Faculty of Agronomy

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TECHNOLOGY OF CEREALS

doc. Ing. Jindřiška Kučerová, Ph.D.

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FOREWORD

Generally, the greatest impact on the quality of any food product may occur during the actual technological processing. Previously, the processes were uniform and binding, while today different versions of classic process apply. Modern, usually more efficient and faster processes are used, with better valuation of raw material dry matter. Waste is minimised and automation and computer control increases, which aims to achieve high quality and standardization of finished food products. Manufacturing firms protect their particular specific manufacturing processes that allow them to gain a competitive edge and promote sale of their products.

There is a need to constantly respond to the ongoing structural changes. In the main, this concerns the development of production of frozen bakery products, the emergence of in-store bakeries in supermarkets, and the industrial production of oven-ready or ready to cook foods. Production of functional and dietetic foods is a rapidly growing segment, which affects further possible development of the mill industry and the use of other cereals in human nutrition. Customized flour is produced according to customer requirements. Flour may also be fortified with vitamins and trace elements. Production of improvers and premixes has increased considerably.

Apart from high quality raw materials and technologically correct processing, there are still many other factors that influence the final quality of the food (consumer packaging, transport, improper handling in the store). Final quality may also be affected by consumers and their ignorant or improper handling. Therefore the quality control along the entire food chain is essential, from the processing of raw materials into end products to consumption.

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CONTENTS

1 CEREAL RAW MATERIALS

1.1 Production, importance and use of cereals

Cereals are strategically and historically the most important crop. Early man began to collect seeds from wild plants to complement his primarily carnivorous diet. The first dish was crushed meal, then followed soup, porridge and later leavened bread. Archaeological excavations show that the cultivation of cereals started already in the Neolithic period when people came to know that they were irreplaceable. Later written records concerning cultivation of cereals dates back to the reign of the pharaohs in Egypt, the ancient Babylonia and ancient China. Cereals spread to Europe from south-west Asia and the Mediterranean. Currently, they are grown almost everywhere in the world where conditions are favourable.

Cereals significantly influence the nutritional balance of the world's population in all continents. They are used for human consumption (mainly wheat and rice) and as the main raw material for the production of foodstuffs, but they are also used for feeding livestock. Smaller amount is processed technologically to produce starch and spirit. Differences occur in the utilization of cereals, which depends on their availability, standard of living and consumer habits of the population, the level of processing industry, trade and others.

Cereal production in individual countries varies primarily due to weather conditions in individual years, change in cropping areas as well as the level and intensity of agricultural production.

The world's most important cereal providing nutrition of the human population is **wheat**. It is the most widespread cereal used for baking and the most important trading commodity in the food sector. World production of **rice** is approximately the same as the production of wheat, but rice is only little processed into flour, hence its use for bakery products is small. Europe’s share of the world **rye** production is dominant, because rye and combination of rye and wheat is traditionally used for bread making in Central and Eastern Europe. World rye production is only slightly higher than in Europe. Outside Europe, **other cereals** are important besides wheat, especially maize, millet and sorghum. But products baked from them are more like pancakes; they are not able to create a solid structure of a dome-shaped product.

In the Czech Republic, cereals are the most important agricultural crop as well as basic raw material for a variety of food productions, fodder industry and industrial raw material. As food, cereals cover about 33% of energy value, provide 30 % of proteins, 56 % of carbohydrates and 10 % of fats consumed. From 6.8 to 7.1 million tonnes of cereals are produced annually, of which 2.1 million tonnes are processed into foodstuffs.

The food industry uses mainly common or bread wheat and rye, which are the basic cereals in bread making, and also barley, oats, maize, rice and smaller quantities of spelt and millet. Among pseudo-cereals, buckwheat is the most important.

All cereal species belong taxonomically to the grasses (*Gramineae*). Almost all known cereals belong to the *Poaceae* family. An exception is buckwheat, which belongs to the *Polygonaceae* family. There is a number of different botanical species of every cereal and a huge number of varieties within those species.

Wheat (*genus Triticum***)** includes about 8 species, of which following are used for production**:**

- ***Common or bread wheat*** *(Triticum aestivum),* widespread, of which a large number of varieties was bred, it is mainly used in bakery production,
- ***Durum or macaroni wheat*** *(Triticum durum),* used to make pasta and cultivated only in favourable, mostly inland areas;
- ***Spelt wheat*** *(Triticum spelta)* has hulled grain, it is used only locally, now mainly in alternative agriculture for making special products.

In terms of cultivation, we distinguish between winter and spring varieties, while from the perspective of flour producers wheat varieties can be classified as soft or weak and hard or strong. The key measure of baking quality is globally considered the volume of the resulting bread.

1.2 Cereals in terms of nutrition

The food we eat determines not only our health, but also our behaviour, mood and well-being. For example, aggression can be caused by magnesium, calcium, and lithium deficiencies, with concurrent E and B avitaminosis. Depression arises as a result of magnesium salts and thiamine deficiencies. If we want to lose weight we need to increase dietary intake of zinc and magnesium. All cells in our body are constantly being formed from individual components of the food and the quality of these cells depends on the quality of food consumed**.**

This quality is judged by the content of nutrients in foods and biological value of foods. Energy-supplying nutrients are sugars, proteins and fats, while nutrients that do not provide energy are minerals, vitamins, fibre, trace elements and water. Harmful substances are represented by heavy metals (lead, cadmium, mercury, and arsenic), antibiotics, colorants, preservatives, nitrates, and so on. Biological value depends on the degree of retention in their natural state, and the time that has elapsed since the harvest. It is reduced by the level of industrial processing, heat processing, storage method used or the final heat treatment before serving.

According to the prevailing nutrient content, we divide foods to those supplying fats (nuts, germs, oils, butter), carbohydrates (flour, cereals, pasta, fruit and vegetables), and proteins (milk, cheese, meat, fish, eggs). Foods high in carbohydrates such as bread, pasta, cereals, a variety of flour products as well as vegetables and fruits should make up 50% of our food intake. The positive fact is that cereals contain carbohydrates mainly in the form of starch that breaks down slowly and does not have adverse effects like sucrose.

Nowadays it is important that refined foods (made with white flour or white sugar, i.e. of which fibre has been removed) are supplemented or replaced by products *with higher content of crude fibre*. Valuable source of fibrous material are cereal products, especially bran (for making porridge, soup or dough), whole grain breads and pastries, cereal flakes and germs or pasta made from whole grain flour. Besides increasing the fibre content in cereal products, some products are increasingly enriched with pectines that have the ability to bind pollutants and bacteria and removed them from the body.

Products made of rye, barley and oats contain β-glucans having a positive effect on health. Buckwheat is significant with its content of rutin, glycoside, which has been proven effective in preventing civilization diseases.

Positive characteristic of fibre is *its favourable effect on physiological function of the digestive system*. It maintains a healthy colon function, creates gel-forming structures, swells and brings a *feeling of fullness* sooner, but does not increase caloric intake. High fibre increases stool volume and ***accelerates intestinal peristalsis***. This prevents rotting of food in the intestines, which are well cleaned. In addition, fibre binds pollutants that are then removed from the body. This helps against ***chronic constipation and colon tumours***. Part of the food is subject to fermentation in the colon to produce fatty acids with short chain (acetic, butyric, propionic acid, and so on), thereby creating favourable conditions for the proliferation of beneficial intestinal microflora. The number of beneficial microorganisms (*Bifidobacterium*, and so on) is rising, which affects the absorption and metabolism of end products (fats, carbohydrates, and other substances). *Fibre* ***slows the absorption of sugars and reduces the absorption of dietary fats***, thereby reducing blood sugar and cholesterol, and hence the risk of cardiovascular diseases. Fibre *also positively impacts the balance of bile acids* and produces favourable results in the diet of diabetics, where it ***regulates blood sugar levels*** and lowers the glycaemic index of carbohydrate foods.

Negative characteristic of fibre is the faster rate of passage of digesta through the digestive tract, which reduces its usability. Higher amounts of cereal fibre achieved e.g. through high consumption of bran or oatmeal *increase the level of phytic acid and phytates*, which irreversibly bind certain minerals into complexes and make them unavailable as nutrients (Ca, Mg, Fe, and so on), This *lowers the utilization of calcium and iron*, which can subsequently cause e.g. osteoporosis. So in case of high intake of fibre it is necessary to supplement these elements.

Recommended daily dose (RDD) of fibre or average intake for adults is 30 g, of which 6 g should come from soluble fibre. The criterion for assessing the amount of fibre in the diet is the time it takes for food to travel through the digestive tract and the amount of faeces.

1.3 The anatomy of cereal grain

The anatomy of cereal grain is important not only to assess it, but also for storage and subsequent processing. Each caryopsis or cereal grain consists of a layered coat surrounding the endosperm and germ. Percentage weight of grain parts is different for each cereal and variable due to internal and external factors. The individual components of grain have different structural, mechanical and physicochemical properties and perform specific functions in the life of the caryopsis and its subsequent utilization (Pelikán, 1999).

Coating layers – exosperm (pericarp and seed coat or testa) makes up about 8 to 12.5 % by weight of kernel. It protects cereal grain against external influences; in mill technology it is referred to as bran. It consists of several layers of cells which protect germ and endosperm from drying and mechanical damage. The proportion of coating increases with the hull content of grains. The coating layers have two main parts – the pericarp and testa**.**

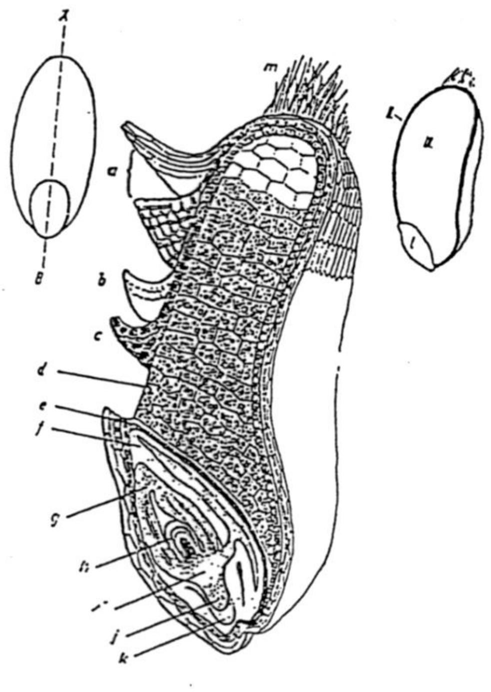
Pericarp is made up of the skin (*epidermis*), longitudinal cells (*epicarp*), transverse cells (*mesokarp*) and hose-shaped cells (*endocarp*).
Seed coat (perisperm, testa) is formed by coloured layer and hyaline (glassy) layer**.**

The coating layers are a valuable source of fibre (cellulose and hemicellulose) and minerals (calcium, iron, magnesium, silicon, phosphorus). The outer layers (pericarp) are composed mainly of insoluble polysaccharides of cellulose type with high mechanical strength and can serve as a source of indigestible fibre. In terms of baking technology, these components have deteriorating effect on the quality and workability of dough, and often even on the appearance of the finished product. Seed coat contains also polysaccharides, which are water-swellable or partially dissolve, and are able to tightly bind water.

Aleurone layer lies between the coating layers and the endosperm. It constitutes about 8 % of the entire grain and contains primarily protoplasmic proteins, fats, vitamins and minerals. Technologically, it is included in the total endosperm. It contains significantly more protein than other endosperm, but these proteins are generally not gluten-forming and so do not carry the baking strength of flour.

Endosperm (inner core of grain) makes up the largest share of grain (84 – 86 %) and is technologically the most important part. It consists of large prismatic cells and relatively fine cell membrane. It contains mainly starch (nearly three quarters) as well as proteins, which are of high importance for bakery technology (about 10 % of the endosperm). The content of proteins and their varying quality is decisive for bakery processing quality of wheat flour. The endosperm contains the storage material such as starch and proteins for germinating plants. Wheat flour is almost pure crushed wheat endosperm, while rye flour has more under-coating layers.

Germ (embryo) is the smallest, but most fluctuating share of grain. It represents 2.5 to 3 % in wheat and 12 to 15 % in maize. It is the embryo from which a new plant develops and carries genetic information. It is a valuable source of fats, simple carbohydrates, proteins, enzymes, and fat-soluble vitamins (E and group B). Significant is the scutellum, which contains up to 33% protein. Germ is separated during milling, because its stability in the air is very short due to the high fat content. In addition to feeding purposes, wheat germs are used in the food and pharmaceutical industries.



I. Germ; II. Bran; III. Endosperm

a – pericarp, b – seed coat, c – aleurone cells, d – endosperm, e – layer of compressed cells, f – scutellum, g – sheath, h – seed leaves, i – collar, j – embryonic root, k – root cap, m – brush hairs

Figure 1.1 Longitudinal section of a grain of wheat

1.4 Material composition of the grain

Chemical composition varies by region, variety, fertilization, seeding time, agricultural technologies, climatic conditions and numerous other factors.

An important component of the grain is **water**, because all the biochemical and physiological processes occurring during the growth, maturation and storage take place at its participation. From a technological point of view, according to the water content, we are talking about wet grain (over 17 %), humid grain (over 15.5 %), medium-dry grain (over 14 %) and dry grain (up to 14 %).

The basic structural components by amount are:

- carbohydrates and proteins
- lipids and minerals
- vitamins and dyes
- components that have growth regulating and genetic functions

1.4.1 Carbohydrates

The amounts of **free monosaccharides** in mature cereal grains are small. These are pentoses and hexoses. **Oligosaccharides** are present in low concentrations (sucrose and maltose, raffinose).

From a technological point of view the most important group together with proteins are **polysaccharides** which have storage and structural roles.
Starch, the storage polysaccharide, is the most important component of the grain. It is contained in the endosperm. The state of starch and activity of amylases determine the quality of bread and bakery products, in particular the consistency of crumb and colour of crust. The starch content is from 55 to 75 % of the dry grain, and varies according to species and varieties. The starch content of the flour, which is composed predominantly of endosperm, is higher (about 80 %).

The starch in cereals and plants occurs in the form of starch grains. It is composed of two fractions - amylose and amylopectin. Both fractions are composed of glucose units (in the case of amylose they are formed by alpha-1,4-glycosidic bond, while in the amylopectin molecules also alpha 1,6 bonds are frequent). They differ in their relative molecular weights (amylose approximately 10^6 and amylopectin 10^7–10^9). The ratio of our cereals is 25 % amylose and 75 % amylopectin. Due to their different structures, both fractions differ also in their chemical and physical properties. Amylose is soluble in water, while amylopectin only swells and is unable to form a solution.

When making the dough and crumb of bakery products, the whole starch grains are not fully gelatinized. Among the starches with the lowest gelatinization temperatures is rye starch. The most difficult to gelatinize is rice starch. It does not create a complete gel even after reaching 95°C and it is necessary for some time to maintain it at this temperature.

The main significance of starch for the bakery products consists in that, after cooling, the product will create an elastic starch gel, which is the main carrier of smoothness and water contained in the crumb. The second function of starch is to become a source of fermentable sugars for the yeast during dough leavening.

Non-starch polysaccharides

Cellulose is neither completely soluble in water, neither significantly swells at normal temperatures. Cellulose derivatives have the ability to bind water and swell. It is a major component of coverings and cell walls. Wheat contains about 1.6 % of cellulose, barley 4 % and oats over 10 %. When added to the dough in crushed or powdered form (modified bran), it lowers the binding capacity of water and strength and elasticity of the dough. In this case, improvers are added to flour to strengthen the gluten structure, e.g. dried gluten and ascorbic acid.

Hemicelluloses are soluble in dilute alkali. They can be found mainly in cell walls, where they act as supporting tissues and storage material, which decomposes into simpler sugars upon germination.

Lignin is an essential component of insoluble fibre found in bran and especially in hulls of barley and oats. It is insoluble, composed of phenylpropane units.

Pentosans are polymers containing a substantial proportion of pentoses in the molecule. They are part of coverings and cell walls. *Pentosans insoluble in water* are often included in hemicelluloses. They accompany cellulose in the cell walls and have a higher degree of branching than the water-soluble pentosans. *Soluble pentosans*, often referred to as slimes, are based on xylose and arabinose forming polymeric chains – arabinoxylans. Also arabinogalactans can help to create a spatial network of rye dough.

Pentosans are extremely hydrophilic. They are able to bind large quantities of water (multiple amounts of water for their percentage by weight as compared with gluten proteins). This water is released in the oven, remains in the crumb and is used for starch gelatinization and swelling of insoluble pentosans to form a gel-like structure of the bread crumb. Together with starch they form the basis of rye dough structure. The correct ratio between starch and pentosans is crucial. Excess starch causes dry crumb, while excess pentosans cause batter spilling and moist crumb.

The pentosans content of cereals varies. It is reported as 5 – 7 % for wheat, while 6 to 9 % for rye. Beta-glucans are hexosans, soluble polysaccharides that accompany pentosans. They are found in greater amounts in barley and oats. They can generate high viscosity gels. Barley and oat cereal products are characterized by smoothness and favourable physiological effects during digestion.

Pentosans also contain some **reactive groups** enabling the formation of different complexes. An important role plays the ferulic acid that can, assisted by an appropriate component such as Ca ions, form a bridge between pentosan and protein chains, which is important for the stability of gel. Pentosans have been shown to slow the aging of bread.

Carbohydrates can be divided generally also in terms of usability to:

- **usable**: *polysaccharides* – starch, glycogen, amylodextrins, *oligosaccharides* – sucrose, maltose, lactose, *monosaccharides* – glucose, fructose, galactose, *alditols* – glycerol, glucitol, xylitol, mannitol
- **unusable,** the so-called ballast fibre: *polysaccharides* – cellulose, pectins, lignin, *oligosaccharides* – raffinose, melibiose, *monosaccharides* – sorbose, mannose, *alditols* – dulcitol, arabinitol.

1.4.2 Cereal proteins

Mature grains contain between 9 and 13 % proteins by individual species and varieties. Most proteins are stored in the endosperm and the aleurone layer. Basic building blocks are amino acids. The most dominant amino acid in cereals is glutamic acid, which is present in the form of its amine – glutamine. It represents more than 1/3 of the total amino acid content. The second most abundant amino acid is proline (more than 10 % of the wheat protein), which due to its structural arrangement provides the background to create an elastic spatial protein structure of the wheat dough. The content of lysine, threonine and tryptophan is small.

Proteins may be formed by polypeptide chains only as **simple proteins** or may be **composite proteins** (proteids), i.e. they contain also other substances of non-protein nature in the molecule (cereals contain glycoproteids having carbohydrate components and lipoproteids having lipid components).

Simple proteins are divided according to their functional properties to ***protoplasmic*** proteins (albumin and globulin), which are mainly found in the germ and the aleurone layer and ***storage*** proteins (prolamin and glutelin), which constitute an essential part of cereal grain.

Protoplasmic proteins are made up of catalytic, enzymatically active and structural proteins. Albumins are soluble in water, globulins in salt solutions. Albumin-globulin content of wheat amounts to 15 – 20 %, and is little dependent on ambient conditions. For rye and triticale, the content of these proteins is higher.

Storage proteins determine the technological, nutritional, feeding and biological value of grain. Individual cereals accumulate different amounts of prolamins and glutelins. The prolamin fraction is soluble in 70 % ethanol, is highly heterogeneous, and consist of numerous components (α, β, χ, ω). It is present in all cereals: gliadin in wheat, hordein in barley, avenin in oats, and zein in maize. The glutelin fraction is soluble in dilute acids and bases, and yet is the least studied.

Wheat prolamins (gliadins) migrate during electrophoresis in PAAG or starch gel and form distinct bands on the gel characteristic for varieties. This is used as proof of the authenticity of varieties. The structure of gliadin apparently comprises of one polypeptide chain, wherein the short helical sections (α-helix) with hydrophobic residues, which are inverted inwards the spiral, alternate with relatively straight sections with high content of glutamic acid and proline. Helices are maintained by hydrogen bonds, chain bends are held by strong disulphide bonds (Fig. 1.2). Gliadin is known as ***low molecular weight storage wheat protein*** or ***LMSP***.

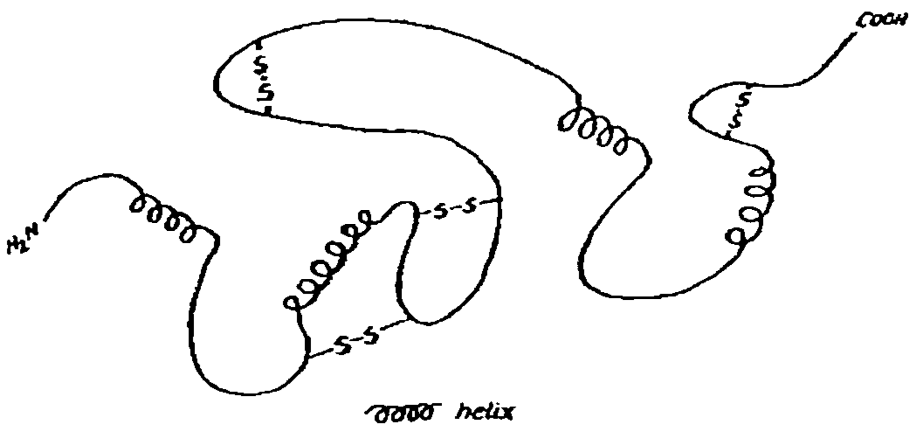


Figure 1.2 Gliadin structure scheme (Lásztity, 1984)

Wheat glutelins (glutenin) are high molecular weight gluten fractions with a molar mass from 100 to several thousand kg/mol. They are known as high molecular weight wheat storage proteins or HMSPs. They consist of a mixture of protein subunits, wherein hydrogen and in particular disulphide bonds are present, thereby achieving high molecular weights. Figure 1.3 shows a schematic idea. Low molecular weight chains D are maintained inside with disulphide and hydrogen bridges, but outwardly they are connected with other chains only by means of hydrogen bonds and maintained by hydrophobic forces E. The high molecular weight components A have two types of disulphide bonds, intra-chain B and inter-chain C to maintain strong and elastic texture.

