some of the chemical and physical properties of wheat:

(i) The hectolitre weight of durum wheat can negatively influence the ratio of semolina produced during milling. A hectolitre weight which is too low will lead to an unfavourable ratio between the starches and bran products; in our experience this negative influence commences when hectolitre weight falls below 80 kilos.

(ii) Humidity decreases output because it prevents the addition of water to wheat. Given that ground products have a humidity of between 15 and 16%, a wheat with 10% humidity will provide 105 kilos of product for every 100 kilos of wheat while a wheat with 15% will only provide 100 kilos.

(iii) Mineral content is particularly important in those countries where there are legally stipulated limits for ash in semolina. In Italy, for example, a product with ashes of dry matter superior to 0.9% cannot be legally defined as semolina.

(iv) Waste materials: These obviously don't go into milling but output ratios are directly proportional to the amounts of waste matter present in durum wheat.

(v) Caryopses stained black by parasite attack lead to black specks in semolina.

(vi) Caryopses which are non-vitreous are softer and more easily ground and tend to produce fine flours thus reducing granular output of product and therefore the amount of semolina. It should be remembered that non-vitreous caryopses have a lower protein content than vitreous caryopses coming from the same area of cultivation.

On the basis of our experience on milling durum wheat, a simple formula was determined to predict the output of semolina from a durum wheat with specific characteristics. In order to provide even higher quality, Barilla has dropped the limit of mineral substances from 0.90% to 0.87% of dry matter. This value is used to calculate the semolina outputs from durum wheat in our mills. The formula is as follows:

$$\text{output (\%)} = \frac{136}{\text{mineral (\%) / dry matter}} \times \frac{100 - \text{wastes (\%)}}{100} \times \frac{100 - \text{U \% wheat}}{88} + \text{C}$$

where:

C is a negative correction factor of 0.5 per kilogram of hectolitre weight so that clean wheat is under the value of 82;

U grain moisture

Pasta requirements

Granulometry is becoming more important for quality than it was in the past because modern pasta making technology has introduced new technical requirements where semolina granulometry plays an important role. It is well known that a semolina granule which is too big will not be sufficiently hydrated during pasta making and will produce a white spot on pasta which cannot be removed during drying. Modern large-scale, high-output pasta making plants have considerably reduced pasta making times down, in some cases in our works, to 12-15 minutes. Under these conditions, innovative machinery (such as turbo-centrifuges) must be used to help the semolina absorb water or semolina granulometry must be reduced so that the ratio between semolina surface area and water surface area is increased. Both of these solutions present difficulties in that the increased mechanical stresses induced by a centrifuge and the stresses undergone by fine semolina particles during milling can lead to a fall in gluten quality. Turbo-centrifuging and granulometry reduction are therefore two technical solutions which must be implemented with considerable care.

Modern drying technology, especially where drying takes place above 85°C, can also produce complications in the form of Maillard products. High temperatures in low water activity environments can cause the formation of Maillard products; these are compounds derived from the chemical synthesis of protein and starch or, rather, between protein and the carbohydrates with a low to medium molecular weight derived from starch. These compounds have a colour which ranges from red to brown and have a characteristic aroma very different from that of pasta. In pasta these products are regarded as defects for two reasons: (i) the organoleptic reason: Maillard products alter the appearance, aroma, and taste of pasta; (ii) the nutritional reason: Maillard products remove a fraction of amino-acids from pasta.

Recent studies, at our laboratory, have shown that fine granulometry is one of the factors in semolina which favours the formation of Maillard products since it enriches the semolina carbohydrates with a low to medium molecular weight. Based on our experience and on the technical requirements of our pasta making plant we have defined the following optimum semolina granulometry:

- Rejection at 500 micron sieve	0%
- Rejection at 400 micron sieve	<5%
- Rejection at 300 micron sieve	40 - 50%
- Rejection at 200 micron sieve	30 - 40%
- Passage through 200 micron sieve	<20%

In practice this granulometry is technically defined as *compact* since it is almost entirely concentrated in the 200 to 400 micron range; the fines passing through the 200 micron screen must also have a low content of simple carbohydrates.