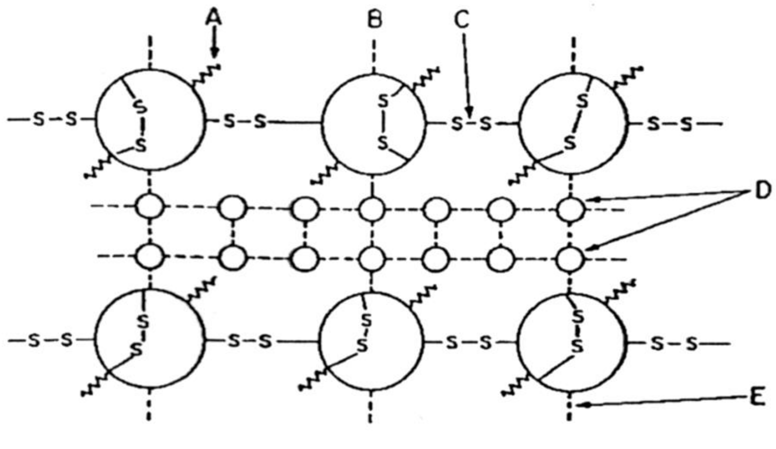


Figure 1.3 Model of glutenin structure (Khan, Bushuk, 1978)
A – glutenin subunits II, B – intra-chain disulphide bonds, C – inter-chain disulphide bonds, D – glutenin subunits I, E – secondary bonds (hydrogen, hydrophobic interactions)

1.4.2.1 Gluten

The most important are wheat proteins, which differ from other plant proteins by their ability to form gluten, an elastic gel. Gluten plays a decisive role in dough formation and determines its baking properties. Gluten is the composite of two proteins insoluble in water, gliadin and glutenin. The quantities and properties of gluten are the main criteria of baking quality of wheat. Gliadin provides stretch, while glutenin provides elasticity and swelling. Small part of the population, especially children, has an allergic reaction to wheat gluten (certain gliadin fractions) known as celiac disease or gluten intolerance. Suitable for a gluten-free diet are cereal products made from maize, rice, and buckwheat.

As far as the **gluten constitution** is concerned, it forms a three dimensional network of peptide chains, variously folded and connected to each other by bridges and bonds, wherein also a thin layer of lipids is significant (Fig.1.4).

Differences in the organization of this structure are then considered as the cause of various properties of gluten. The greatest attention has been paid to redox thiol/disulphide system, where bridges are formed in oxidation:

$$\begin{matrix}\text{-R-SH} \\ \text{-R-SH}\end{matrix} \; + \; 0{,}5\ O_2 \; \rightarrow \; \begin{matrix}\text{-R-S} \\ | \\ \text{-R-S}\end{matrix} \; + \; H_2O$$

Formation of bridges strengthens the gluten, since this limits the relative mobility of peptide chains. The reaction is reversible – reducing agents cleave bridges and thereby weaken the gluten, which becomes more stretched. However, the increasing influence of oxidation of the thiol groups on the dough's structure is far from unambiguous. A balance between SH and S-S groups will be probably crucial.

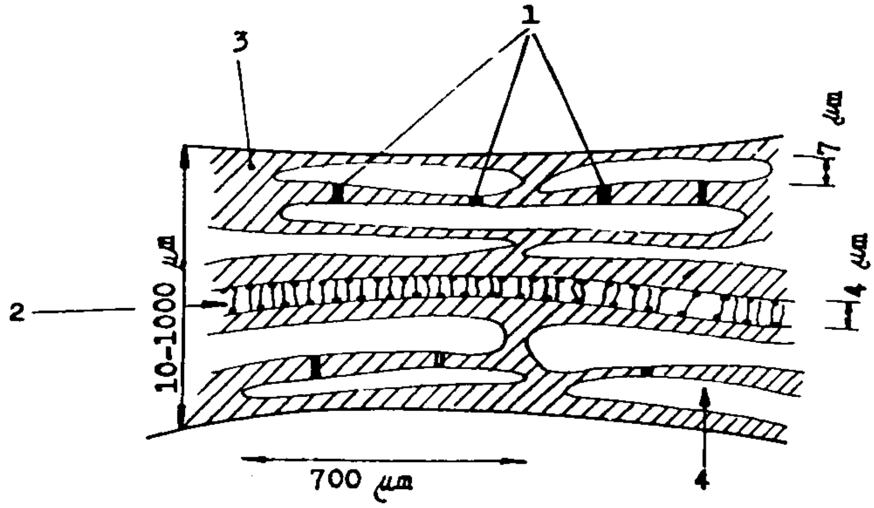


Figure 1.4 Model of hydrated gluten fibre structure (Hampl, 1988)
1 – hydrogen bridges, 2 – lipoprotein layer, 3 – aqueous phases, 4 – protein plates

In terms of **biological value,** protoplasmic proteins have optimal composition, but due to their low presence in cereal grain the ***biological value of cereals is small***. Regarding the biosynthesis of individual protein fractions in wheat, structural proteins (albumins and globulins) are synthesized first, then glutelins, and the production of protamines is the last to be realized.

Proteins also form a substantial part of **enzymes** that function as biocatalysts of a living cell, and regulate metabolism during germination, growth, storage, and technological processing. For enzymes we evaluate the enzyme's ability to catalyse a reaction under given conditions. Increasing of activity is called activation, while decreasing is called inhibition. Loss of catalytic ability (denaturation) is called inactivation of the enzyme.

Cereals contain enzymes which hydrolyse the starch – ***amylases***. Additional enzymes are included in small quantities: ***proteolytic enzymes*** which hydrolyse peptide bonds of proteins, ***lipases*** which hydrolyse lipids, and redox ***lipoxygenases*** which oxidise unsaturated fatty acids from cereal lipids.

1.4.3 Cereal lipids

Caryopses are the seeds with the lowest content of fat (1.5 – 2.5 %), only in oats, sorghum, millet and maize the fat content is higher (4 – 7 %). Most fats are found in the germ and aleurone layer.
A substantial proportion of **non-polar fats or lipids** (72 – 85 %) are unsaturated fatty acids, of which the essential linoleic acid constitutes at least 55 %. Linoleic acid is easily oxidised, which results in rancidity of flour during prolonged periods of storage. Even more susceptible is the unsaturated linolenic fatty acid, which is also present in lesser amounts.

The cereal grain contains part of polar lipids (***phospholipids*** 15 – 26 %). By their composition, they are similar to fats, but also contain phosphoric acid and organic base in the molecule.
Other lipids include **lipophilic dyes**. ***Carotenoids, yellow and orange dyes*** are present in cereals. Particularly durum wheat (*Triticum durum*) has a higher content of them.

1.4.4 Minerals

The ash content in the cereal grain ranges between 1.5 and 2.5 %; in hulled caryopses (oats, barley) it is higher than in hulless (naked) ones. The largest amount of minerals is present in the germ and coating layers, especially the aleurone layer. Ash consists primarily of phosphorus pentoxide, the most common metals are magnesium, potassium, calcium, and iron. Unequal distribution of minerals within the grain became the basis for assessing the quality of flour. In terms of contamination from industrial fallout and agrochemicals, the final cereal products contain least residues because during mill processing the coating layers are largely separated.

1.4.5 Vitamins

High levels of vitamins are in the coating layers and germ, particularly in the scutellum and aleurone layer. Endosperm of cereals is poor in vitamins. During the milling process, two thirds of the original content of vitamins from the grain pass to the consumer flours on average, depending on the rate of extraction.

Mainly the **B-group vitamins** are essential. *Thiamine (B1)* and *riboflavin (B2)* are present in the coating layers and germs of most cereals. The *nicotinic acid*, also known as *niacin (vitamin PP or B3)* and *nicotinamide* are found in higher amounts in the wheat and barley grains, while *pantothenic acid (B5)* in the coating layers.

A high concentration of **vitamin E** *(α-tocopherol)* is in the wheat germ, from which it is isolated in the production of vitamin preparations.

1.4.6 Biologically active substances

Phytic acid is present in the form of phytates mainly in the coating layers. It has the ability to bind to one of its molecules as much as 6 atoms of calcium, magnesium or bivalent iron. These compounds are not biodegradable in the human organism, therefore metals which are bound this way are no longer usable.

Choline is distributed quite evenly in the cereal grain**.** It is very important for the neuro-motor activity.

Para-aminobenzoic acid (PABA) is an essential growth factor and is contained most in the coating layers.

Cereals have an increased content of the so-called "***phytochemicals"*** (flavonoids, gluconates, phytates, lignins, and so on), which have a protective effect against certain diseases.

2 TECHNOLOGY OF FLOUR MILLING

Czech milling industry has always had an important position in the world. Every year, it handles about 1.2 million tonnes of wheat and about 120 thousand tonnes of rye of food quality, 15 thousand tonnes of oats, 5 thousand tonnes of barley, 4 thousand tonnes of maize and 3 thousand tons of other crops.

Cereal nutrition in our country has certain specifics compared to the other countries. It is the production of rye bread made from a spontaneous sourdough starter (Central European specificity). In contrast, the bulk of the world consumes the wheat bread leavened with the help of yeast. Czech speciality is the production of dumplings, classic bread crumb dumplings, but also dumplings made from boiled and raw potatoes as well as fruit and bacon dumplings. This needs that both coarse and medium coarse flours are produced. Also the assortment of fine bakery products and confectionery products is considerably different. Coarse and medium coarse flours are used in these products, which is not quite common in the world.

Classical Czech milling technology is different from other technologies, account being taken to the specific quality requirements for flours. It uses more complex technology needed for gentle milling and cleaning of semolina and all flours are produced at once in one continuous process.

The main task of the milling technology in processing of cereals is to separate the individual parts of the grain which have different user properties and nutritional value. This is performed by staged milling of grains and grist with subsequent sorting and cleaning. In preparation and milling itself the physical properties of cereals are utilised, where each type of cereal requires different technological processing method depending on its properties.

Processing of cereals in the mill has these basic steps:

- grain reception, preliminary cleaning and storage
- preparation of grain for milling
- milling
- preparation of commercial flour types, storage and expedition

2.1 Grain reception, preliminary cleaning and storage

Grain is mostly transported to mill as a bulk cargo. Its quantity and quality is controlled upon reception. During the entry check, samples are collected by means of samplers for the purpose of verifying the quality. Then the grain goes into the ***receiving hopper*** and from there to the ***scalper*** (air separator) where grain is stripped of the coarse dirt and dust. Metal impurities are removed on magnetic separators.

Pre-cleaned raw material is deposited in the ***silo chambers***. Depending on the quality, grain batches of different categories can be stored separately. Mills need to have a reserve of grain to observe the standard quality of flours when fluctuation in the quality occurs**.**

2.2 Preparation of grain for milling

The first step is usually to sort or categorize the received grain on the basis of laboratory analysis, i.e. ***to establish a grain mixture for milling test*** (grain mixing), which is conveyed via dosers to the screenrom, where grain is ***cleaned and further treated***.

2.2.1 Assembling a mixture of grain to milling test

Grain from different batches is mixed so that the resulting properties of the mixture as much as possible correspond to its determination for further processing. Properties of individual batches of wheat are appropriately combined to guarantee the standardization of flour production. In terms of parameters required for quality baking flours, the content and quality of wheat protein is important as well as the activity of amylolytic enzymes and extent of starch damage in wheat and rye. By creating an optimal mix to mill we must improve the worst indicator.

According to the behaviour in a mix, wheat is classified into:

- strong wheat, which can be used either alone or as an improver of weak wheat
- normal (standard) wheat used alone
- weak wheat, which can be used only in combination with strong wheat

Strong wheat must be characterized by a high **mixed value**, i.e. the ability to achieve, when in a mix with weaker wheat, significantly better results against the theory. Less problematic indicators (moisture content, N-substances, gluten) can be easily calculated using the mixing rule, the mixed value.

Calculation of the theoretical value:

$$c_t = \frac{ax + by}{x + y}$$

c_t - Theoretical resulting property of the mix A+B
a - Property of component A
b - Property of component B / both expressed in terms of value/
x, y - Proportions by weight of components A, B in the mix
c_p - Practical resulting property of the mix A + B

From the theoretical value thus obtained we can calculate the ***mixed value for a given mix*** according to the following relationship:

$$SH = \frac{c_p - c_t}{c_t} .100 \qquad (\%)$$

Mixed value reflects the improving effect and indicates by how many % the theoretical result is surpassed by the practical one. Technological effect of mixing is generally higher than would correspond to the average of technological characteristics under the mixing rule. If the practical result of analysis is equal to the theoretical one, the mixed value is zero**.**

In practice, the mixes with a high mixed value are used e.g. to increase the alveographic or extensographic energy (addition to elite wheat).

To assess the suitability of wheat as an improver, it is most appropriate to make a baking test.

The practice of mixing grain for milling test shows that mixing different varieties from one area is more effective than mixing one variety of different provenance. Preferred is mixing of 3 to 5 varieties. Mixing grain brings better results than mixing flours.

2.2.2 Cleaning – screenroom

The task of screenroom is to remove the impurities and contaminants, including shrivelled, underdeveloped and immature caryopses and fractions. It should also remove impurities stuck to the surface or accumulated in the furrow of caryopses, or parts of the surface layer (hairs, pericarp and dust from the groove).

This process is very important and any failure at this stage is negatively reflected in the final product.

Grain from the silo‘s storage bin is conveyed to a dry stoner. This machine separates the particles of about the same size as cereal grain, but with different weight. The principle of separation involves creating a fluidised bed of cereal grains flowing in the air which passes through from the bottom of the sieve. The sieve has a slight incline, so the grain layer floating above the sieve slowly flows down in the direction of the sieve’s inclination. Particles with larger weights remain on the sieve and by vibratory motion of the sieve they are thrown against the direction of the sieve’s inclination, so they come out on the opposite side than the cereal grain. Stones and heavier impurities and foreign matters are separated. At the same time the suction shrivelled grain, which is treated as “kalibrát”.

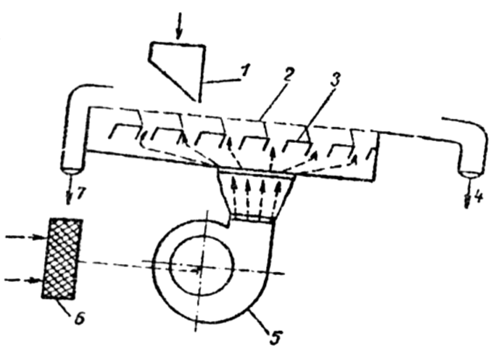


Figure 2.1 The principle of sorting in the dry stoner (Pavliš a kol., 1979)
1– hopper, 2 – sieve, 3 – grid for air distribution, 4 – grain exit, 5 – fan,
6 – air filter, 7 – stones exit

Next cleaning process takes place in the ***screen separator with connected aspiration cabinet*** – it removes dirt and impurities from the grain mass, while the aspiration cabinet provides the separation of light particles. ***Built-in permanent magnet*** captures the metal contamination. Three cleaning units are combined here, the sieve, wind and vibrations.

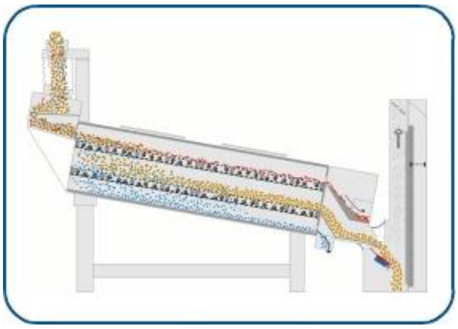


*Figure 2.2 Screen separator scheme (*JK Machinery s.r.o.)

The separation of impurities and dirt is completed on trieur station. ***Trieurs*** (Fig. 2.3) are long hollow cylinders on whose inner surface dimples or pockets of exact size are moulded or milled into which respective grains fit and are lifted up the cylinder wall. Before the top dead centre the grains fall out from the dimples into a catch trough, which passes through the centre of the cylinder. Mounted in the trough is a spiral worm which shovels the grains out. According to the shape of dimples, round shaped impurities such as cockle with a dimple diameter of 4.5 – 5 mm (***cockle cylinder***) or long thin grains mainly of oats with a dimple length of 8 – 9 mm (***oat cylinder***) are eliminated.

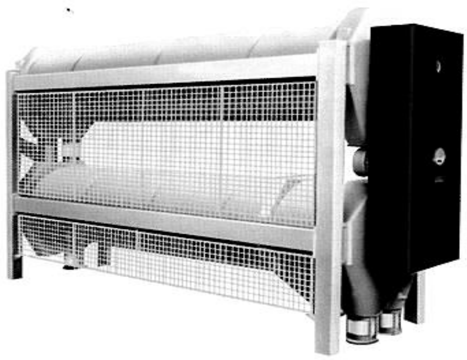


Figure 2.3 Trieur station (Prokop Mlýnské stroje)

Figure 2.4 Screen separator, dry stoner, and intensive dampener

Next, the grain is sprayed with water in an **intensive dampener** – aquatron, which dispenses water according to the grain moisture level ***(first step prior to scouring)***. Here, the grain is perfectly mixed with water, and sometimes, especially during the winter months when frozen grain is not able to absorb enough water, the grain is pre-heated in a conditioner. After being moistened with water the grain rests in **tempering bins** in order to toughen the coating layers and soften the endosperm to make the separation of hulls much easier. Well-prepared grain should have dry endosperm and wet hull. **In the first step** the grain is moistened by 1 – 1.5 % (if the grain at input has moisture content of 13.5 – 14 %, we add water to make it 15 %, values above 15.5 % are already limit).

- Intensive dampener – moistening takes place in a horizontal cylindrical housing, in which there is a rotor with a number of bars. The grain continuously moves. The amount of water is regulated by a flowmeter.
- Time of tempering (rye 2 – 3 h, wheat 4 – 6 h) depends on the moisture content and temperature of the grain. At higher moisture content or temperature level, the time is shortened. When the moisture content reaches 16 %, the grain should rest no more.

Then the grain passes into a scouring machine for surface cleaning, removal of the pericarp and hairs, and cleaning of the kernel groove.

Scouring machine is made up of a steel casing. The grain is fed to the machine through the inlet stub. In the working space, the grain is thrown by rotor blades against the sieve and passes towards the outlet. Impurities, hairs, coating layers or even germ (rye) are loosened by rubbing the grains against the sieve.

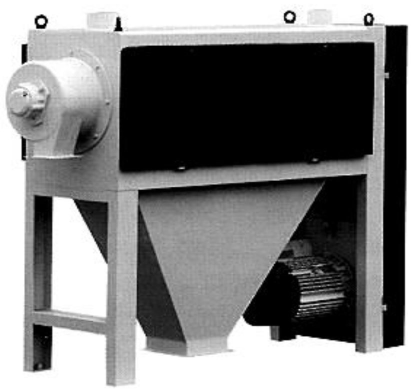


Figure 2.5 Scouring machine (Prokop Mlýnské stroje)

Then follows the adjustment of the moisture content prior to milling (first break) (**second step of dampening**).

- **The importance of the second step -** moistening of coating layers (intensive dampening with very short resting time)
- In the second step we increase the moisture content to 15.5 – 16 % (i.e. by 0.2 to 0.5 %). The tempering time is between 5 and 10 minutes in the tempering chamber, which serves as a preparatory bin before milling.
- From there, the grain falls on the scales and through a magnetic separator onto the roller mills.

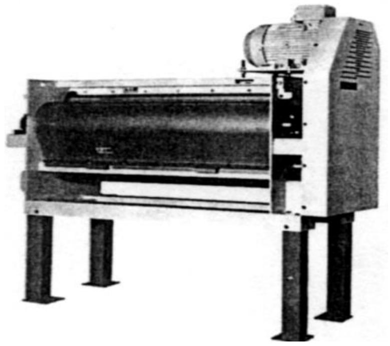


Figure 2.6 Whirl dampener Turbolizer (Bühler)

In the cleaner, the **main mass of grain** is separated from impurities, dirt and small grains to give rise to following fractions:

- ***unprocessable waste*** (composed primarily of inorganic matter and is not used further in the mill)
- ***processable waste*** (composed of organic substances which pass into feeding residues after being crushed)
- ***"kalibrát"*** (consists mainly of small shrivelled grains and is processed into meal)

Proper preparation of grain for milling is especially important when processing inferior or damaged raw materials. It also helps in pest control. Well cleaned grain is almost entirely devoid of mites and usually also the content of residues of foreign matters is reduced.

2.3 Grain milling

Milling itself is a complex process, whose task is to separate the coating layers from the endosperm as completely as possible and grind the endosperm into fine lots of prescribed granulation. The whole process takes place gradually and is composed of several basic **technological stages known as milling steps or passages**.

Each passage or milling step always involves one ***breaking operation*** followed by ***sorting*** the ground stock or ***grist*** on a sieve sorter by size and partially also by quality. Part of overtails is conveyed to additional ***sorting of semolinas***, while the rest goes to subsequent repeated milling steps with other break rolls and sieves. In a varying degree also pure, finely granulated flours (less than 200 microns) called ***passage flours*** (Fig. 2.7) already come out from the plansifter after individual milling steps are finished. Respective passages then constitute stages of the technological process and from each passage we gain a wide range of products categorized by the plansifter according to granulation.

The milling process is governed primarily by the requirements for the quality and properties of the grain mill products, but also the structural and mechanical properties of the processed grain.

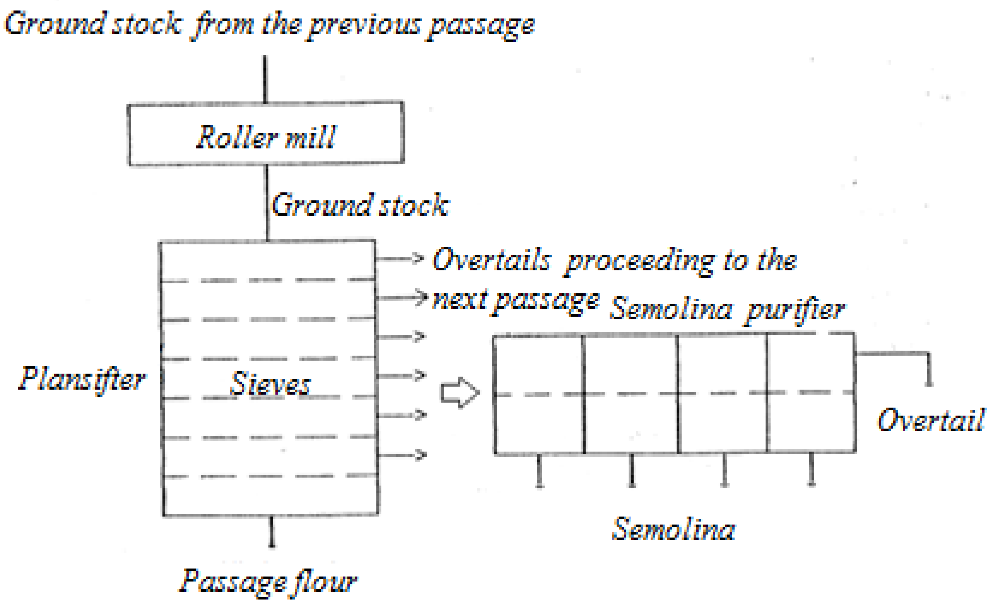


Figure 2.7 Schema of the basic node of one mill passage

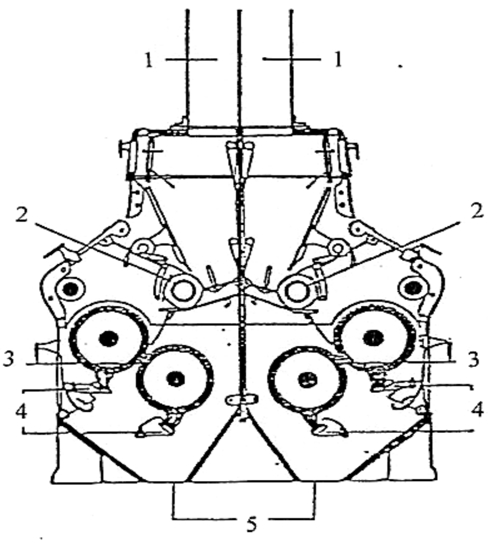
The current mill technology distinguishes between two basic ways to grind grain:

- ***Grinding into flour*** (older name "flat grinding") - grinding rye with a view to obtain as much flour as possible
- ***Grinding into semolina*** (old name "high grinding") - grinding wheat, the technological process is tailored to obtain the maximum amount of semolina, which is further purified, dehulled and scoured

Certain combinations of the two methods are applied during milling of barley, maize, soybean, and so on.

Basic machines that provide individual operations are roller mills, plansifters and semolina purifier machines.

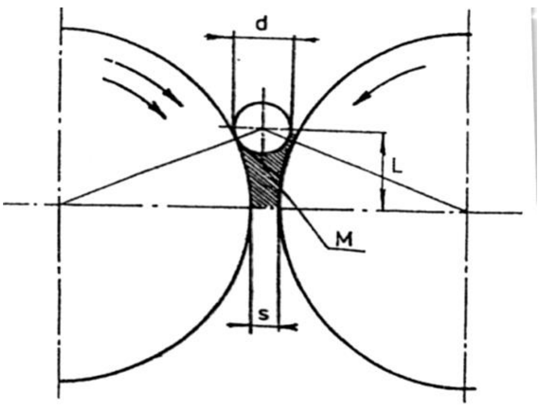
The milling itself is performed on **roller mill** (Fig. 2.8) with adjustable parameters that correspond to the needs of the respective passage. Roller mill grind the grain and intermediate products. Their body of work is a pair of counter-rotating grinding rollers, which may have smooth or grooved surface. The rollers are made of cast steel and rotate at different speeds; one is fast running roll and the other is slow moving roll. The speed ratio high speed roller to a slow speed is called the **advance**.



1 – supply of grain, 2 – feeding equipment, 3 – grinding rollers, 4 – scraper, 5 – exit of ground stock

Figure 2.8 Roller mill

For each pair of rollers the width of the ***grinding gap*** between the rollers can be adjusted (Fig. 2.9). The gap must not be substantially smaller than the size of the raw material (this relationship of the milled grain and gap is characterized by the angle of nip).



d – particle diameter, s – grinding gap, M – grinding space, L – grinding path

Figure 2.9 Grinding zone of the roller mill

Due to the different speeds of the rollers a distinction can be made between different relative positions of roll flutes as they meet opposite to each other. A pair of rollers can be thus orientated in four positions: sharp to sharp, dull to dull, sharp to dull, dull to sharp (Fig. 2.10). The most widely used position is sharp to sharp.

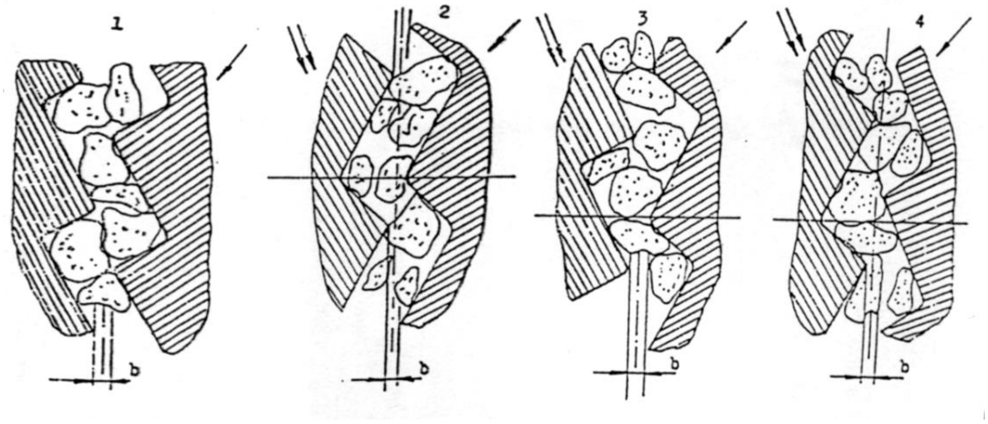


Figure 2.10 Relative position of roll flutes (Muchová a kol., 1996)
1 – sharp to sharp, 2 – dull to dull, 3 – sharp to dull, 4 – dull to sharp

The roller surface is either ***smooth*** or ***fluting,*** with the grooves having a slight inclination on the roller surface. In cross-section, grooves have a general triangle shape. The shorter side is called the sharp**,** while the longer one is called the ***dull.*** Distance of peaks of neighbouring flutes is called the ***pitch*** (Fig. 2.11)**.** The roller is characterized by the pitch of flutes per ten millimetres of the roller's circumference**.**

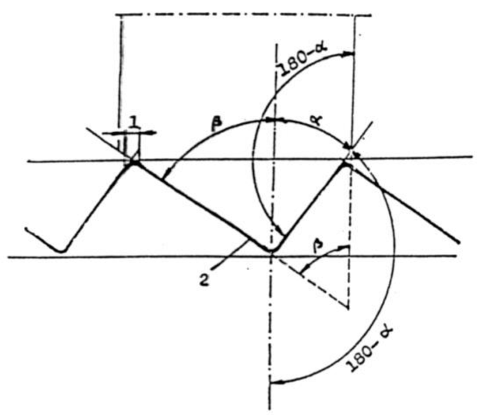


Figure 2.11 Cross-sectional view of the grinding roller grooving profile (Muchová a kol.,1996)
1 – facet of the crease, 2 – dull, α – angle of sharp, β – angle of dull

Small angle of the sharp leads to grinding into semolina, the large one provides finishering. Sparse and deep creases with a medium advance (1 : 1.5) lead to the production of semolina and are used for wheat breaking. Frequent grooves with a larger advance (1 : 3) and the position ´dull to dull´ lead to the production of flour, especially when milling rye. Smooth (ungrooved) rollers are used to sizing reduction or reduction semolina.

By adjusting the shape, depth and frequency of creases, their inclination and position to one another, the width of the grinding gap, speed and advance, the roller mill adapts to any stage (breaking, sizing reduction or reduction).

Specific load of a roller mill (Fig. 2.12) determines the amount of ground stock in the grinding zone. It is the load per unit length of milling roller in the given passage per unit time. Roller mills are two-paired, powered by electric motors. Ground stock between the rollers is spread by feed rollers.

Grinding effects in grist are also provided by **bran finishers** (Fig. 2.13), which sometimes complement the roller mills, especially when milling rye.

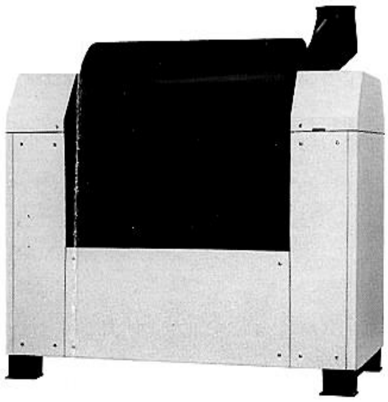


Figure 2.12 Roller mill (Prokop Mlýnské stroje) *Figure 2.13 Vibratory bran finisher*

Ground stock coming out from roller mills for further processing must be divided according to the size and partly to the quality, which is performed by sifting, sorting and purifying.
Stock particles have very diverse shapes. Their size is indicated by the number of sieve, which the mix fell through or over. When sorting the stock, a large number of size fractions is obtained, varied even in the content of endosperm

Roller mills provide the grinding of ground stock, the most important of them is breaking.

Breaking result in following fractions:

- ***coarse and fine break tailings -*** proceeds to subsequent breaking steps
- ***coarse, medium and fine semolina -*** processed by semolina sizing reduction
- ***dunsts, coarse and fine -*** partly ground into flours
- ***flours -*** the finest particles below 190 μm

Sorting of ground stock after breaking based on the particle size is done by a **plansifter** (Fig. 2.14). It is a sealed cabinet with a set of horizontally superposed sieves. Frames with appropriate sieves are inserted into sifter frames with sheet metal bottom and with central or side exit. The motion of the material is vibrational (lengthwise) and elliptical. The entire cabinet performs a horizontal circular motion on the principle of manual sifting.

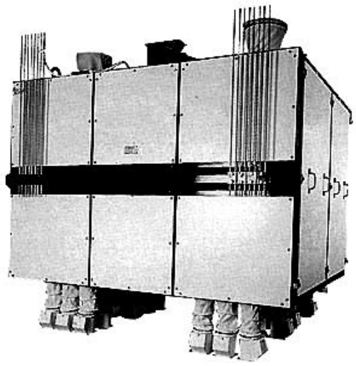


Figure 2.14 Plansifter (Prokop Mlýnské stroje)

Sieve coverings have a decisive influence on the quality and effectiveness of sifting and can be metal, silk or plastic. We use plastic coverings from no. 7 to no. 67. The number indicates the number of threads per 10 mm. Cleaning of sieve coverings is done by dual bristle brushes. The lower bristles wipe the metal sheet bottom of the frame, while the upper bristles clean the sieve from bellow.

Sifting process is complicated (Fig. 2.15), the main effect, besides sorting by size, involves self-sorting and separation of light particles, which float to the surface of the stream of grist and do not come into contact with the sieve. From each passage we obtain a wide range of products classified by plansifter according to their granulation. Products are passed either to the next grinding operation, or are mixed into the resulting products.

By sorting ground stock in a plansifter we obtain:

- ***intermediate products*** to be further processed (disintegrate, purified – gross overtail, semolinas)
- ***products not further processed*** (various factions of flour, semolinas, germs)

Figure.2.15 Movement of ground stock on the sieves of a plansifter (Hampl, 1988)

Semolina purifier (Fig. 2.16) is primarily used for sorting intermediate products by size and quality. Semolinas obtained in the first three to four breaking passages contain a high proportion of endosperm and are made into the highest flour grades.

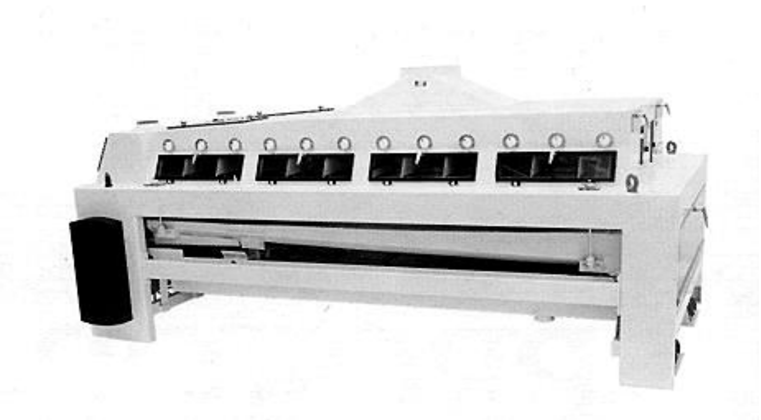


Figure 2.16 Semolina purifier (Prokop Mlýnské stroje)

Semolina purifier is basically a hanging inclined rib moving in a closed cabinet and consisting of four sieves mounted one behind each other. Layer of ground stock is moving over them, through which a current of air passes from the bottom and **sorts out ground stock by weight to**:

- ***pithy semolinas*** that pass through the sieve
- ***lighter particles (overtail)*** that fall over the sieve and are collected for further processing (sizing reduction)
- ***lightweight parts of hulls*** borne by air to the cyclone separator

The rib has a small slope, it vibrates and maintains the ground stock in a fluidized state.

The task of semolina purifier is to:

- sort out semolinas, which contain a higher proportion of endosperm than the original mix;
- sort out fractions, which contain a substantially higher proportion of coating layers than the original mix

They are produced as one-, two- and three-tier semolina purifier.

Roller mill

Plansifter

Semolina purifier

2.3.1 Milling of wheat and rye

When milling wheat, it is desired to obtain a maximum amount of quality semolinas, especially coarse ones, at the beginning of the grinding process**.**

We divide the wheat milling process into three main stages:

- ***breaking*** **–** gentle opening of grain, separation of endosperm from the coating layers in coarser particles with low yields of passage flours and semolinas
- ***sizing reduction*** **–** grinding of sorted and purified semolinas containing part of adhering hull, so that the hull remains intact and can be separated on the sieve
- ***reduction*** – scouring of endosperm residues adhering to parts of the coatings and grinding of particles of pure endosperm to the desired granulation so that bran is only pure coating particles**.**

Technological process usually include 5 ***breaking*** passages, 4 to 5 **sizing reduction** passages and 6 and more ***reduction*** passages. From each of them we obtain one or more passage flours, which are mixed according to their ash content and granulation to make commercial types of flours.

Breaking passages have grooved rollers, 1S – 4S have position of grooves H : H (dull to dull), 5S has position of grooves O : O (sharp to sharp). The advance is 1 : 1.8, 1 : 2.2, and 1 : 2.6 on the rear steps. Sorting and purifying of semolina is performed on semolina purifier.

The first sizing reduction has finely flutes rollers, others are smooth. Advance is 1 : 1.25.

- ***The 1st and 2nd*** sizing reduction steps process purified coarse, medium and fine Class I semolinas
- ***The 3rd*** sizing reduction step processes Class II semolinas
- ***The 4th*** sizing reduction step processes the remaining semolinas and at the same time edible cereal germs are obtained here**.**

Sizing reduction semolinas are of higher class than **breaking semolinas**. Small semolina from sizing reduction steps is purified in sifters and semolina purifiers, and if necessary it is carried on to coarse flours.

In reduction the material coming from semolina purifiers is ground ***(advance 1 : 1.25, higher at the last steps).***

- ***The 1st and 2nd*** reduction steps process Class I dunsts (smooth rollers)
- ***The 3rd and 4th*** reduction steps process Class II dunsts (smooth rollers)
- ***The 5th and 6th*** reduction steps process dunsts (“dotahované” in Czech) (smooth rollers)
- ***The 7th and 8th*** reduction steps process dunsts (“domílkové” in Czech) (from the 4th and 5th breaking, finely grooved rollers, advance 1 : 2.5)**.**

Results of milling are evaluated according to the coarse flour drawing. Coarse flour is obtained mainly from undersizes from sifters and semolina purifiers after sizing reduction and reduction, and pure break, small semolina and dunst (sharp) can be added.

The rye milling technology is simpler. Technological process includes 4 to 5 breaking steps and 1 to 2 semolina passages without purification. Rye endosperm easier receives water, so we need to work with lower humidity (14 – 15 % before the first break) and shorter resting time. Rye grain has a greater adhesion between endosperm and coating layers, so the endosperm does not separate easily. The grinding is more violent, larger pushing force is involved with the effort to get as much flour as possible from each passage. Mutual position of the grooves is dull to dull. The advance with S1 is 1: 2.6 and 1 : 2.8 in other passages. The efficiency of roller mills is complemented by the performance of bran finishers. The fraction from bran finishers goes immediately to another breaking step, and the overtail to the plansifter.

After passing through the rollers, the grist comes to the plansifter, where it is classified to overtailes and undertailes. **First overtailes** go to the bran finisher, which also has a sifting system. **Second overtailes** (coarse semolina) are processed at the first semolina grinding passage and the **third overtailes** (small semolina) is processed separately on the second semolina passage.

Undertailes are fine flours (T500 or T930). T 500 – the light patent rye fine flour – is obtained from the first breaking passage and first sifting.
Undersizes on other passages have higher ash content (over 0.5 %) and comply only with the requirements for type T 930 – dark rye fine bread flour.

2.4 Preparation of commercial flour types, storage and expedition

After every grinding passage we obtain a certain amount of flour, i.e. **the passage flour**. The type (commercial) flours are mixed from individual passage flours and they are divided by granulation to fine, medium coarse and coarse flour. According to their extraction rate, the passage flours vary also in the ash content, which is, together with the granulation, the main criterion for the flour characterization.

The resulting quality of the flour must be clearly defined in advance. It is fine-tuned by mixing and tempering, and possibly final treatment (fortification). The purpose of this finalization is to achieve balanced standard parameters of flour and compensate deviations that could not be eliminated in the previous steps.

Flour intended for commercial types is mixed in a **mixing machine**, which takes the flour evenly from the bin by a screw conveyor. In the process the flour is homogenized and returns back into the bin. The contents of the bin is thus transferred 4 to 5 times.

By blending different cereal varieties with specific baking properties or milled flours we can prepare a **customized flour** that is tailored to meet specific needs and requirements of the customers (e.g. for pastry production). This flour is perfectly tailored and standardized for certain types of goods.

The most important aspect in flour trading today are its user parameters, which are usually anchored in the terms of contract concluded between suppliers and customers.

Baking value of flour can also be **improved** by various additives, e.g. potato flour, legume flour, malt products as well as chemical additives.

Flour can also be **enriched** with minerals, vitamins and other products that increase its biological and baking value.

Besides the classic mill products, mills also produce finished **flour mixtures** for various purposes, which include flour with precisely defined characteristics for a certain type of use. They usually contain also other ingredients.

Flour is stored in **silos** (bulk), which have many advantages (mechanized handling with flour, less storage space, accelerated flour maturation) or in **packaging**, either in bags or it is wrapped in cross-bottom sulphate paper sacks, mostly containing 1 kg, for small consumer packaging.

Distribution of flour from mill is carried out in tank trucks. Flour also comes in bags. Smaller tonnage tank trucks (e.g. 3 t) suitable for supplying smaller bakeries are manufactured abroad**.**

The main mill products are flour, semolina and dunst. Their share in wheat is about 72 – 73 %. **Feed products** include production residues from coating layers of the grain (shorts, bran and cereal germs); their share is about 27 %.

2.5 Properties of flour

Freshly ground flour is unsuitable for baking. To acquire the necessary baking quality, it needs to be kept in appropriate conditions to age during storage; seven to ten days for rye flour, two to three weeks for wheat flour. Flour has a large active surface and readily absorbs vapours and gases from the environment; it is hygroscopic.

Flour ageing is the process of biochemical changes that result in increased binding power of flour, and thus the yield of the dough and final product. Most important of these changes are ***oxidative processes in flour proteins*** and ***enzymatic degradation of flour fats***, wherein the released unsaturated fatty acids favourably affect the properties of both gluten and flour starch. These changes are reflected in the improved quality of gluten. Gluten loses its stretch, and strength, elasticity and swelling capacity increase.

The effect of storage on the quality of flour

- stabilization of the equilibrium state of flour moisture
- increase in the flour acidity due to enzymatic hydrolysis of fat
- oxidation-reduction processes improve the quality of flour proteins
- starch gel becomes strengthened due to thickening of amylopectin coating of starch granules and due to unsaturated fatty acids released from fats
- water binding capacity of flour becomes higher and subsequently the strength and stability of the dough increases, and thus the yield of finished products
- the volume of product increases in the first months, when the gluten quality is clearly better; later it is lower as a result of the reduced gas generation capability (Skoupil, 1989)

If optimum conditions for flour storing are not met, the quality can deteriorate.