Drying temperatures of pasta

Unlike milling and pasta mixing, drying can make real improvements in pasta quality. In 1970, Barilla discovered that drying at temperatures above 75°C (the technical threshold at that time) increases the quality of cooked pasta mainly because it eliminates sticky surfaces. This discovery gave rise to the introduction of high temperature drying cycles commonly referred by their abbreviations: HT, UHT and THT. This, combined with improvements in cooking, contributed to raising output standards. The new methods virtually zeroed micro-organisms loads, drying times were reduced from 15-24 hours down to 3-8 hours and the output of existing plant was tripled. The new processes were a rich source of further developments but also required the introduction of technological innovations in pasta-making plant. Innovations included: (i) stainless steel structures to support the new, high temperatures; (ii) perfect insulation to prevent heat losses to the surrounding environment; (iii) lubricants suited to work at high temperature and humidity levels; (iv) sensors designed to operate under the new production conditions; (v) instrumentation for automatically recording internal plant conditions; the high speed and temperature of modern plant means that plant checks can no longer be carried out by a human operator.

All these innovations went into what today constitutes a modern production plant capable of producing 100 to 120 tons of dry pasta per day. Figs 1 and 2 show two typical Barilla diagrams for long and short pasta.

Further progress in modernizing the lines described consists of full automation where a process control linked to a central computer will automatically control the line and special programs will vary the hygro-thermal cycle in accordance with the data detected by sensors situated at critical points along the line.

Pasta in the diet

The last point illustrates some of the characteristics which have contributed to making pasta one of the foodstuffs suited to a modern diet. These characteristics are based on the assumption that a balanced diet must provide the human organism with carbohydrates, fats and protein with each of these providing 55%, 30% and 15% respectively of daily calorie requirements. At least 66% of the fats in our diet must be in the form of unsaturated fatty acids. Pasta is an ideal source of carbohydrates given its average composition which is as follows:

	Semolina pasta	Egg pasta
Carbohydrates	74-75%	70-72%
Proteins	10-12%	13-15%
Fats	1-2%	3-5%
Water	11-12%	11-12%

Over 70% of the fat component in pasta consists of unsaturated fatty acids. It can be said then that pasta is a carbohydrate food, low in fats with an average protein content. Modern dietary theories define pasta as being particularly suited to balancing a daily diet which is today too rich in fats and sugars. The United States Department of Agriculture (USDA, 1991) produced the *Pyramid of Healthy Eating* showing the recommended proportions to be consumed of each type of food (Fig. 3). This pyramid has been rapidly adopted by all scientific texts on food and is now synonymous with the Mediterranean diet.

References

USDA (1991). The Food Guide Pyramid. *Home and Garden Bull.*, number 252.