Products of decomposition of fats, in particular the oleic acid and hydrogen phosphates, flour pH, oxidizing agents and others act directly on gluten or on activators of proteolysis, which they convert into the inactive state. Participants in the ***oxidation-reduction process*** are primarily amino acids with a thiol group which easily undergo oxidation to form disulphide bonds. The course of reactions can be generally expressed by:

$$2\,(R - SH) + \tfrac{1}{2}\,O_2 \xrightarrow{\text{oxidation}} R - S - S - R + H_2O$$

In this reaction, S-S bridges are formed which strengthen the gluten.

By action of lipolytic enzymes and oxidation processes, **fat in the flour** decomposes during storage to form glycerol and fatty acids. Higher temperature and flour moisture in the presence of atmospheric oxygen accelerate this decomposition. During extended periods of storage the **flour gets bitter**, which is caused by oxidation of unsaturated fatty acids by atmospheric oxygen or by action of the enzyme lipoxidase, producing aldehydes and ketones, which gives flour a bitter taste. Also the proportion of free fatty acids rises, which together with the released phosphoric acid increase the acidity of the flour.

Also the **starch properties** change during long-term storage. Especially starches in rye flour are aging, which has an impact on the course of gelatinization and the resistance to decomposition effects of amylolytic enzymes increases. Baking value of an older flour can be improved by addition of a fresh flour with high activity of amylases

2.5.1 Flour yield and production control

The yield of flour or total edible products is expressed as a percentage to the original weight of the grain. The higher the rate of extraction is, the greater is the proportion of coating parts which come into the flour, which then results in a higher ash content.

Control activities in the mills are focused on**:**

- the control of raw materials as well as intermediate and finished products
- the control of the technological process itself

The quality control of every supply of cereal raw material is necessary in order to guarantee that the cereals are free of contaminants that could not be removed during processing and would make the finished product unfit for human consumption.

Technological level of the mill is assessed by the so-called ***specific load***, i.e. ground stock in kg per 10 mm of total length of all rollers per 24 h. This load is high in the Czech Republic; it ranges between 100 and 120 kg per 10 mm per day**.**

Mill diagram

This is a schematic plan of the technological process, which includes all the necessary technological specifications. Diagram marks are standardized and included in the relevant Czech Standard (ČSN). It contains parameters of milling machines, numbers of coverings on the sifters and semolina purifier. and the scheme of transport of intermediate products.

Ash content diagram

Mill technological process is controlled ***by the ash content***. Ash content diagram graphically illustrates the relationship between the flour's ash content and yield.

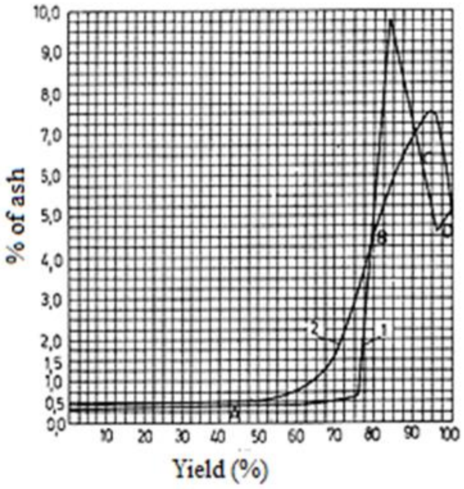


Figure 2.17 Relationship between ash content and flour yield (Pavliš a kol., 1980)
1 – Ideal milling, 2 – Practical results
Curve 1: Part A – Milling of endosperm, B – Milling of aleurone layer, C – Milling of pericarp and testa, D – Separated germ

Reduction rate (mineral content) of cereal products indicates what proportion of flour was obtained from 100 parts of the cereal. If all parts of the cereal grain remain in the floury product, we are talking about 100% extraction. Flour, which contains no or little of the surface layers of the grain, has rate of extraction from 40 to 75 %. Very fine flour has a low rate of extraction, while the extraction rate of coarse wholemeal is high.

Product diagram (Reduction key)

It summarizes the balance of manufactured products. According to this diagram, the mill produces an appropriate amount of edible products. The extraction currently amounts to 70 to 74 % in wheat and 72 to 76 % in rye.

2.6 Commercial types of flours

More than 70 % of mill cereal products is used in bakeries, 8 % in households, 10 % in fodder factories, 8 % in biscuits industry, and approximately 4% in dough making plants.

Flour is a mill cereal product obtained by grinding cereals and classified by particle size, mineral content, and the type of grain used.

Criteria of flour quality

- **content of ash (minerals)**

The ash content is the ***main distinguishing as well as quality criterion*** in the Czech Republic, to some extent related to whether the flour comes from the front or rear steps of the milling scheme, and it is related to the share of mechanically and thermally damaged starch in the flour. Most minerals are present in the outer layers of the caryopsis (up to 2 %), and towards the centre the amount of minerals decreases (0.4 %). ***Type of flour*** is a numerical designation used for 1000 times the ash content in the flour's dry matter.

- ***Colour of the flour*** depends on the extraction rate of the flour, the ingredients used, and the original colour of wheat

It generally applies that the high extraction flour, with a greater proportion of peripheral parts of the grain, is darker. This essentially correlates with a higher ash content, but there is no high correlation between them.
The use of additives of wholemeal flour or meal, or even meal products from other cereals, legumes and grains, affects the colour or hue of the bread crumb more strongly than only flour from variously extracted wheat.

- ***Flour granulation*** (coarse, medium coarse, and fine flour)

It expresses the size of flour particles defined by prescribed sieves with a particular mesh size.
Flour properties are affected not only by the rate of extraction, i.e. the chemical composition, but also by granulation. Fine (smooth) flour has greater sorption surface area, therefore it swells faster than the coarse flour. Because fine flour pass several times through the grinding rollers during production in the mill, the particles are more mechanically disturbed and more susceptible to enzymatic degradation than the coarse flour. The bakeries process mainly fine flour.

Classification and designation of flours
(according to the Decree of the Ministry of Agriculture No. 333/1997 Coll.)

- ***Fine flours***
  Light wheat flour (ash content max. 0.60 % of dry matter)
  Medium wheat flour (ash content max. 0.75 % of dry matter)
  Wheat bread flour (ash content max.1.15 % of dry matter)
  Light patent rye fine flour (ash content max. 0.65 % of dry matter)
  Dark rye fine bread flour (ash content max.1,10 % of dry matter).
- ***Semi-granular flour***, wheat (ash content max. 0.50 % of dry matter)
- ***Granular flour***, wheat (ash content max. 0.50 % of dry matter)
- ***Wholemeal flour,*** wheat (ash content max. 1.90 % of dry matter)

Sensory requirements for flour colour
- Wheat flour is white with a yellowish tint
- Wheat bread flour is white with a yellow-grey or greyish tint
- Wheat wholemeal flour has a brownish, reddish or dark red tint
- Light rye fine flour is white
- Dark rye (bread) flour is grey-white with a green-blue tint

Semolina is a mill cereal product obtained in the first grinding stage in the form of coarser particles deprived of hull.

Classification and designation of semolinas

- ***Semolina***
  Granular wheat semolina (ash content max. 0.50 % of dry matter)
  Fine wheat semolina (ash content max. 0.50 % of dry matter)
  Fine dehydrated wheat semolina (ash content max. 0.50 % of dry matter)
  Maize semolina (ash content max. 0.90 % of dry matter)

2.7 Residues and waste from the mill industry

Residues of the food mill industry include shorts, bran, meal, and grain germs and germ meal. The **waste** includes soil dust from filters and other unusable waste.

Fodder flours or **shorts** are dark "rear" flours of the worst quality. They contain a significant amount of ash (3 – 4 %), fibre, fat and protein, not forming gluten. Their share is about 5.5 % of the processed grains**.**

Bran includes usable wastes from cleaning, except the germs and "kalibrát" in wheat. It contains mainly the outer layers of the grain. The higher the rate of extraction, the worse is the quality. Wheat bran is of reddish colour, rye bran grey-green. It contains up to 7 % of ash and no more than 1.5 % of sand in the dry matter. Their share is about 21 % of the processed grains.

Meal after "calibration" comes mainly from crushing the fraction of small and waste grains separated during wheat calibration. It is produced only in the processing of wheat and its amount is 4.5 % of raw material.

Germs are separated during processing of grain in an amount of about 0.5 %. They are rich in fats and contain biologically important nutrients, especially vitamins B and E. They are mainly used in compound feed, but also have applications in food and pharmaceutical industries. Wheat germs resemble flakes and contain up to 40% of bran, about 25 % of proteins and no more than 0.2 % of mineral impurities.

Soil dust from filters is used in the production of compost. **Unusable waste from cleaning** is not used in any organized or unified way. It is usually provided for feeding field and forest wildlife.

2.8 Processing of other grains

Specialized plants (groat mills) within the mill industry process other cereals and grains, which are used for human nutrition.

Barley

Barley is processed mainly to ***groats***, ***grits***, less to ***barley flour, barley semolin***a and ***barley flakes***. Barley groats were an important part of the diet, used as a garnish in soups, a side dish for meat dishes or an independent dish. Flour has been used to make pancakes. Barley semolina is used to surrogate beer. Currently, the importance of these products has declined, but there are efforts to increase interest in their consumption for the content of β-glucans (soluble component of fibre).

Groats are produced from spring barley. **Technological process of barley groats production** comprises ***cleaning***, i.e. separation of impurities and contaminants, air separation of light impurities, destoning, ferromagnetic control, removal of round shaped impurities, and ***sorting*** of the cleaned grain into size fractions. Next follows intensive ***peeling*** on a rough emery stone, where apex is removed and closely adhering husk disrupted, ***grinding*** on vertical scourer, where hull residues are removed, and finally ***polishing*** on scouring machines. ***Sorting of groats*** by size is carried out on sieves with circular holes. Their size and quantity is given as a percentage passing through a sieve of defined mesh size with circular apertures (μm).

By size the groats are sorted into large, medium, "pig-slaughter", and small. Grits are classified as pearls and cracked barley ("lámanka"); pearls measure between 1 and 2 mm and lámanka are fragmented small ungraded grits. The sorted groats are packed. The groats yield is reported as 73 % and 26 % is barley bran.

Barley semolina is made by crushing cleaned barley.

The **production of barley flour** is similar to that of rye, but for the great toughness of grain the milling is more difficult. Hulls clog the apertures of the sieves and it is difficult to remove them. Barley is therefore better to peel harder than rye. Grinding of barley should proceed quickly, otherwise the flour turns brown and its quality deteriorates. When sifting the flour it is necessary the use thin coatings to separate the floury particles as quickly as possible. With the same rate of reduction, barley flours have a higher ash content than rye flours. Flour can also be made by grinding groats and grits.

Oats

Oats have the highest fat content (up to 7 %) compared to other cereals, with a high share of unsaturated fatty acids, as well as high content of protein, minerals, vitamins of group B and the highest nutritional value. Oats contain seven of the nine essential amino acids. They are mostly processed to ***oat flakes, crushed oat flakes*** and less to ***oat flour*** (grinding of flakes on a roller mill and sieving).

Technological process of production comprises separation of impurities and contaminants, destoning, ferromagnetic control, removal of round shaped impurities, and sorting to three size fractions. Then the grain proceeds to the vertical ***peeling-hulling machine***, which removes the oat hull. Then follows sorting on impact tables, where unpeeled grains are sorted out and a special ***scouring machine,*** where it is ground. Lightweight particles (beard) are removed by means of air.

Conditioning of oat rice - reduction of moisture by 3 to 5 %, ***steaming*** with low pressure ***steam*** up to 100 °C for removing the bitter taste, humidity between 18 and 22 °C. This hydrothermal treatment leads to biochemical changes when proteins are denatured, starches partially hydrolysed and enzymes, mainly lipolytic, inactivated. After adjusting the moisture, oats proceed to a ***flaking roller mill***. The resulting flakes are ***dried*** in belt driers and after ***cooling*** they are ***sorted by size***, pass through ferromagnetic control and are ***packed***.

Maize

For mill processing and subsequently for human nutrition the maize with high protein content is requested. The important technological indicator for mill processing is the glassiness. Maize endosperm has corneous surface layers, which contain a lot of proteins; the inner layers are mealy. The ratio of glassy and mealy parts of the grain affects the yield of semolinas. Maize grain has a germ (8 – 14 %), which contains up to 35 % of fat and should be removed prior to milling. ***High quality oil*** is pressed from the maize germs and the remaining ***cake*** or ***extracted meal*** are used as protein feed. The maize is further processed by grinding to ***maize semolina***, less to ***flour***.

The processing of maize comprises cleaning (separation of impurities and contaminants), hydrothermal treatment, separation of germs and grinding of degermed endosperm (grits).

The most demanding operation in mill processing of maize is ***degermination***, which is performed by dry breaking of grain with subsequent air flotation of maize grit, thereby removing the germs. Degermed maize grit is then ***milled*** into flour like rye and the germ residues are removed from the first two crushing steps on sifters as oversize. Technology of dry degermination process has fostered the development of use of maize.

Maize semolina is mostly used for the production of ***extruded products***. When extruded, it gives the best volume and structure of products (e.g. puffs), therefore it is either the sole or major component in mixtures for extrusion. Maize semolina and flour are part of many kinds of ***roasted or fried chips***, of which the most famous are ***corn flakes***. These chips are often added to ***cereal snack mixes (muesli)***. Maize flour and semolina are used for ***differently flavoured porridge***; ***polenta*** is produced in northern Italy similar to our potato dumplings. It has also been successfully used in the ***manufacture of biscuits***, which do not need a dough with developed gluten structure. Attempts have been made to use it for ***pastry purposes***. Maize is one of the raw materials used for gluten-free diet.

Rice

Rice is the seed of a cultural crop called *Oryza sativa* and its varieties. Commercially, the rice is not distinguished by variety, but the **shape and size of the grain**. The different types of rice include the following: *white rice* (peeled, abraded and polished endosperm of the rice grain), *brown, red cargo rice* (just peeled, with partially abraded endosperm), *broken and damaged – paddy rice* (fragments of white grains, partly abraded), and *parboiled rice* (by soaking and steaming of whole grains, the moisture penetrating the grain drives nutrients from the sub-coating layers (bran) to the centre of the grain (endosperm). Then the grain is peeled, abraded and brought to dryness.)

Based on the grain shape and length we distinguish ***long-grain rice*** – average length of 6 mm, length/width ratio is usually more than 3 mm; ***medium-grain rice*** – length of 5.2 – 6 mm, length/width ratio less than 3 mm, and ***round-grain rice*** – length smaller than 5.2 mm, length/width ratio of grain is less than 2 mm.

Mill processing is similar to the production of groats. Rice grain is cleaned, peeled, sorted, then abraded, sorted by size, and polished. The processing provides rice in three quality grades - premium, Class I and Class II, rice flour, and bran. Rice flour is less made and is used only for special bakery products. The rice milling line has 2 to 4 roller mills and reforms.

Rice comes to stores as **husked rice** (natural) from which only the outermost layer (husk) has been removed and **milled rice (**either semi- or wholly milled), from which pericarp and testa have been removed, is also polished or glazed. Sold is also **pre-cooked rice** (cooked and then dehydrated) and other variously modified rice. Rice is mostly eaten as a side dish with meat, or can be prepared in numerous ways as a separate dish. White rice has a low content of B vitamins and minerals compared to other cereals. It is among the raw materials that can be used for a gluten-free diet.

Millet

Millet groats are called hulled millet and are produced with the same technology operations as barley groats.

Technological process of production comprises cleaning, sorting by colour, where black millet grains are separated, hulling, polishing, and sorting of groats. Yield of millet groats is about 65 %.

Hulled millet is produced in one size fraction and for special purposes it can be processed into millet flakes. Hulled millet has yellow or yellow-orange to yellow-brown colour and slightly sweet flavour characteristic only for millet. Millet can be ground into flour as well.

Buckwheat

At present, buckwheat becomes an attractive crop for its nutritional and dietetic properties. Due to a very favourable composition - proteins, carbohydrates, fats, fibre and minerals in an appropriate ratio, it has a positive effect on the human body by strengthening the immune system. Hulled buckwheat is easily digestible, suitable for dietetic purposes, particularly for someone suffering from vascular difficulties. It increases the elasticity of vessel walls, regulates blood clotting and cholesterol content. It contains rutin (vitamin P), which is considered a significant antiatherosclerotic factor. It is suitable for a gluten free diet and recommended in case of ulcer diseases.

Difficulties in the processing of grain result from its shape, which is a triangular achene, where large **share** of unhulled achenes and large share of crushed material occurs when hulled. **Technological processing comprises *cleaning*** (removal of impurities and contaminants) and ***hydrothermal treatment*** which takes place in a steaming worm, where the grain is boiled with subsequent drying. This reduces adhesion between coating layers and endosperm, the endosperm solidifies, so it becomes less crumbly during hulling, the yield increases, and unpleasant bitterness is reduced. Next follows ***sorting*** of grain by size to 4 to 6 fractions and ***hulling*** of each fraction separately. An appropriate gap between grinding wheels according to the size fraction ensures good hulling, reduces waste and increases yield. Then groats are produced and ***products of hulling separated out***. The yield is 65 – 70 % of groats.

Hulled buckwheat is light brown to brown, and bright white when broken. The taste is slightly bitter, characteristic of buckwheat. Mostly groats are used or it is milled into flour and can be processed into flakes. Groats are used in soups and porridges as well as a side dish, while flour is suitable to make pancakes.

2.8.1 Cereal mixes

Cereal mixes are cereal based products with an addition of other ingredients, which are intended for direct consumption or use after heat treatment. They include the subgroup of muesli and powder mixtures. Abroad they are known as ***breakfast cereals***.

Muesli is a mix of grain mill products processed by flaking, extruding or another appropriate technology, to which other components are added, especially dried nuts, dried or otherwise processed fruits and substances regulating taste, flavour and consistency (Decree no. 333/1997 Coll., as amended by Decree no. 93/2000 Coll.). The cereal components are extruded cereal preparations and instant cereal flakes. Usually they contain also the so-called corn flakes – flaked and roasted maize products.

Cereal porridges can be produced by extrusion technology or by drying loose suspension on roller mills. The obtained semi-finished products are further ground and sieved. They are used for the preparation of separate dishes or into instant soups or sauces.

Cereal flakes are obtained from cleaned and peeled cereal grain, hulless (naked) or dehulled, by pressing or cross cutting. They are divided into oat flakes, crushed oat flakes, wheat, rye, barley and other flakes (flakes of buckwheat or millet). Prior to flaking, food oats and buckwheat are peeled on special peeling machines.

Quality requirements

They have the ***consistency*** of loose mixes; smaller, easily spreadable lumps are not a flaw. The ***colour*** is balanced after the raw materials used. ***Flavour and taste*** are pleasant, natural, reflecting the nature of the components and flavourings used.

3 BAKERY TECHNOLOGY

Bread and pastries are among the basic food in human nutrition. First findings on bread and bakery products date back to the period up to 10 000 years before Christ. In the beginning, man consumed collected grains, later he roasted them. Then he began to crush cereal grains in stone mortars and grind in primitive mills. He prepared mash from the crushed cereals and baked from it his first bread in the form of unleavened pancakes on a hot fire. Any findings about when the first leavened bread was made do not exist, but it is assumed that it was baked in Egypt 6,000 years ago. The dough made from flour, water and salt was allowed to spontaneously ferment and bread after baking was light and airy with a delicious crust.

In the 13th and 14th centuries, bakers were esteemed and wealthy people. In different historical periods not only the position of bakers, but also machinery has changed. The manufacturing process has been gradually mechanized; continuous baking lines have been introduced into production resulting in the changes in technology.

Currently, the assortment of bread and pastries is very diverse, from classic products to products with a higher proportion of wholemeal flours, specialty products and mixes having a positive impact on health. Smaller craft bakeries complete the product mix of industrial bakeries.

3.1 Raw materials for bakery production

The basic raw material for bakery production is flour. The other main ingredients are water, salt, and yeast. The other ingredients are sugar, fat, dairy products, eggs, and chemical raising agents. Bakery technology uses a number of improvement additives such as oxidants, emulsifiers, enzymes, water binding substances (natural hydrocolloids and modified starches), flavouring and aromatizing agents, colorants (caramel, roasted rye or barley). Also various kinds of seeds are used for making special products.
Ingredients for fine bakery products include dried seeds or nuts, cocoa, jams and canned fruit, while cocoa and chocolate icings, cocoa and dairy products are used for making confectionery products.

3.1.1 Flour

Flour is a versatile raw material for the entire assortment of bakery products. In most doughs it comprises 60 % or more of their weight. Essential are wheat and rye flours of varying rate of extraction (ash content). Flours extracted from other cereals, legumes or other crops are regarded as additives.

3.1.1.1 Baking quality of wheat flour

Baking quality is expressed as:

- ***Flour strength*** is determined by the amount and quality of protein (gluten) and physical properties of doughs (the dough's ability to retain leavening gases generated during rising)
- ***Gassing power of the flour*** is determined by the ability to generate sufficient amounts of leavening gas (CO_2). The correct course of fermentation is ensured by a sufficient activity of yeast
- ***Sugar-forming ability of flour*** is given by the sufficiency of fermentable sugars, which are already present in the flour (pre-existing sugars), sugars generated in the dough by the action of amylases on starch as well as sugars added as recipe ingredients.