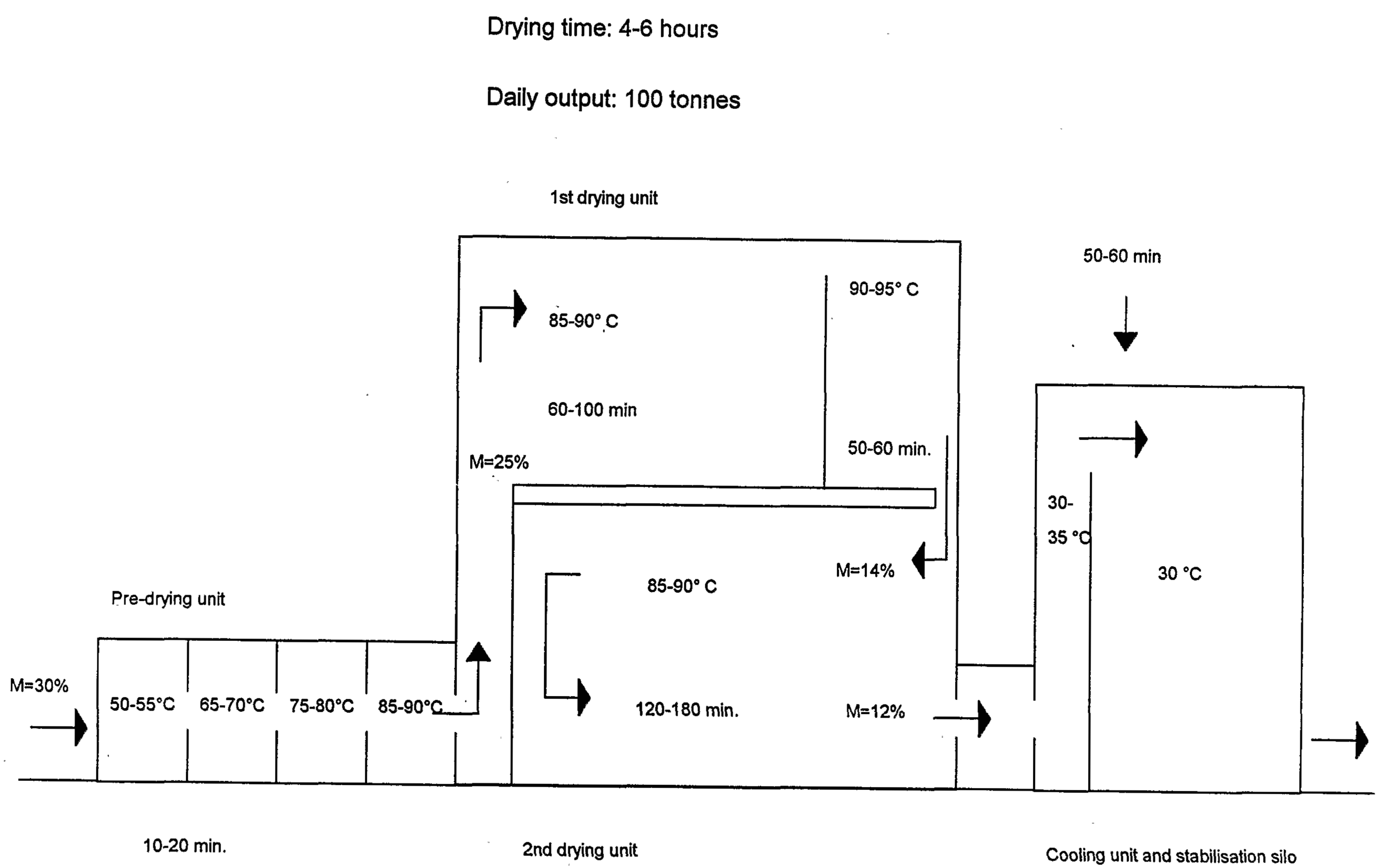

Fig. 1. Barilla drying line for short pasta.

Drying time:3-4 hours

Daily output: 120 tonnes

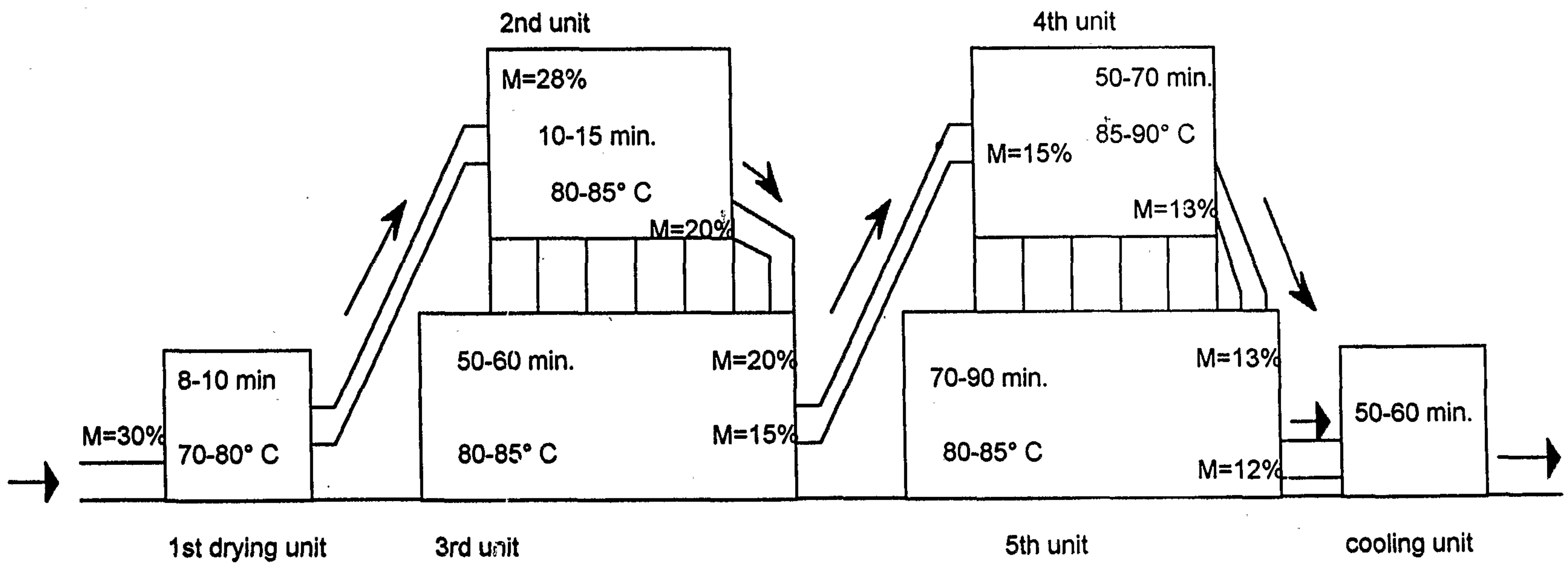

Fig. 2. Barilla drying line for long pasta.