Carbohydrate-amylase complex

Prerequisite for good gassing power and sugar-forming ability of flour is the good condition of the carbohydrate-amylase complex in flour. This complex consists of carbohydrates and amylolytic enzymes. The flour contains monosaccharides, oligosaccharides and polysaccharides (starch, pentosans, cellulose). From the baking perspective, the most significant are polysaccharides. The activity of amylolytic enzymes affects the state and quality of starch. By the action of amylases the starch breaks down into dextrins and even simple sugars like maltose and glucose. During baking the starch gelatinization occurs and large amounts of water are bound. Enzymatic activity of the grain is characterized by the ***falling number*** (FN).
Wheat flour generally has deficit of enzymes, so they are added in the form of various improvers.

Protein-proteinase complex

It consists of flour proteins and proteolytic enzymes which act on proteins during the technological process. The quantity and quality of proteins are the main criteria of baking quality of wheat. We determine the **amount (content) of proteins** *according to Kjeldahl* or using the *NIR analyser*. An important component of wheat flour is gluten, which we determine as *wet gluten content in dry matter*. Upon swelling gluten forms an elastic web in the dough which traps the fermentation gases. Gluten provides the pastry structure and affects its shape and volume. To detect the **quality of proteins** we use the *Zeleny sedimentation test*, *gluten properties*, and also the Gluten Index (GI) is illustrative of the gluten quality.

Objective assessment of baking properties of the flour is based on ***rheological properties*** determined with special devices (farinograph, alveograph, and so on).

The baking trial (or baker's experiment) provides general overview of the baking strength of flour.

Baking quality is given by the amount and quality of wheat proteins, viscoelastic properties of gluten, and enzymatic activity of the grain.

3.1.1.2 Baking quality of rye flour

Parameters determining the baking quality of rye flour are different from that of wheat flour:

- ***rye protein*** is unable to create a coherent spatial structural network that is the supporting framework of wheat pastry; therefore the rye pentosans provide the rye flour with its high water-binding capacity already at normal temperature during kneading and also starch plays a role during crumb formation of the finished product
- ***gassing power and amylase-starch complex***

Crucial for evaluating the baking quality of rye flour is the state of the amylase-starch complex. It is about the action of amylases on starch components. If there is an ***excessive activity of amylolytic enzymes*** or pre-damaged starch granules, the rye flour is able to rapidly develop a range of products of starch hydrolysis (maltose, dextrins) and its processing quality deteriorates. If the tumultuous fermentation occurs soon after kneading the dough, the yeast fermentation capacity runs out quickly and at the end of processing the product loses its volume or the shape vaulting completely slumps. The ***dough*** with an increased content of dextrins ***becomes sticky*** and no longer machinable. The state of the amylase-starch complex is characterized by the ***falling number*** (FN) and *amylographic assessment* with the amylograph.

Because milling of rye flour takes place under harsher conditions than that of wheat flour, more likely there occurs a ***higher proportion of damaged starch***, that's why rye starch gelatinizes sooner. The activity of amylases which act on the damaged starch is higher in the rye flour than in the wheat flour. If the rye bread is made in the traditional manner, i.e. loosening with rye sour, the ***activity of amylases is soon reduced by higher acidity of the matured rye sourdough***, therefore the fermentation during further processing and baking already proceeds in a desirable manner.

In comparison with the wheat starch**, rye starch** has ***more amylopectin and less amylose,*** which retrogrades back and is a major cause of wheat pastry hardening, which may explain the ***slower hardening of rye bread***. Also pentosans, which have a large swelling capacity and bound firmly water even at normal temperature, participate in higher softness and slower hardening of crumb. They help to strengthen the spatial structure of the dough and crumb by cross bounding its macromolecule with the macromolecule of proteins.

3.1.2 Water

Water is a basic raw material and by its mixing with flour and kneading the dough is formed. Water that is added to the dough must be drinkable. The manufacturing plant must ensure the safety of water and its control in all of its own distributions.

One of the water quality indicators is its **hardness**, which is the content of dissolved calcium and magnesium components. When boiling under certain circumstances they cause considerable encrustation on the heating surface. In case of an extraordinary hardness of water it is recommended either to increase the amount of yeast or reduce the amount of yeast and add malt flour.

Moderately hard water (3.5 – 8 mmol/l) is optimal. Up to 3.5 mmol/l we considered water soft, above 8 mmol/l it is hard. ***Soft water*** accelerates the fermentation and gives looser, flowable and stickier dough with a lower binding capacity. ***Hard water*** slows fermentation in dough and toughens the gluten.
Another characteristic of water is its **acidity or alkalinity**. At pH 6 to 8 the water is neutral, up to pH 6.5 it is slightly acidic and above pH 8 it is alkalic. This indicator may also affect the dough process, especially of yeast-leavened doughs. More acidic water (lower pH) supports and accelerates the fermentation and maturing processes of sourdoughs and doughs; doughs are more flowable, crumb is not very elastic with non-uniform pores, the product is lower and the colour weaker. Alkaline water slightly hampers the fermentation processes, gives smaller volume of bread, but with better crumb colour and texture.

In addition to water intended into doughs and sourdoughs, water is needed to generate steam. This water has to be as soft as possible to prevent salts clogging the pipes and nozzles of the steaming appliance. The conversion of 1 litre of water into steam at 100 °C requires 2258 kJ. One litre of water gives 1700 l of unsaturated damp steam. Steam generation needs almost the same amount of energy as the baking itself of bread or pastry (Šedivý et al., 2013).

3.1.3 Salt

Edible salt is defined as a crystalline product containing at least 97 % of sodium chloride on a dry matter basis, optionally enriched with food supplements (iodine, iodine with fluorine, or other substances). For the human body it is indispensable, but harmful in excess. The recommended intake is maximally 6 to 8 g per day.

Salt is ever present in all recipes for leavened products, even the sweet ones. It is used not only as a ***seasoning***, but also as a ***regulator of important technological processes***. Addition of salt affects the rheological properties of the dough, toughens the consistency of gluten protein, but also reduces the flour's binding capacity. At the same time the period of dough development is extended. It makes dough stiffer and hinders all enzymatic and thus also fermentation processes. Addition of salt decreases the activity of yeast resulting in reduced production of CO_2 and hence slower course of maturation. Therefore, it is not added to the preliminary fermentation stages, which require intensive fermentation, but only to the dough.

Salt also supports adequate colouring of the crust during baking. Unsalted dough easily overleavens and runs, oversalted dough, on the contrary, poorly rises and creates small products with bad porosity. Increased amount of salt (up to 2.5 %) is useful in the processing of low quality flour or flour from pre-harvest sprouted grain.

Finely ground salt is used into dough, usually in solution or water; coarse crystals are mainly used for decorating products.

For quick dissolution a ***vacuum edible salt*** is used, which is obtained by evaporating sea brine in vacuum evaporators. Crystals are ***0.25 to 0.5 mm*** large. It is suitable for adding directly to the dough or for the preparation of brine.

3.1.4 Yeast

Fresh compressed yeast is the most widely used for economic reasons. It is available in cuboids weighing 500 g and 1000 g, but also in small cubes weighing 42 g. It may contain up to 74 % of water. Yeast must be kept in dark at temperatures from 4 to 6 °C, because otherwise it loses its activity very quickly. Its shelf life is at least 14, but usually 20 to 35 days from the date of packaging, for some special kinds even longer. It is intended for preparation of leavened doughs, for controlled rising, frozen semi-products and there are also yeast specially adapted for loosening sour bread doughs.

Liquid creamy yeast contains up to 22 % of dry matter. Yeast is usually delivered in cardboard boxes or plastic bags. Storage temperature inside a special cooling box in which the yeast is kept is 2 to 6 °C. The shelf life is 28 days from the date of packaging.

Dried yeast is produced in the form of granules or beads. It has a longer shelf life; at room temperature it survives even 24 months (it is filled under nitrogen atmosphere or in vacuum). Moisture ranges from 7 to 9 %. Before use, it needs to be activated in water (one part of yeast and three parts of water at 35 – 40°C) for 10 minutes. The ratio of the dosage of the active dried yeast to the compressed yeast is 1 : 3. After opening it should be consumed within 24 hours.

Instant dried yeast is in the shape of small needles with a diameter of 0.4 mm, which are porous and contain emulsifier, so they strongly bind water. This yeast neither needs to be soaked in water beforehand nor mixed with flour, but it is added directly to the dough during kneading. It is vacuum-packed. Shelf life is two years when the storage conditions are observed.

Our recipes indicate doses of compressed yeast; when instant dried yeast is used, approximately 1/3 of that value is dosed. The difference in the dry matter of both yeasts must be compensated by higher addition of water to the dough. Recommended dosage is 1 to 2 % to the amount of processed flour.

The activity of the yeast is important for the entire course of maturing and leavening of the dough. It is monitored either through the volume of released CO_2 or the increase in the volume of the dough.

3.1.5 Sugar

Commercial types of sugar are available for general use and classified as coarse, standard and fine sugar. Liquid sugar is a sugar solution which contains a small amount of non-sugars and includes liquid sugar solution (refined white sugar), invert syrups and special syrups (they are coloured and enriched with another component, e.g. caramel).

Slight addition of sugar does not affect the rheological properties of doughs. In the technological process for the production of yeast-leavened dough, the addition of sugar (1 to 3 % for flour for common pastry) serves as a source of fermentable sugars for the yeast.

From 5 to 15 % of sugar is added into fine pastry, which positively affects the taste (together with salt it creates a full-bodied taste). It softens the crumb porosity and emphasizes the crust colour. On the other hand it reduces the binding capacity of flour and high doses of sucrose inhibit fermentation (they reduce the yeast's activity due to the high osmotic pressure of the sugar solution on the yeast cell wall, thereby causing its dehydration). Unleavened breads contain 20 to 30 % of sugar.

3.1.6 Fats

Fats are involved in the processing qualities of the dough, character of products, especially in terms of sensory evaluation, and also slower aging of bread. They increase the porosity and volume of products, prolong the softness and durability. The disadvantage is the high energy value.

Currently, the most widely used are vegetable oils, which may be readily dispensed. Solid fats are usually warmed up and dispensed as liquid. Solid fats include shortenings, margarines, butter, and in some cases also lard. Vegetable oils and fats are positive in terms of nutrition and contain unsaturated fatty acids. Partially hardened fats and palm tree oils (coconut, palm, palm kernel) are used for fine and durable bakery products. These fats have inadequate composition of fatty acids, particularly in terms of cardiovascular diseases.

Shortenings (100% fat) are edible fats which have been obtained by hardening or mixing of hardened fats and edible fats and oils, or by mixing edible vegetable and animal oils and fats.

Margarines are emulsified fat spreads with a minimum fat content of 80 %. They are produced by emulsifying blends of fats and oils with skimmed milk, whey or water. The margarine's properties depend on the fat blends used as well as conditions of production. They often contain emulsifiers, colorants, flavours, and antioxidants**.**

Butter is a traditional raw material. Butyric aroma is very pleasant and attractive. Butter disadvantage is that at low temperatures it is too firm to hard, while in the hot state it is too soft. In comparison with margarines, butter has poorer technological quality and higher price, therefore margarines are flavoured with a target for their sensory properties, fuller flavour and aroma to approach the butter. In comparison with other fats, leavened products with butter have smaller volume, and butter creams have worse whipping ability than special creams. Sponges containing butter have lower porosity.

According to the use, the fats can be divided into:

- extensible margarines (characterized by high plasticity, may not be too stiff or crumbly or soft)
- bakery margarines (especially for leavened and puff pastries)
- margarines for production of whisked and batter masses (soft margarines)
- fats for making creams and fillings (which should be plastic, adequately pliable, not crumbly)
- frying fats (neutral taste and odour, higher smoke point, oxidative stability, minimal water absorption into the product)

3.1.7 Dairy raw materials

They are usually in dried form and include dried non-fat skimmed milk, buttermilk powder, whey powder and dried cheese. Less often used are dried yoghurt and dried curd cottage cheese. Liquid milk is used only rarely, usually in small premises where it is consumed immediately and not stored. Dairy products improve crust colour, crumb structure and texture, aroma and taste of bread. They increase the content of calcium and other minerals in the product.

3.1.8 Eggs

Bakeries and pastry shops use exclusively chicken eggs. Using fresh eggs is very risky due to the difficult handling and possibility of easy contamination of a product, therefore egg products preserved by freezing or drying are used. Egg products are obtained exclusively from broken chicken eggs by homogenization. The product can have addition of sugar or salt. Eggs have universally improving effect; they increase the nutritional value of bread and pastry, and egg yolks strongly influence the colour of the crumb by their content of carotenoid pigments. They also contain lecithin, a natural emulsifier. They extend the life and durability of the product and soften its taste. Whipped whites act as a leavening ingredient, which increases the pastry volume.

They are supplied as liquid chilled egg mass, frozen egg mass, dried egg mass, and flavoured egg mass.

3.2 Improvers and additives

Improvers contain flour as a carrier and therein evenly dispersed microcomponents of an active substance (ascorbic acid, enzymes), emulsifiers. They may contain malt flour, dried milk, dried eggs, and sugar.

Composition of improvers:

- **base** – carrier – flour (wheat, rye, maize), wheat starch
- **active substance** – enzymes, emulsifiers, oxidizing and reducing agents, hydrocolloids, preservatives
- **other active components -** malt flour, sugar, dried milk, whey powder, soya flour, wheat gluten, instant fat, salt, spices...

3.2.1 Hydrocolloids

Hydrocolloids are high molecular weight binders, mostly polysaccharides. These are substances of plant, animal, microbial or synthetic origin which contain a large amount of hydroxyl groups, and have the ability to bind large volumes of water in an amount corresponding to one hundred times their own weight. They are mainly used for thickening or jelly formation.

Hydrocolloids:

- increase the ability of the dough to bind water and thus increase the yield of dough,
- increase the volume of bakery products,
- stabilize the foams, toppings, and fillings,
- stabilize the ice cream – they bind water in frozen products,
- increase the stability of thawed dough,
- increase the smoothness of products,
- extend the life of bakery products, and
- have dietary effects in bread and fillings.

According to the source from which hydrocolloids are derived, we can distinguish *hydrocolloids of*

- ***animal origin*** – gelatine, egg albumin, casein, and so on,
- ***vegetable origin*** – vital gluten, gum arabic, tragacanth, pectin, carob bean gum flour, guar gum,
- ***marine origin*** – agar-agar, carrageenan, alginates,
- ***microbial origin*** – dextran and xanthan,
- ***synthetic origin*** – modified starches and modified fibre**.**

3.2.2 Chemical leavening agents

Leavening agents, also known as raising agents, are substances or mixtures of substances which, by their decomposition, release leavening gases and thereby increase the volume of the dough. These gases are mainly carbon dioxide (CO_2), ammonia (NH_3), and water vapours (H_2O). They are used for loosening doughs (masses) for biscuits, some kinds of fine pastry and confectionery products such as cakes. Sufficient carbon dioxide formation can be ensured:

- biologically, i.e. by carbon dioxide resulting from the activity of micro-organisms (yeasts)
- chemically, i.e. by carbon dioxide resulting from the reactions of added chemicals (acid and sodium or potassium bicarbonate)

3.2.2.1 Ammonium carbonate (baker's ammonia)

Ammonium carbonate at higher temperatures decomposes to give off breaks down into ammonia, carbon dioxide and water vapours, which expand and loosen the product at baking temperatures.

$$NH_4HCO_3 \rightarrow NH_3 + CO_2 + H_2O$$

The advantage of using ammonium leavening agents – large leavening power, they are more water soluble than sodium leavening agents
The disadvantage – ammonia occurs by decomposition

It is used when loosening heavier doughs and batters - gingerbread, biscuit, Linzer and waffle.

3.2.2.2 Baking soda (bicarbonate of soda)

Sodium bicarbonate decomposes into sodium carbonate, carbon dioxide and water.

$$NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$$

The advantage of using baking soda – it does not release ammonia, affects the colour of baked products and their softness
The disadvantage - after decomposition it leaves a solid residue in the product, which negatively affects the taste of products with higher fat content**.**

3.2.2.3 Baking powder

Baking powder comes as a mixture of the alkaline component $NaHCO_3$ and acid component such as citric acid, sodium citrate, tartaric acid and others. The carrier (filler) is flour, sugar, or starch. Baking soda decomposes in contact with moisture and CO_2 is released. Baking powder is white in colour and is odourless.

It is used for loosening looser doughs and masses, cakes, pastries, products from batter masses.

3.2.3 Emulsifiers – surface active agents (SAAs)

Emulsifiers are substances that allow the formation of a homogeneous mixture of two or more immiscible liquid phases, or maintain such mixture. They facilitate the emergence and stability of emulsions of fat with water, which occur in most bakery doughs.

The most widely used emulsifiers in bakery sector include *monoacylglycerols (MAGs)* and *diacylglycerols (DAG), derivatives of monoacylglycerols and diacylglycerols, sucrose esters of fatty acids, and lecithin*. Lecithin is a natural emulsifier, which forms complexes with proteins and starch.

Emulsifying agents may be directly the recipe ingredient (e.g. egg yolk) or additive (e.g. monoacylglycerols). By action of emulsifiers the fat is better dispersed within a dough mass.

Foaming agents are substances that allow the formation of homogenous dispersion of a gaseous phase in a liquid or solid foodstuff.

Emulsifiers improve the technological properties of the dough and sensory characteristics of final products.

Emulsifiers:

- improve the properties of dough (plasticity), strengthen the dough structure,
- support the whipping ability of masses and foam stabilization,
- improve crumb softness and porosity,
- increase bread volume,
- improve digestibility of products,
- prolong the shelf life of products, slow aging of bread and pastries,
- support homogeneity in chocolate toppings,
- soften crystals in ice creams, and
- increase the microbial stability.

3.2.4 Oxidizing and reducing agents

They are added to flour or dough to improve the baking qualities. They may be oxidizing or reducing in nature.

Oxidizing agents

The only permitted oxidizing agent in the Czech Republic is the L-ascorbic acid (L-AA), in the necessary quantities.

L-ascorbic acid – an oxidant (vitamin C) used to adjust the flour**:**

- strengthens the gluten structure (toughens the dough, which results in increased elasticity and better machinability)
- improves the crumb porosity (fine pores) and shape of bread
- increases the product volume**.**

Reducing agents

Reducing agents are used to weaken the resistance of doughs with strong gluten. The most common is the synthetically produced amino acid *L-cysteine*, *various bisulphites* and *tripeptide glutathione* present in the yeast. Reducing agents shorten the kneading time and weaken the dough; its stretch rises. They are used in bakery technology to manufacture the biscuits. They can also be used if the enzymatic activity of flour is low (FN above 350 s).

3.2.5 Enzymes

Enzymes act as biocatalysts for chemical processes in living organisms. They are contained in the flour as well as in the yeast. Yeasts are able to ferment only some mono- and disaccharides, therefore starch must be initially degraded in the flour by amylase to a fermentable sugar. Wheat flours, mainly low extraction ones, do not have enough amylases, so enzymes are added to wheat doughs.

In the bakery technology, **amylases** are added **in the form of malt flour or malt extract**s. They increase volume of the product, improve crust colour and crumb texture, and retard the aging process in products.

Proteases - cleave bonds within the peptide chain, weaken the strong gluten. They are used to manufacture biscuits.

3.2.6 Preservatives

Preservatives are substances which prolong the shelf life of foods and protect them against deterioration caused by microbial activity.
Decree no. 53/02 Coll. permits the use of following preservatives in bakery products: sorbic acid, sulphur dioxide and compounds thereof, and propionic acid and salts thereof.

3.2.7 Comprehensive baking improvers

These products simplify the bakery technology in the following ways:

- provide a standard course of dough maturation and leavening
- compensate for shortcomings in the quality of wheat gluten
- improve the overall stability and machinability of dough
- improve the taste and colour of the product

They contain various combinations of surfactants, chemical improvers, hydrocolloids, enzymes and chemical leavening agents. The market offers a wide selection of these products for different kinds of products.

3.3 Bread making

In industrial bakeries, bulk flour is usually stored in silos, and local transportation involves pneumatic conveying and screw conveyors.

Technologies used for bread making

- ***bread made by traditional technology*** from rye sourdough starter in a three stage or accelerated process. By building a natural sourdough starter from rye flour and water, the manufacturer attains, by biochemical processes that take place in the sourdough starter, the formation of acids (acetic and lactic acid), and thus the characteristic pleasingly acidulated taste of the bread. During sourdough fermentation, CO_2 is produced which allows maturation of dough and leavening of bread.

- ***bread made from flour and dry, liquid or pasty leavens,*** which rises by yeast and is acidified by non-vital (lifeless) leaven, which contains acids (citric acid, acetic acid and so on). Taste and quality parameters are somewhat different from the "sourdough" bread

- ***pan breads (rye, wholemeal, multigrain and special)*** are usually baked in bread pans because due to the nature of the dough they would not be able to maintain the shape and volume during rising and baking.

3.3.1 Preparing pre-ferments for bread making

Sourdough is a slurry prepared from rye flour and water, fermented spontaneously thanks to the presence of natural microflora of the rye flour.
The most commonly used rye flour is type T 930. By mixing flour and water we obtain a slurry, and the fermentation starts in the warm environment due to microorganisms present in the flour, i.e. the mixed culture of yeasts and lactic acid bacteria.

Sourdough yield (density)

It is expressed in relative percentages and indicates the ratio of the weight of prepared sourdough to the weight of consumed flour, including flour contained in the base (matured starter from the previous stage) multiplied by 100.

Sourdough yield (V) = (sourdough weight : flour weight) . 100

The higher the yield, the thinner is the sourdough. The yield of 250 describes a liquid sourdough, which contains 150 l water and 100 kg of rye flour. The yield of 160, which is a solid sourdough, means 60 litres of water and 100 kg of rye flour.

Classic three stage sourdough process

It begins with the **starter called "zákvasek"** (thickened sourdough of stage 3) from which the base is prepared by dilution with water to a slurry with a yield of 230 to 250 (mixing equal parts of base and rye flour, with addition of twice the amount of water). This ***first stage of sourdough*** is intended mainly for the propagation of yeasts and matures 5 to 6 hours at 23 to 25 ºC.

The second stage of sourdough has a stiffer consistency with a yield adjusted to 190 to 210 by adding water and rye flour. It matures 4 to 5 hours at 26 to 28 °C and is suitable for the propagation of lactic acid bacteria.

By adding more flour and water we obtain ***the third stage of sourdough*** with a yield of 220 to 240 that matures about 3 hours at 30 °C, wherein the joint action of yeast and bacteria allows alcoholic fermentation and lactic acid fermentation to take place at the same time.

The third stage can be repeatedly multiplied by ´dividing to thirds´; repeated sourdoughs have the same technical specifications as the stage 3.

Two thirds from stage 3 are taken away **to prepare the bread dough** and the remaining **one third is used to produce the repeated sourdough**. Brine is added to these 2/3 for dough preparation plus such amount of flour to have a resulting yield of about 163. It is mixed well and the dough is left to mature for 30 minutes at 30 °C.

The above method shows best results in terms of sensory quality of bread, but is the most laborious and demanding as regards the expertise and skills of staff. The yield of the finished product is the lowest, around 142.5. Starter or "zákvasek" is intended to bridge a longer period. *Mature sourdough* (V = 220 to 230) *chilled* to a temperature of 5 °C can be used or "*nátěstek"* (V = 160), which is a mature sourdough thickened with 0.5 multiple of rye flour, or mature sourdough thickened with 1.5 multiple of rye flour and subsequently mechanically disintegrated to form *"drobenka" or dry sour* (V = 130).

On termination of sourdough production, all sour dough is used to make a bread dough. From the final mature sourdough a sufficient amount is collected to produce any kind of the starter.

Since the late 90s of the 20th century, changes in the production of sourdough and machinery replacements have taken place in most bakeries. Today, fermenters are used for the production of stabilized sourdough, in combination with a periodic mixing of the dough. Systems of two- or one-stage sour dough processes as well as accelerated sourdough fermentation process have been developed.

Accelerated process from a starter culture

The starter culture is a **solid stabilized sour dough**, which comprises pre-fermented culture of lactic acid bacteria (homofermentative and heterofermentative), which are stirred with flour and water directly to make a necessary volume of sourdough, or are intended for sequential multiplication in two or three stages. Preparation conditions do not allow a substantial development of yeasts, conversely organic acids are produced, mainly lactic acid and acetic acid. The use of starter cultures enables production of a sourdough with natural products of lactic acid fermentation, which may be, in the absence of yeasts share, stable for quite a long time. This allows the mature sourdough to be retained for several days. Yeasts are not able to multiply and produce their metabolites in the solid environment of the sourdough (V = 150 and lower).

The titratable acidity **in a solid stabilized sourdough** after 48 hours of maturation at 25 to 30 °C is between 260 and 300 mmol/kg. Sourdough is possible to multiply indefinitely by repeating, only at the time of the first commencement of production a pure starter culture of lactobacilli must be used that is supplied by specialized companies (e.g. Continuum Isern Häger, Hansen).

During the dough making, *yeast must be added* for loosening. In this way it is possible to prepare sourdough in a single vessel. Tanks called fermenters are supplied for production of these stabilized sourdoughs.

This production process is very simple, flexible in terms of time and assortment and in large volumes also economic. The taste of thus produced bread comes closest to the bread made in a traditional way. The finished product's yield is around 145; is therefore higher than when produced in a kneading trough (Venhuda, 2000).

For a liquid stabilized sourdough, it is necessary to use a starter culture at the commencement of production. Fermenters are used, which enable intensive stirring of sourdough especially in the first 10 hours of maturation when large amounts of gases are generated. Maturation period is about 48 hours. At a temperature between 32 and 38 °C the growth of yeasts will be reduced, and thereby the generation of carbon dioxide. Sourdough has a titratable acidity from 320 to 360 mmol/kg and remains unchanged over the next few days.

Sourdough concentrates

Rye sourdough concentrates for the straight dough process and loosened by yeast (at a dose of 1 to 1.5 %) are gaining in importance. The yield of the bread made in this way is at least 150. ***Sourdough concentrates*** are obtained by concentrating a natural rye leaven. These compounds are either *dry or liquid*. The sourdough basis are organic acids: lactic, acetic, citric, tartaric or malic acid, colorants that give bread crumb its characteristic appearance, and often other components, in particular hydrocolloids. Also combined improver compositions can be added comprising in addition to acids effective stabilizers of dough and substances prolonging bread freshness.

3.3.2 Dough making

Straight dough method (yeast-leavened dough process)

Straight dough process means making dough without pre-fermentation stages. All raw materials are dispensed into a mixing machine, including acidizing products or non-vital leaven. The baker's yeast is always used to loosen the dough.

Sponge and dough method

First, the rye sponge starter is made. Then all the ingredients are mixed: rye and wheat flour, water, salt, mature sponge and, where appropriate, acidizing product, yeast and other ingredients (improver, caraway seeds, or bread spices).

3.3.2.1 Raw material dosing

Recipe ratio of individual constituents in the dough is usually expressed as a percentage on the weight of flour. All raw materials are dosed exactly as prescribed by the recipe, only the water is measured according to the desired dough consistency mainly depending on the water binding capacity of flour. Before dispensing, the flour is sieved and thus aerated, which ensures proper development of the dough structure. Salt is added dissolved in water (brine) as well as acidizing products or non-vital (lifeless) ferment.

When manually dispensed, constituents are weighted directly into the kneading trough**.**

For continuous production, except flour, all other constituents are dosed by pumps in a solution or water suspension. With adding water into the dough, the temperature of the dough is controlled at the same time. To achieve the required water temperature, hot and cold water is mixed in the required ratio by a mixers.

3.3.2.2 Methods of mixing and kneading the dough

At the beginning of kneading, water gets in contact only with the surface of the flour grain and penetrates the flour components only slowly by diffusion. Initially the water is in a considerable excess. By further mechanical stirring the hydrated portion transforms into a continuous gel. Excess water then rapidly decreases, while the concentration of gel and solution rises. The gel viscosity increases and hence the resistance of dough to stretching. Also the elasticity of the dough increases. This period until the maximum resistance is achieved is called the *dough development.*

From the moment of achieving the optimum, colloidal constituents do not take any more water. If we continue kneading, the viscosity decreases, the dough surface sweats and part of water is released (over-kneading). After a certain resting time the dough is kneaded briefly (this is called hardening or "*přetužení*" in Czech), its structure solidifies, the dough development gets more even and its porosity refines.

- **Periodic (discontinuous) process** – raw materials are dosed into the mixing vessels (troughs) and are mixed and kneaded in a kneader mixer to obtain a homogeneous dough, which matures in the trough or is tumbled out into the hopper and from the hopper to a maturing belt.
- **Continuous process -** raw materials are fed into the back part of a screw kneading machine where they are mixed and kneaded to obtain a homogeneous dough, which falls out on the underside of the front part of the kneader

Rye flour usually has a higher rate of extraction than the wheat flour and contains a greater proportion of components from the so called outer endosperm and other coats. Therefore, it also has a higher content of insoluble and soluble polysaccharides whose essential constituent are pentosans.

When dough is made from a pure rye flour, an intensive water binding by soluble pentosans takes place, which also contributes to the fact that rye protein is unable to create a continuous gluten structure. The basis of the purely rye dough support structure is a highly viscous gel of insufficiently dissolved soluble pentosans and insufficiently swollen proteins. That is why the character of the rye dough is rather a viscous liquid with less elasticity than that of wheat dough. Usually, it is also stickier. To ensure its machinability and reduce stickiness to an acceptable level, water dosing must be restricted so to avoid any greater dissolution of pentosans.

Also in the rye dough the oxidative environment has a positive effect during kneading and development of the dough, since it promotes the linking of the dough's protein components with chains of pentosan polysaccharides.

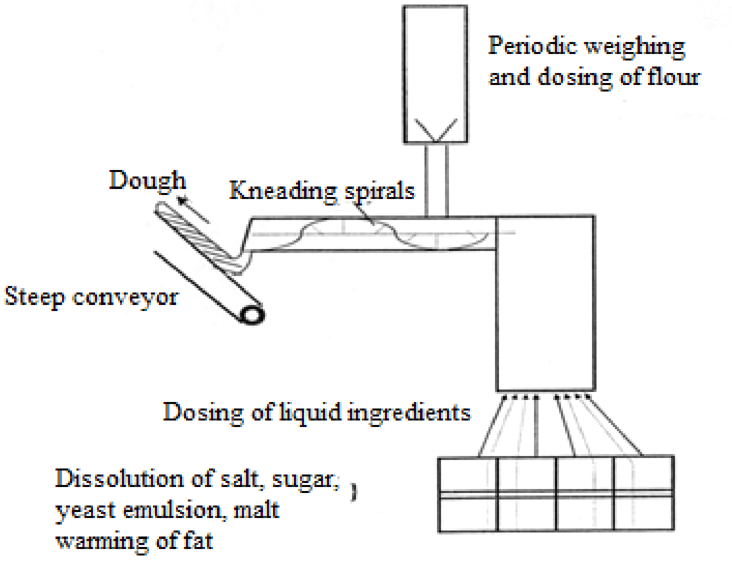


Figure 3.1 Scheme of the continuous wheat dough maker (Příhoda a kol., 2003)

Equipment for the preparation of dough

The dough is prepared in kneading machine or mixers. Kneading machines may be of low intensity (kneading time 15 to 20 min) and medium intensity (kneading time 6 – 10 min). Mixers have a high intensity of kneading up to 2 minutes. Kneaded dough has a temperature between 27 and 29 °C, with titratable acidity of 70 to 90 mmol/kg.

3.3.3 Ripening, dividing, shaping and proofing of dough

After kneading, the dough is allowed to **matures** for 15 to 30 minutes depending on the character of the dough. In *biologically loosened doughs* the processes of alcoholic fermentation take place. Yeasts consume fermentable sugars; products are CO_2 and ethanol. In fermentation with rye sour doughs, acetic and lactic acids arise as well as smaller amounts of other organic acids, aldehydes and ketones. The ripening temperature is important, at higher temperatures lactic acid fermentation and formation of acids occur, while at lower temperatures rather the alcoholic fermentation and formation of loosening CO_2 take place.

In smaller bakeries the dough matures in troughs or ripening baskets above the dividing machine, in larger bakeries on ripening belts of continuous production lines. The fermentes dough has a temperature between 29 and 30 °C, with titratable acidity of 70 to 80 mmol/kg.

After dough ripening, the dough is **divided** (cut) into loaf-sized quantities (dough pieces) of required weight. Continuous dividing and hardening machines are applied in large volume production of bread and pastries, mostly in continuous production lines. Besides dividing and hardening mechanisms, all machines have also a transport equipment for the continuous removal of hardened chunks. Dividing machines operate on a weight or volume basis. The weighed dough chunk goes to a rounding machine.

3.3.3.1 Moulding machines

Bread moulding machines are:

- **rounding machines** – dough is homogenized, the rounder closes the cut surfaces and gives each cut piece a uniformly spherical shape (conical rounder of dough loaves, belt-type rounder for bread dough) of the loaf
- **molder machines** – shape of rolls (forming the dough into a cylindrical shape). Shaped bread pieces are stored in baskets either manually or using the mechanical equipment of the proofer

Dough pieces may **proof** in trays (wicker), metal pans or loosely on baking trays (sheet). Proofing time is around 40 minutes. Dough temperature is between 27 and 30 °C, the temperature in the proofer is 32 to 35 °C and humidity of 70 to 75 %.

Dough proofing (or final fermentation) is ensured by yeasts producing CO_2 (fermentation gas) and ethanol, which after heating of dough in the oven can also function as fermentation gas.

Part of the continuous lines are usually automatically operating belt-type proofers, from which the proofed pieces are automatically charged into the oven.

Proofers

Smaller artisan bakeries use ***proofing boxes***.

Continuous proofers consist of a steel frame and trays with banneton baskets suspended on chains. Air temperature and humidity are controlled inside**.**

Belt-type proofers may have three to six levels, with a possibility to set different climatic conditions in each level. Proofing time is regulated by varying belt speed.

Desk proofers, where the dough proofs on plastic or wooden desks suspended on chains. Proofing time is adjustable by the number of loaded desks. Different types and sizes of bread may rise here. Proofer is not suitable for loose doughs.

3.3.4 Baking

At the beginning of the baking process, the oven is steamed up. Steam is injected into the baking chamber. The water contained in the steam condenses on the surface of the dough piece, thereby moistens it. Starch on the surface of the dough piece swells, then it gelatinizes due to the high temperatures in the oven, thereby creating a flexible membrane on the surface so that the volume expansion does not break the surface of the product. Time of steaming is 1 to 3 minutes and exhausts are closed. After that the steam exhausts open in order to draw off the steam.

After the withdrawal of steam from the baking space the bread bakes at 250 to 280 °C for 10 to 20 min. Steam exhausts are open. In the second half of this initial baking stage the temperature is reduced to about 230 °C.

During **baking through** the temperature in the baking space is further reduced to about 200°C. Steam exhausts are open. At the end of this stage the crust is already coloured.

In the **final baking stage** the temperature of the baking space is less than 200 °C (170 to 190 °C). Crust colour is not changing any more. The product must be well baked through with a sufficiently thick crust. Final baking stage lasts 15 to 30 minutes.

3.3.5 Cooling and dispatch

As soon as bread is removed from the oven the process of baking off begins. The bread cools down and crumb stabilizes. The temperature on the surface of the bread crust after baking is about 170 °C, the temperature of the layer of the crust adjoining the crumb is between 110 and 115 °C and that of crumb is less than 100 ºC.

After baking, the escape of heat from the product is as slow as the heat penetration into the dough. Sufficient cooling of products for safe handling may take up to tens of minutes depending on the bread size.

In some bakeries the bread is transported to a turntable, which works on the principle of a rotary table with a capacity of one tray. Baked bread is left to cool down freely on trolleys, from continuous ovens it is usually manually loaded onto shelf trucks or is allowed to cool down in containers. Bread may also be placed into a cooling device immediately after baking.

Prior to **packing and dispatch**, some products are sliced on string or blade cutters. Also this operation must be performed with already the cooled down products. Handling products after baking should be under increased sanitary supervision.

3.4 Production of common bakery products

3.4.1 Traditional production of wheat doughs

When kneading wheat dough a three-dimensional network of the gluten protein gradually forms. This is the support structure of the dough having the character of a stiff resilient gel. In oxidation and mechanical approaching of two different amino acids with -SH groups the disulphide –S-S- bond is created.

In creating elastic spatial structure of wheat dough the disulphide bonds, cross peptide bonds between the branched amino acids, hydrogen bonding between adjacent chains and other physical forces are important in the **gluten protein**. Principal importance in the creation of wheat dough have **oxidizing agents** (L-ascorbic acid).

Using intensive oxidation during kneading is important for special procedures of accelerated dough development with a highly intensive kneading. When kneading the final structure of the dough is formed in a very short time and doughs have considerably shortened or no maturing at all. The protein structure of the dough is much stronger than with traditional kneading and allows creating very thin walls of pores that keep the leavening gas. This results in a much larger volume of products. At the same time high mechanical strength and thin walls allow the creation of a very flexible crumb structure.

Also the hydrated *starch* in the gelatinized state plays an important role in dough preparation. The amount of bound water is to some extent also involved in the pliability of the dough and consequently the pliability of final products. Hydration processes in starches are influenced by the amount of water, temperature, type and quality of the flour starches. The initial gelatinization temperature of the wheat starch is 50 to 62 °C and the optimum viscosity at about 90 °C.

Sponge and dough method of wheat dough making

It is a preparation of pre-fermented stage, fermentation of added yeast well before the final dough mixing.

In the Czech lands, the most common and traditional type of the *pre-fermentation stage* in the production of wheat bread in the past was a *sponge* prepared with flour, water and yeast. Barley malt (malt flour, extract) was added. These raw materials were mixed into a thin mixture (thinner than the dough) and left 1 hour to mature.

The pre-fermentation stage (sponge) is used only ***rarely*** and mostly in smaller bakeries. It is prepared in a mixer or whipping machine (ferment beater) so that the fragmented yeast is first whipped with water and malt into a homogeneous mixture, then flour is added and the mixture is again whipped into a homogeneous smooth appearance free of lumps.

Straight method of wheat dough making

Bread is produced mainly by the straight method. In the straight method all ingredients are dosed simultaneously, and immediately mixed and knead. This straight method is preferred in terms of time and labour. Its use also prevails thanks to the bread improvers used.
The dough maturation period depends on the method of kneading and the improvers used. Time necessary for straight method may be shortened if the recipe dose of yeast is increased. What is needed is its sufficient activity and standard gassing power. Straight method requires higher costs of raw materials. Without the use of improvers the bread requires a longer maturation period.

3.4.2 Dough dividing

After maturation, the dough is divided into loaves. Continuous dividing and hardening machines are applied in the mass production of common bakery products, mostly in continuous production lines. Besides dividing and hardening mechanisms, all machines have also transport equipment for the continuous removal of hardened loaves.

Division of dough to loaves is done using dividing (cutting) machines. In small artisan bakeries they are periodic - semiautomatic or automatic and in industrial bakeries they are of a continuous type. Most of the dividing machines is also integrated with rounding.

3.4.3 Dough shaping

Mechanical shaping (moulding) of products is done in a dual process: the dough is rolled out into a thin sheet, and then rolled up (rolls, batons), or a circular or oblong dough piece (small loaf called “klonek” in Czeck) is prepared, onto which various designs are embossed on a continuous belt by pressure of a die.

Machines for shaping common bakery products

They mainly process wheat flour doughs of low weight. More intensive mechanical working of the dough and more complex shape of intermediate product are required. They are:

- Roll making machines - mimic the traditional hand shaping
- Embossing machines - mimic the traditional design of the product

The principle of shaping in the ***roll making machine*** consists in inserting pre-leavened hardened dough pieces into the machine, rolling them out into sheets, and rolling up into the shape of "straight rolls."

Embossing (stamping) machines (bun making machines) are essential for shaping buns, sandwich buns, or kaiser rolls. In these machines cuts are embossed into hardened pre-leavened dough pieces or batons. Functional tools are dies made from plastic or light alloys. The die surface must be perfectly smooth, so that the adhesion of the dough is only minor.

3.4.4 Proofing of dough pieces

Automatic belt-type proofers are usually part of the continuous production lines, from which the proofed pieces are directly charged into the oven.
In smaller bakeries the shaped products are placed onto trays that are stacked in a trolley and transported to the proofer box with controlled temperature and humidity. After proofing they are decorated.

3.4.5 Baking

The initial phase of the baking process needs the highest temperature of 200 to 240°C. After some time, the temperature is gradually lowered and the final phase usually takes place at temperatures around 200°C. Common bakery products made from wheat flour are baked in a steamy space.

3.4.6 Cooling and dispatch

Baked pieces are shaken down to the counting belts and conveyed to the sensing probes. The counting device is intended to count straight rolls weighing from 45 to 60 grams and the embossed assortment. When counted, baked pieces are loaded into crates and stored in a warehouse for shipping.

Batons are sliced (cut) on a slicer (cutter) after cooling and then packed. Semi-automatic to fully automatic equipment is used with an option to load packed products into crates.

3.5 Baking ovens

In any bakery, ovens are the limiting factor in terms of the production efficiency. The production efficiency is closely related to the performance of other equipment in the bakery or in the production line. Basic value for technical and technological assessment of the oven is the size of the baking surface given in m^2.

According to the method of operation, ovens are divided into **periodic (discontinuous) ovens** where loading and baking proceed in cycles, and **continuous ovens** where the dough pieces are loaded onto a moving belt and after passing through the whole oven they are baked (at the end they are manually or automatically removed).

Periodic ovens are divided into deck (charging) ovens, box-type (trolley) ovens and periodic belt-type ovens (during baking the bread moves into the oven and when baking off the belt moves back).

Deck (charging) ovens are of cyclothermic and thermal oil types. The heat from above is distributed by radiation, while heat from below by conveyance.
Deck ovens are baking surfaces located in several tiers one above the other (Kornfeil). They are distinguished by their heating systems, static or dynamic atmosphere during baking, the height of the tiers, charging or pull-out tiers, the number of baking decks from stone or steel. The main advantage is the saving of built-up space.

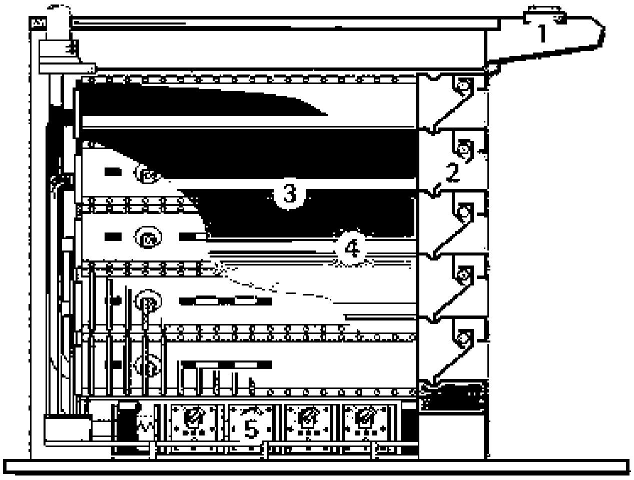


Figure 3.2 Scheme of deck oven
1 – protective cover with exhaustion, 2 – patented stress door, 3 – two-stage insulation, 4 – refractory protection (20 mm), 5 – steaming equipment

Rotary ovens ("Rototherm" ovens) are trolley - box-type (rack) ovens. In terms of the shared heat they are convection ovens. The product shares heat mainly by hot air circulation. The trolley is slowly rotated in the oven to obtain more uniform baking of products. These ovens require a large area for trolleys for both proofing and cooling down the products.