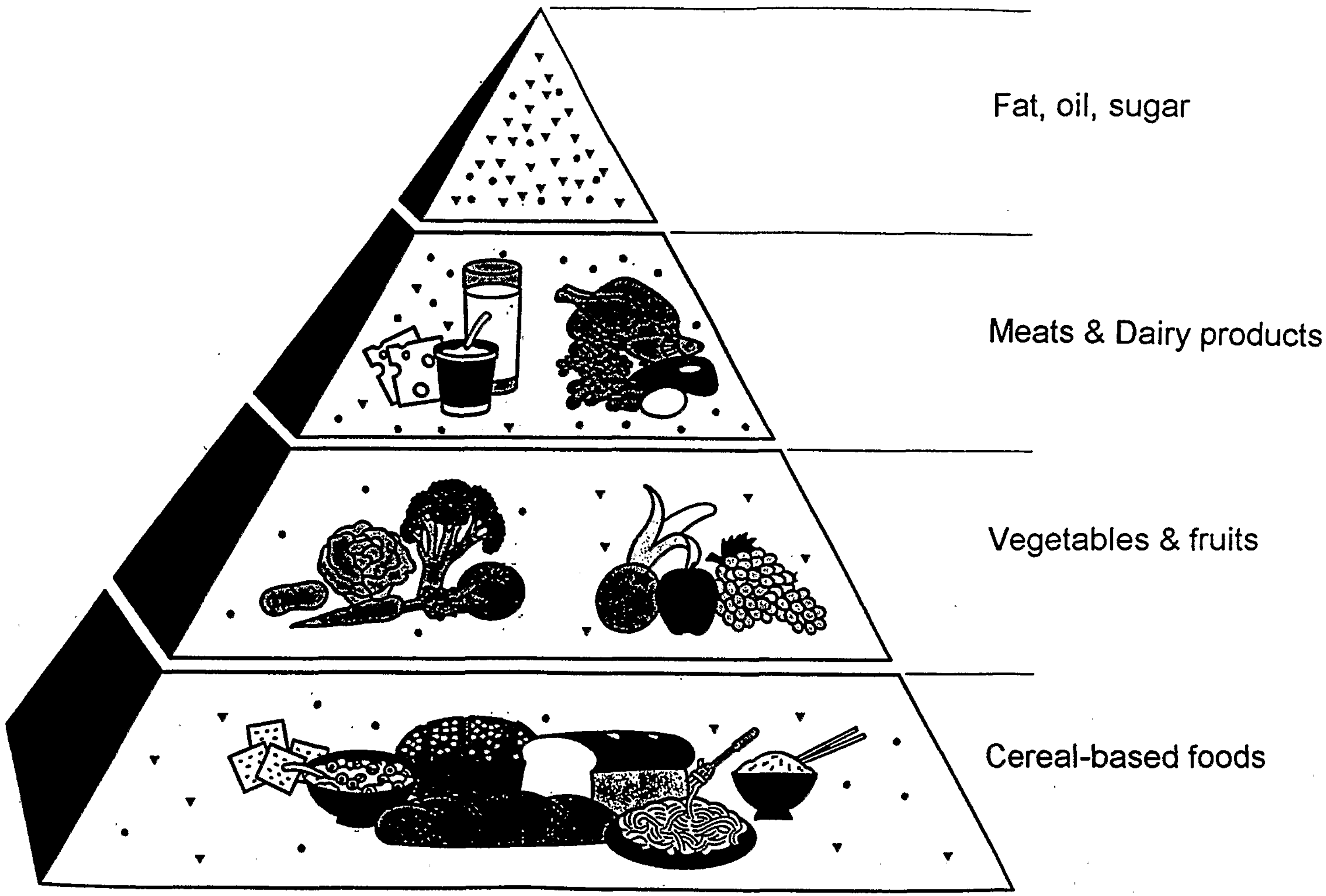

Fig. 3. Food guide pyramid (USDA, 1991).