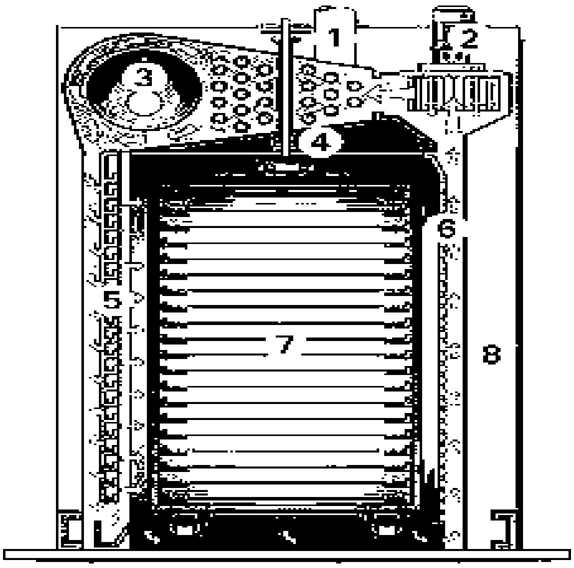


Figure 3.3 Scheme of rotary oven
1 – flue gas exhaust, 2 – fan, 3 – burner, 4 – rotary mechanism, 5 – efficient device for hot air distribution, 6 – exhaust wall, 7 – suspended trolley, 8 – thermal insulation

According to the method of heating they rank among the **hot-air ovens** (hot air is blown into the oven chamber, where it circulates in a controlled manner). In the hot-air ovens the intensity of heat transfer is much higher. Products are passed around by flowing hot air evenly from all sides, thus leading to a faster and more uniform baking.

The bakeries usually use them for baking fine and common bakery products. Also various types of bread up to 1 kg of weight can be baked there. The oven can also be used for thawing or processing of frozen loaves. Products are delicious and crunchy up to 4 hours after baking. Then their consumer value diminishes drastically. The white bread (rolls and batons) from rotary ovens is inappropriate for distribution at greater distances.

Cyclothermic belt-type ovens can operate continuously or discontinuously (periodically). ***Continuous belt-type ovens*** belong to the basic equipment of large industrial bakeries.

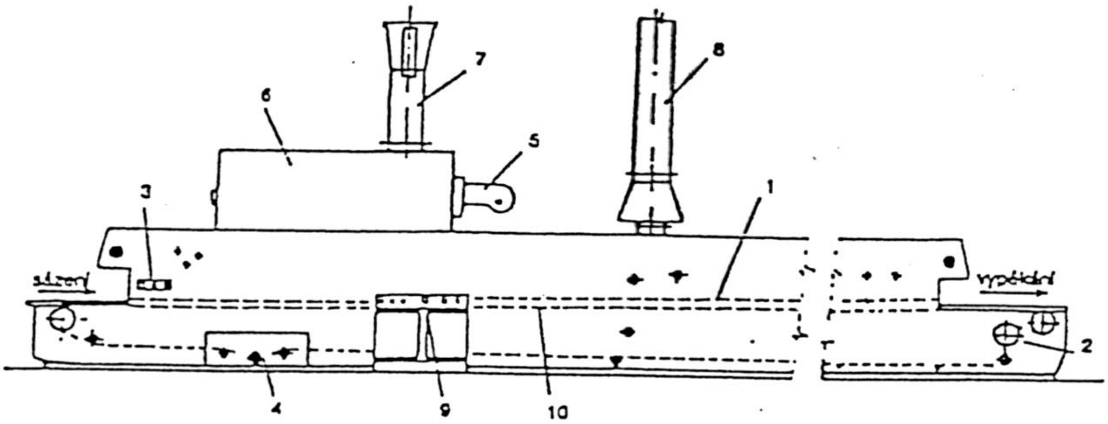


Figure 3.4 Scheme of continuous belt-type oven

1 – baking belt, 2 – belt drive, 3 - steam inlet, 4 – belt movement control, 5 – burner, 6 – combustion chamber, 7 – flue gas exhaust, 8 – combustion product exhaust, 9 –control panel, 10 – baking space

A continuous belt-type (band) oven has a relatively simple structure - mostly comprise a conveyor belt, smooth operation without lost time during charging and baking as well as the largest specific baking performance of all types of oven. It has universal application - breads, pastries, cookies, biscuits, cakes. The tunnel furnace results in better and more intensive steaming and even baking of products.

3.6 Dough yield and losses

Calculation of the indicators is given according to Skalický (1997).

Dough yield (V_t) represents the ratio of weight of the dough (flour and the sum of weights of individual components, including water, which is not indicated in the recipes and is dosed according to the flour’s water binding capacity) to the weight of flour. The yield of the dough is given by the recipe and the way of dough making process. It may be affected by the flour’s water binding capacity and its moisture.

$$V_t = \frac{m_t}{m_m}.100 = \frac{m_m + \sum m_i}{m_m}.100 \quad \textbf{(\%)}$$

m_t dough weight (kg)
m_m flour weight (kg)
$\Sigma\, m_i$ sum of weights of individual components (kg)

Yield of the final product (V_v) indicates how much bread or pastry was baked from 100 kg of flour. It is expressed as a percentage on the weight of the processed flour and represents very important economic indicator for bakers. In practice we can only determine it if we know the weight of products baked from a certain amount (weight) of flour. The weight of the baked product is determined after cooling (ca 2 hours).

$$V_v = \frac{m_v}{m_m}.100 \qquad (\%)$$

m_v weight of the baked product (kg)
m_m weight of the consumed flour (kg)

We can also determine it from the dough yield (V_t), if we know the baking loss (Z_p). Baking loss must be expressed in % to the weight of flour.

$$V_v = V_t - Z_p \quad (\%)$$

Yield of products depends on the flour's binding capacity, the degree of doneness (baking loss) and the size of technological and handling losses. The yield of our breads varies from 130 to 144%, the yield of sweet braided Christmas bread (called "vánočka" in Czech) is higher. Skalický (1997) reports 164% as the value verified through practice.

Losses

Technological losses:

Fermentation losses – ranging from 1.5 to 2 % of weight of the processed flour – can be limited by addition of salt in the dough.

Baking losses (shrinkage) – these are losses resulting from loss of water by evaporation. Size of losses depends on the shape and weight of the product, baking time and temperature, dough moisture, type of processed flour, and so on. Losses amount to 10 to 15 % of the weight of the processed dough. Larger breads and rye breads have relatively lower shrinkage because rye flour binds more water as well as some improvers, 10 to 13 % in common bakery products, 12 to 14 % in fine pastry. The larger the surface of the product, the larger are the losses (Hampl, Příhoda, 1985).

$$Z_p = \frac{m_t - m_v}{m_t}.100 \quad (\%)$$

m_t weight of dough (kg)
m_v weight of baked product (kg)

Handling losses occur mainly in handling flour. When carefully working, losses may be reduced up to 0.5 % of the processed flour.

Losses arising from breach of the product quality (reject rate)

Rejections which are hygienically safe, e.g. rolls and other pastry, can be used for the production of breadcrumbs. Rejected bread is dried, crushed, mixed with water in a pasting device to form a paste which can be incorporated into the dough (2 – 3 %).

3.7 Bakery products

Bakery products include bread, common bakery products (rolls, buns…), fine bakery products (pastries, cakes…), and durable bakery products (biscuits…).

3.7.1 Bread and common bakery products

Characteristics and classification of bread and common bakery products to groups

According to the implementing Decree of the Ministry of Agriculture no. 333/1997 Coll. as amended by Decree of the Ministry of Agriculture no. 182/2012 Coll., bakery products are classified and defined as follows:

Bread is a bakery product loosened by sourdough or yeast, shaped like a baton, loaf or panned, with the exception of non-traditional types of bread, with a weight of 400 g and more, with the exception of sliced bread and non-traditional types of breads.

Common bakery product is a shaped bakery product made of wheat or rye flour and other ingredients and additives, which contains less than 8.2 % of anhydrous fat and less than 5 % of sugar, based on the total weight of the grain mill product**.**

Following types are further defined:

Wheat bread or **wheat bakery product** is a bakery product containing at least 90% share of wheat grain mill products out of the total weight of grain mill products

Rye bread or **rye bakery product** is a bakery product containing at least 90% share of rye grain mill products out of the total weight of grain mill products

Rye-wheat bread or **rye-wheat bakery product** is a bakery product in the dough of which there should be higher than 50 % share of rye grain mill products and higher than 10 % share of wheat grain mill products out of the total weight of grain mill products

Wheat-rye bread or **wheat-rye bakery product** is a bakery product in the dough of which there should be higher than 50 % share of wheat grain mill products and higher than 10 % share of rye grain mill products out of the total weight of grain mill products

Wholemeal bread or **wholemeal bakery product** is a bakery product, the dough of which should contain at least 80 % of wholemeal flours or equivalent amount of treated outer layers of the caryopsis out of the total weight of grain mill products

Multigrain bread or **multigrain bakery product** is a bakery product, to the dough of which grain mill products are added from cereals other than wheat and rye, for example legumes and oilseeds, in the total amount of at least 5 % out of the total weight of grain mill products

Special bread or **special bakery product** is a bakery product that in addition to grain mill products from wheat and rye contains also other ingredients, particularly cereals, oilseeds, legumes, fibre, dried seeds or nuts, vegetables, dairy products and potatoes, in the amount of at least 10 % of the total weight of grain mill products, or non-traditional types of bread such as arabic pita bread or similar types of flat bread weighing less than 400 g, which contain at least 50 % share of grain mill products, and are generally loosened by sourdough or yeast

Fresh bread is an unpacked bread, whose technological process of production, including putting into circulation, was not interrupted by freezing or any other technological treatment to extend the shelf life, and which is offered for sale to consumers within 24 hours after baking or other similar heat treatment

Unpacked bakery product that was frozen in a finished state and is offered to the consumer thawed, must be visibly labelled 'thawed' and this label must be visibly placed near the name of the product in places, where the product is offered to consumers.

Unpackaged bakery product that was finished from the frozen semi-finished product must be visibly labelled 'from frozen semi-finished product' and this label must be visibly placed near the name of the product in places, where the product is offered to consumers.

Labelling of bread and bakery products
Bread and common bakery products are labelled by the name of type and group.

Bread assortment

Today, there is a very wide range of breads of different weights, e.g. consumer bread with caraway seeds, farmer’s bread, dark round bread, white round bread, and so on. Consumer wheat-rye bread or rye-wheat bread usually contains 30 to 60% of rye bread flour (T930) in the recipe, supplemented with 70 to 40 % of wheat bread flour (T1000). It may be with caraway seeds (0.5 to 0.8 % is added to the dough) or without caraway seeds. Wheat breads include also pan toast breads and Graham wholemeal bread. Weight of bread is usually 700 to1200 g/pcs.

Assortment of common bakery products

Roll, bun, hamburger bun, bun sprinkled with cheese, bun topped the sesame seeds, twist sprinkled with salt and caraway seeds, French baguette, baguette topped the sesame seeds, baton, sandwich bun, kaiser roll and many more.
Most often wheat products are made, but also wheat-rye (bread roll) and multigrain (baguette, kornspitz, baton, and so on).

3.8 Production of fine bakery products

Fine bakery products (flour confectionary goods) are bakery products obtained by heat treatment of doughs or masses with at least 8.2 % of anhydrous fat or 5 % of sugar by recipe of the total weight of the grain mill products used, or stuffed with various fillings before or after baking such as marmalade, fruit spreads, fillings that are microbially stable at normal conditions of storage, jam or damson cheese, or sprinkled or decorated on the surface with icing or glaze (Decree of the Ministry of Agriculture no. 333/1997 Coll., as amended by Decree of the Ministry of Agriculture no. 182/2012 Coll.).

For classification in the fine bakery products, meeting of just one condition is sufficient, i.e. either anhydrous fat content of more than 8.2 % or the sugar content over 5 % to the weight of flour.

So also salty or sugar-free products intended for special diets can be included in fine bakery products category.

Fresh fine bakery products are unpacked fine bakery products, whose technological process of production, from the dough preparation to baking or similar heat treatment, including putting into circulation, was not interrupted by freezing or any other technological treatment to extend the shelf life, and which are offered for sale to consumers within 24 hours after baking or other similar heat treatment.

Fine bakery products are labelled with the type name – ***fine bakery product or fresh fine bakery product.***

Fine bakery products are not sorted into groups; they can be identified by words expressing the recipe or technological process such as made ***with puff pastry***, ***fried***, ***with pulled dough***, ***drop batter***, ***foam mass***, ***sponge cake batter***, ***short-crust pastry***, ***nut-powdered sugar mass***, t***ea biscuits***, ***fruit bread***, ***salty and cheese pastry***.

They represent a wide range of products, but smaller production volume in comparison to bread and common bakery products. This is due to high labour input, demands for raw materials and high energy value.

3.8.1 Sweet Christmas breads and cakes

Sweet Christmas bread dough is stuff, well matured (ripe), unfilled, only with luxury types raisins, almonds or candied fruit are directly added to the dough. Sweet Christmas bread products are mostly in pieces of greater weight. They have an elaborated shape; they are braided or twisted or with cut surface. Their surface is well brushed with beaten eggs (or today with egg substitutes which are whisked with water) before being put into oven. Sometimes they are sprinkled on top with sliced almonds or poppy seeds.

The most common unfilled fine bakery products are Christmas breads, Easter cakes, stollens, poppy seed breads, poppy seed shaped breads, Carlsbad rolls

The cake dough is looser, rather younger, has a high proportion of fillings. Cake products have simple shapes and pieces of smaller weights dominate. A characteristic feature is a high proportion of fillings, which significantly improves the cake yield when compared with Christmas bread. The filling is either partially or completely wrapped in the product (rolls, sweet filled buns), or is deposited on the dough sheet and the surface is poured with crumb topping called “žmolenka” in Czech (flour, sugar and butter mix in a ratio of 2: 1: 1). The free surface of cake products can be brushed with “Novolesk” (milk protein concentrate with sugar and modified starch) or melted fat.

The most common filled cakes and pastries are cakes and buns with different fillings such as poppy seed, curd cheese, damson cheese, jam, and so on, baked in pans and brushed with oil, small buns baked in the pan, Bundt cakes unfilled or filled with poppy seeds, baked in pans, rolls with fillings, pies and tarts, triangular shaped pastries and cones with different fillings, wedding cakes and others**.**

Raw materials

Basic ingredients: fine “special” wheat flour, fat (possibly table margarine, table butter, oil, lard), caster sugar, egg content, Diapol (enzyme preparation), yeast, salt, water (milk)

Enhancing ingredients: curd cheese, poppy seeds, fruits, semi-finished fruit products (candied fruit)

Improving ingredients: dried seed or nuts (almonds into sweet Christmas breads), raisins, lemon and orange peel, spices, and so on.

Fillings made from: curd cheese, poppy seeds, curd cheese-poppy seeds, marmalade and jam, damson cheese, apples, peanuts, cinnamon and others.

Production process technology

Sponge-and-dough method is the most common in ***dough preparation***. A sponge is prepared from the baker´s yeast. After fermenting it is dosed into the dough. The dough can also be prepared by straight-dough method, where all ingredients are mixed at one time;

dough fermentation, dividing, shaping and filling;

proofing of shaped semi-finished products in proofers (temperature 35 to 40 °C at a relative humidity of 75 to 80 %, time by weight from 15 to 50 minutes);

baking (without steam, at lower temperature of 220 to 250°C and longer time 9 to 60 min according to the principle: the bigger the weight and richer recipe, the lower temperature and longer baking time. The large volume of filling also slows baking.

Durability of unpackaged products is one day.

3.8.2 Fried products made from leavened dough

The filling is usually introduced after frying or products are unfilled. Production range is constantly expanding with new products. The production is advantageous from several aspects: frying time is shorter than baking, energy savings are achieved, doughnut shaping is quick and easy, looser doughs are prepared, so a higher yield is achieved.

Raw materials
Coarse wheat flour, fine “special” wheat flour, whole milk powder, superfine sugar, table oil into the dough, liquid pasteurized egg yolks, salt, yeast, lemon paste, fresh water into milk powder, domestic rum, shortening for frying, jam, powdered sugar for sprinkling.

Doughnuts (or donuts) contain more eggs and yeast than sweet Christmas breads. The dough is often made from supplied ***ready-made doughnut mixes***.

Production process technology

Sponge-and-dough method is the most common in ***dough preparation.*** Rum is added to the dough. After maturing, the dough is divided into pieces, which are ***hardened*** and ***rise*** at 28 to 30 °C, with higher relative humidity to prevent them crisping up. Leavened dough pieces are placed into fat having a temperature of about 150 – 180 °C and are ***fried*** on each side for 2 to 4 minutes. Rum supports the product’s fluffiness and reduces fat absorption during frying.

Light rim along the doughnut’s periphery arises so that a crust begins to form on the bottom (submerged) side of the doughnut being fried immediately after insertion into the fat, while the upper (non-immersed) side sharply rises and becomes specifically lighter (has less specific weight). After the doughnut is turned to the other side, it does not submerge completely, so part of the product’s surface does not come into direct contact with hot fat and remains white.

After frying, doughnuts are filled with microbially stable fillings, fruit preserves and spreads with a piston filler with two hollow filling prongs. The amount of filling is about 14 % of the total weight of the doughnut. The filler may also be part of a mechanized line. Cooled doughnuts are put into crates for dispatch, usually in a single layer, and poured with icing sugar. Frying shortening (100 %) is used for frying, because it is practically anhydrous and free of organic non-fat substances (proteins, sugars), which would accelerate its thermal decomposition.

Only specially treated fats and oils are recommended for repeated long-term frying. On the Czech market they include Omega fat, palm oil, palm olein or some fractions of palm oil.

In small-scale production the used, but not impaired fat, is refined. After each frying about 1.0 to 1.5 litre of cold water is added into still hot fat in small quantities, into which most of the impurities are absorbed. The purified fat, as specifically lighter, settles on the water level, so it is relatively easy to pour it off. Dark residues of flour and dough are deposited on the bottom of the vessel within the water fraction. In large-scale production the used fat is discarded and replaced with fresh.

Products
Jam filled doughnut, custard filled doughnut with chocolate coating, sprinkled with coconut, chocolate cognac filled doughnut, braided doughnut, twisted doughnut, pierogies with various fillings and toppings.

3.8.3 Puff pastry products

Puff pastry is a dough with high fat content prepared without the use of leavening agents. It consists of individual layers of water-based dough and fat, which after heat treatment exhibit characteristic flakiness.

The flaky texture is produced by regular alternation of horizontally laid layers of water-based dough and fat. These layers must remain separated until the baking starts. Therefore, the dough is prepared in cold premises and extensible margarine is used as a roll-in fat, which has a higher melting point and lower water content so it is not absorbed into the basic dough. Only during baking the fat melts and dough loosens by steam which escapes from the basic dough and must wade through the layers of fat.

Due to higher content of fat and little loosening the puff pastry products are more crispy than plump.

Puff pastry can be prepared at home or purchased as a readymade chilled or frozen product. It is among the products with the greatest growth in the volume of production and consumption. Production is intensive in physical work and accuracy, therefore, machinery used in the large scale production is often combined in entire production lines.

Raw materials

Basic raw materials are fine “special” wheat flour, fat, water and salt. Other ingredients can be yolks, vinegar, yeast in the case of plunder (yeasted puff) dough and improvers. Commonly they are prepared without sugar. If sugar is listed in some recipes, it is usually only small amounts to improve the colour of the baked product.
Flour should have a sufficient content of proteins – gluten (over 30% of wet gluten in the dry matter of flour). This creates the dough's structure and affects the rheological properties of the water-based dough. Flour should have a higher content of gluten which rapidly swells and is strong and stretchable. As far as fats are concerned, both butter and extensible margarine can be used. Vinegar promotes swelling of flour proteins; it is fed to flour in the preparation of water-based dough. Egg yolks increase the fragility of the corpus and have positive effect on the sensory characteristics (the colour, flavour and taste).

3.8.3.1 Unleavened puff pastries

Around 70% of fat per the weight of processed flour is rolled into the **unleavened puff pastries;** loosening is physical. Loosening is provided by water vapours between thin layers of dough interlaced with fat.

Production process technology

Preparation of a water-based dough ("vodánek" in Czech), resting of water-based dough, modification of margarine, wrapping of water-based dough around a packet of margarine, rolling, folding and dividing - shaping, resting, baking (Fig. 3.5). **Water dough** is prepared from a high-quality flour (85 % of recipe flour), salt, pasteurized egg yolks and water (about 50 % of water to the amount of flour) by simply mixing the components without kneading.

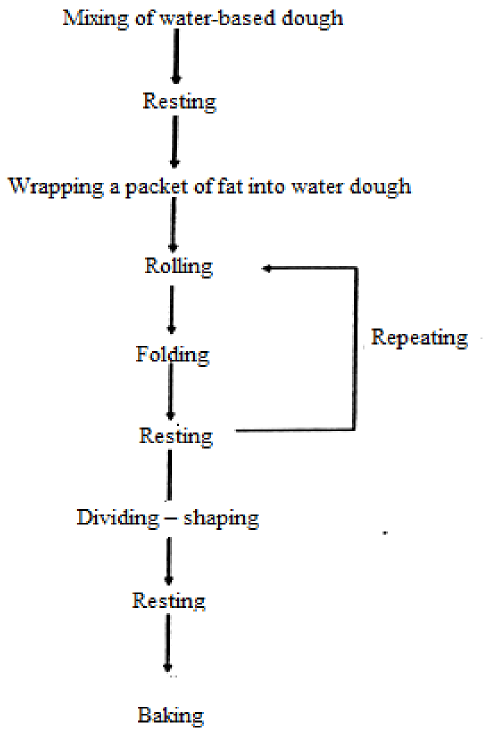


Figure 3.5 Process of making puff pastry

Roll-in fat mass is made from 15 % of recipe flour and extensible margarine (70 %) and wrapped into the water-based dough. Prior to being enclosed inside the dough, the extensible margarine is treated either by mixing with flour or mechanically by passing through a fat pump, by a kneader or otherwise. This will modify the consistency of margarine to become practically the same as the water-based dough. This is important for subsequent processing in a roller. Some margarines need not be fed with flour and can be directly combined with the base dough. Margarine packaged into sheets of 2 kg can be used without this preliminary treatment, which is a variant for small dough producers.

There are several ways how to enclose margarine into the water-based dough. French and English (Fig. 3.6, Fig. 3.7) methods are described below. The fat packet must be completely wrapped in the dough.

Enclosing the fat in the dough is followed by rolling, which is the reduction in thickness of the dough, and must be performed gently and gradually. If higher pressure is applied, the margarine will squeeze into the dough. Wrapped product is rolled out, folded and allowed to rest for about 30 to 60 min at 10 °C, which is repeated 3 times (Fig. 3.8). When using a weak flour, the time of resting is shorter, or the dough is continuously processed without resting. At higher temperatures, the fat gets too thin; low temperatures are unsuitable as well

Rolling is done on rollers having set an optimal mode of operation. Rolled out sheet of dough is manually folded either to three or four parts. When rolling is repeated, always rotate the dough by 90 degrees. These two operations are usually repeated six times. This results in 36 theoretical layers of fat and water-based dough. This sequence of individual steps is typical for **smaller dough producers**.

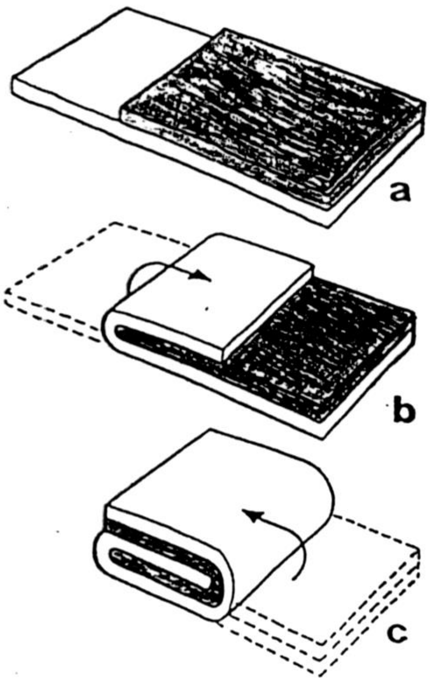


Figure 3.6 Manual wrapping of fat into the water dough English method

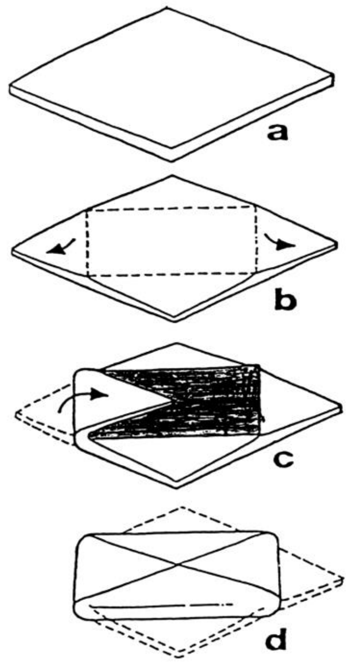


Figure 3.7 Manual wrapping of fat into the water dough French method

Large producers are equipped with continuous lines providing outputs in the form of packages of frozen dough or various frozen semi-finished products. Such a line is able to produce 500 kg of finished dough per hour. In continuous lines, special pumps apply margarine layer evenly to the middle of a continuous dough sheet, which is then folded over to cover it in the next step. Thus prepared dough sheet with margarine is subsequently rolled out and by transversal unfolding reloaded from one faster belt to another, which has a lower speed. In this manner, which may be repeated several times, up to 128 layers of fat and water-based dough can be obtained. Higher lamination contributes to better sensory quality of the finished products, which have higher baking height.

Then the rolled out dough sheet is cut, filled, shaped and brushed.

Recommended ***baking temperature*** is 210 to 220 °C. The product gets its rise mainly from the lamination of simple dough and margarine layers. During baking, water vapour is released from the water-based dough and trapped by margarine layers. Vapour accumulates and exerts pressure against the layers, resulting in their expansion. Flour starch coagulates and guarantees separation of layers after baking. Absorbed fat adds fragility to the structure and at the end of baking the crust is firm enough so that the expanded volume of the product does not fall down.

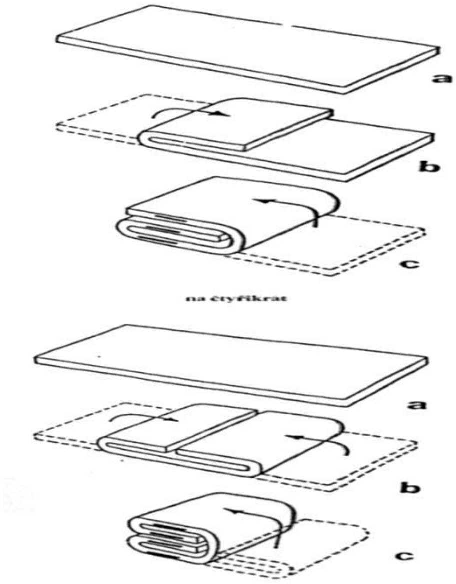


Figure 3.8 Manual folding of puff pastry (into a three-fold and four-fold)

Use of unleavened puff pastries

Puff pastry can be used as material for both traditional sweet pastries and savoury or spicy types of products with meat, soya and vegetable filling.

Apple strudels are made from more expensive unleavened doughs as well as crescents with nut or poppy seed filling and bases for confectionery products (slices, tubes, triangles, and so on) with various fillings and surface decoration. Also unfilled products are made such as "krachles" or salty and cheese pastries.

3.8.3.2 Leavened puff pastries (plunder)

Leavened puff pastry or plunder pastry is a dough high in fat, which is prepared using leavening agents. It consists of individual layers of leavened dough and fat, which exhibit characteristic flakiness after heat treatment.
Preparation of the dough is similar to that of unleavened puff pastry, the difference is the use of yeast for leavening and that the usual amount of in-dough fat is 10 % and roll-in fat 30 % to the recipe flour amount.

Base dough contains 85 % of recipe flour, 10 % of table margarine, salt, sugar, pasteurized egg yolks, yeast, and water. ***Roll-in fat mass*** contains 15 % of recipe flour and extensible margarine (30 % or more to the recipe flour amount).

Conventional leavened doughs are prepared mostly by the sponge-and-dough method. Yeast with a little sugar is mixed in lukewarm milk, part of flour is added (10 to 15 % of the total), and everything is mixed in a thin batter called sponge ("omládek" in Czech). The sponge is dusted with flour on the surface, covered with a towel and let rise in a warm environment (about 25 °C). Next, the risen sponge is mixed with the remaining sieved flour, melted fat and other ingredients, and kneaded thoroughly until a homogeneous mass is obtained. Again covered with a towel, the dough matures at the temperature around 25 °C (dough reaches maturity within 1 to 2 hours, according to the quality of flour and yeast).

After maturing and hardening, the dough is divided into pieces, which are allowed to rest in cold. Then the roll-in fat (extensible margarine) mass is wrapped into them. The wrapped product is rolled out, folded and let rest (about 60 min at 5 °C), which is repeated 3 times.

Compared to the classic puff pastry, the layer of leavened dough is larger than the layer of the water-based dough and folding is usually done only three or four times. Therefore there is not so great danger of dough rupture and escape of fat.

Then it is processed into desired products, which are filled and brushed. They are baked without steam for about 12 to 30 minutes.

When dough improvers are used, doughs are usually prepared by the straight-dough method.

Products

Plunder doughs are used to make pies, croissants, triangles, turnovers, crescents and rolls with various fillings as well as pizza sticks. The crumb is more loosened, softer and the texture is somewhat less obviously flaky.

The plunder dough production prevails in the bakery technology, while puff pastries (unleavened) prevail in the fresh pastry goods production.

3.8.4 Fine bakery products from other doughs and batters

Fine bakery products may be made also from other doughs and batters such as pulled dough, drop batter, foam mass, sponge cake batter, short-crust pastry, nut-powdered sugar mass, tea biscuits, fruit bread, and salty and cheese pastry.

Products from drop batters

The batter is prepared with an oil content of approximately 18 % to flour and is chemically leavened with baking powder. After mixing the ingredients, the batter is poured into a pan in which it bakes. The featured product is the poppy seed cake.

Products from foam masses

Masses are prepared by whipping eggs into foam with gradual adding of other ingredients or by whipping all ingredients at the same time if quick whipping agents (foam stabilizers) are used. The primary leavening agent is the air whipped into the eggs mechanically and also baking powder is added. Finally, the fat is poured inside. Featured products are Bundt cakes and flan bases for fresh made desserts.

Products from sponge cake batters

Batters are prepared by rubbing fat with eggs, with gradual addition of sugar and flour. Products are rich in fat and eggs. Featured products are Bundt cakes, fruit breads, festive cakes baked in pans and moulds (e.g. Easter lamb cake).

Products from short-crust pastries

Short-crust pastry is one of cheaper types of fat-based doughs as far as the ingredients are concerned. It contains 18% of fat (Linzer pastry has 32%) and 29% of sugar (Linzer pastry has 20%). It is necessary to add a liquid (milk) and ammonium bicarbonate. For pastries poor in fat the leavening agents are necessary to achieve a certain looseness and avoid shrinkage and deformation during baking.

Products from nut-powdered sugar masses

The mass is rich in fat; the margarine to flour ratio is 1: 1. The content of nuts is around 30%. At the beginning the nuts are mixed with sugar and rubbed with egg yolks and whites until perfectly smooth. Allow to rest for long and bake slowly at low temperature. Products from these masses are used as **material for confectioneries** (waffle mass for cones, coconut biscuits, and so on).

Tea biscuits and fruit bread

They can be mostly regarded as confectionery products, because they are not homogeneous products made from flour or whipped from egg whites.

Salty and cheese pastries

Products are generally unsweetened, may contain salt, but salt in greater proportion only as a sprinkle on top. Cheese may be added to the dough or sprinkled on top (grated cheese or cheese in slices) before baking.

3.9 Quality of bakery products

We characterize quality as a summary of utility values of a product that determine its ability to satisfy stated or implied needs of the user. The quality of a food product is a complex concept comprising **nutritional quality** made up of main and supplementary nutrients, **sensory quality** that satisfies consumer through his senses, and **hygienic quality** when the product must meet the requirements imposed by health professionals.

The quality of basic bakery products is affected by:

- the raw material. Generally, the quality and composition of raw materials significantly affects the quality of the final food product. Wheat affects the flour quality from 85 to 90 % and flour affects the bread quality from 60 to 70 %.

- the technological processing itself, i.e. correct ratio and correct application of other ingredients, correct preparation of the dough, shaping and leavening of products, baking, cooling and dispatch.

- ***transport and distribution of products from factory to stores and to consumers, i.e.*** suitable crates, method for placing products in crates at the level of in-store handling, and transport of visually high-quality products on the consumer's table.

3.9.1 Quality of bread and common bakery products

Table 3.1 Requirements for the quality of bread and common bakery products (Decree of the Ministry of Agriculture no. 182/2012 Coll.)

Product	Appearance and shape	Crust, surface	Crumb	Aroma and taste
Bread	Regularly formed, domed	Clean, golden brown in colour, without visibly exposed crumb	Well baked through, porous, homogenous	Typical of bread, pleasant
Common bakery products	Regularly formed, domed	Golden brown colour, clean, crispy, without visibly exposed crumb	Well baked through, porous, elastic, homogeneous	Typical of bakery products, pleasant

The main measure of baking quality is globally considered the volume of the resulting bakery products. Because of the diversity of technological processes in different countries and continents, however, the comparability of absolute values of obtained volumes is very difficult.

Digestibility of bakery products is substantially influenced by their looseness or fragility, or a combination of these two characters.

Looseness is one of the basic sensory features in most bakery products. It is related both to the way of dough loosening and the grasp and conduct of technological processes, from the preparation of dough to final baking.

Fragility is typical for bases made e.g. from Linzer dough, puff pastry or similar materials; it is given by a relatively high fat content.

3.9.2 Quality and sensory evaluation of fine bakery products

Table 3.2 Requirements for the quality of fine bakery products (Decree of the Ministry of Agriculture no. 182/2012 Coll.)

Fine bakery products/ fresh fine bakery products from leavened dough	**Appearance and shape**	**Crust, surface**	**Crumb**	**Aroma and taste**
	Regularly formed, domed or filled	Characteristic colour, without visibly exposed crumb	Well baked through, porous, pliant, elastic	Delicate aroma, typical of bakery products, pleasant, with flavour of added ingredients
Fine bakery products/ fresh fine bakery products from unleavened and leavened puff pastry	Regularly formed, domed	Characteristic colour, without visibly exposed crumb (with the exception of cuts), typically crusty surface	Well baked through, with visible flakiness, holes are not a flaw with leavened doughs, filling is visible with filled products when cut	Typical of bakery products, pleasant, with flavour of added ingredients, without foreign odours and flavours
Fine bakery products/ fresh fine bakery products from other doughs and batters than mentioned above	Regularly formed	Characteristic colour, without visibly exposed crumb (with the exception of cuts), or with icing or glaze	Well baked through, corresponding to the ingredients used	Pleasant, typical of bakery products, corresponding to the ingredients used

In cakes and other types of fine bakery products, fillings constitute a substantial part of the product and affect the quality. Some types of cakes have even more that 400 % of filling calculated to the weight of the flour being processed. Poorly homogenized filling or filling made from raw materials that do not meet the appropriate standard of quality can cause a variety of defects (filling leaking out, burning of products, “sad cake”, microbial defects in products, and so on). When preparing the filling, it is necessary to follow the recipe and technological principles given by the nature of the filling.

Fillings must have uniform colouring, coarse components must be evenly dispersed throughout. Aroma and taste of fillings must be pleasant after the ingredients used, without foreign odours and flavours, may not be sour or bitter.
In fried products, the final thermal treatment - frying in hot oil – gives products different sensory properties, by which they distinguish from sweet Christmas breads or cakes. The main characteristics of quality of doughnuts are a high degree of loosening, yellow, finely pored crumb and golden brown crust with bright rim.

For puff pastry products, the most important quality criterion is the increase in height. It depends on the quality of raw materials, recipe and technology. The higher the content of roll-in fat, the higher the product rises, and at the same time any possible presence of fat in water-based dough reduces the volume of the product.

4 CHILLING AND FREEZING

Today, it would be difficult to imagine production in a bakery without refrigeration and freezing. Cold is perceived as a means of maintaining wholesomeness, eliminating production peaks and reducing labour costs. Producers come to the market with pre-baked and frozen products.

The history of pre-baked products dates back to the mid-50s of last century in the US, where bakers produce soft bread, which was baked for only about 70 % of the total baking time and the end consumer finished baking at home. Then there were attempts to sell these goods also in Europe, especially in Germany, but without any marked success. Currently, the sales of pre-baked and deep-frozen products are significant.

In this way, large bakeries, along with large retailers, can approach the assortment of the small artisan bakeries, but with much greater efficiency.

Advantages associated with the use of refrigerators can be defined as follows**:**

- high-quality fresh pastries throughout the day
- quick and easy access to pastries
- broader range of products
- optimization of the production cycle
- elimination of overproduction
- higher profitability of production (Schulz, 2000)

There are currently four generations of frozen products on the market. The first generation of <u>deep-frozen dough pieces</u> was immediately followed by the second generation of <u>pre-leavened dough pieces</u>. The third and fourth generations include <u>semi-baked and pre-baked products</u>.

4.1 The principle of freezing

Freezing means preserving food by lowering the temperature below the freezing point to the value at which the course of physical, biochemical and microbiological processes in food slows or stops (Decree no. 326/97 Coll. for frozen foods to Act no. 110/97 Coll., on foodstuffs., as amended).

Freezing is in fact a change of water, contained in the food, to ice, followed by lowering the temperature of the product to the storage temperature of minus 18 °C.

Since the dough is a living material (yeasts, bacteria), we must realize that any change in temperature will lead to certain changes in product characteristics. To achieve the desired product parameters, the rapid reduction of temperature (shock freezing) must take place. In slow reduction the formation of large ice crystals occurs, which causes the plasmolysis of the yeast cells.

The main problem in freezing of dough is the formation of ice crystals, which mechanically harm the yeasts and gluten grid. At the same time the starch granules are damaged, which have an important influence on the swellability of flour. The size of crystals depends on the fastest exceeding of temperature level of minus 6/7 °C, which is a critical point of the whole freezing process. At these temperatures the water freezes in products. This thermal barrier within the product is exceeded very slowly, or if cooling power of the cooling device is not sufficient, it is not exceeded at all. Thoughtless freezing can break hydrophobic bonds and damage gluten grid, which will affect the rheological and baking properties of dough. Since the gluten is closely connected with starch granules and yeasts, their damage leads to the reduced ability of dough to retain CO_2 after thawing.

4.2 Requirements for raw materials

In the production of frozen or refrigerated doughs, special requirements are put on some raw materials, mainly flour, yeast, improvers, sugar content and the addition of fat.

4.2.1 Flour

Strong and medium flours with good gluten properties give more volume. Also, when weak flours with a well-chosen improver are used, standard quality can be achieved. Flours should have low to moderate enzymatic activity (280 – 320 s). Basic quality parameters of used flours should not fall below a certain threshold:

- ***for short and medium-long cold processes,*** the minimum recommended values for the quality parameters should be as follows: protein content above 12 %, gluten content of 28%, sedimentation value of 35 ml, falling number 280 s;

- ***for extremely long cold process*** the values should be clearly higher: gluten content of 32 %, sedimentation value of 35 to 40 ml, falling number 320 s (Hombach, 2001).

In the production of frozen doughs, the flour is exposed to the negative effects of temperature changes during freezing and thawing. Longer processing of dough at lower temperatures, and especially during freezing, heavily burdens its structure. After long time exposure large degradation of the gluten structure takes place and thus reduction in the ability to retain the leavening gases in the dough.

This offers the possibility to fortify the flour with vital gluten, by which the content of efficient protein (gluten) increases by 1 %. It acts as a cryoprotector (protects yeast cells during freezing) by reducing the amount of free water in the dough.

4.2.2 Yeast

Of all the raw materials that are used in doughs intended for freezing, yeast requires the utmost attention, especially in the selection of its optimum form.

Substances contained in yeast (salt, sugar, soluble proteins) cause reduction of the freezing point, so that the yeast cells freeze usually at -7 °C. In the natural state, they are highly resistant to cold and frost, but in the dough during freezing both the resistance and baking performance of yeast cells rapidly declines. When the yeast cells are damaged by ice crystals or alcohol, the glutathione is released. Its strong reducing properties lead to thinning of the dough, and have resulted in a small volume of the baked end products. Yeast cells are protected from damage during freezing by substances called cryoprotectants. Examples include the disaccharide trehalose, certain amino acids (alanine, glycine, proline, valine), glycerol, glucose, maltose and sodium chloride.

For the production of frozen doughs, fresh compressed baker's yeast can be used with a dry matter content of 30 %. It is suitable for products stored for 2 to 4 weeks. For products stored for 4 to 6 months a new version of dried yeast can be used, which is specially designed for frozen doughs. This yeast has a dry matter content of 75 %. During drying only free water evaporates, resulting in a free-flowing granular product, which is subsequently frozen and packed. When preparing the frozen dough, the amount of recipe yeast can be increased according to the used type by 35 to 65 % compared to conventional formulas.

4.2.3 Improvers

The criterion for choosing the correct preparation is the flour quality and freezing technology. Freezing, storing and thawing has a negative impact on the quality of dough:

- the ability to produce and retain gases is reduced;
- ice crystals break the yeast cells, from which low molecular compounds (glutathione, cysteine, cystine) come into the dough and soften its gluten structure.

Improvers specially developed and adapted to the production of frozen dough. Beside carriers they contain emulsifiers, ascorbic acid, and enzymes.

Emulsifying agents (lecithin, mono and diglycerides) fix the water added to the dough into strong bonds and improve the structure of gluten in order to enhance the ability to retain gases. They also allow for uniform distribution of water within the dough, thereby reducing the risk of formation of large crystals destroying the gluten structure**.**

Ascorbic acid in an amount of about 50 % higher than in normal doughs, strengthens the gluten. Its addition prevents softening of the dough through the release of glutathione and other -SH compounds during freezing.

Improvers for the production of frozen pre-baked bakery products contain in addition also guar flour, stabilizer of carboxymethylcellulose, and Dowe emulsifier (Kaiser-type rolls, baguettes).

Special improver for FFT (Flexible Freeze Thaw) freezing technology (without leavening process - from the freezer directly into the oven). The product is particularly suitable for the production of plunder pastry. It contains a high content of guar gum (Magimix PAF by LESAFFRE).

4.2.4 Fat

The addition of fat ensures that the softness and pliability of crumb will be maintained throughout the period of frozen dough storage at a specified storage temperature well below the freezing point. At the same time it has a beneficial effect on the fragility of the crust and reduces the crust flaking when the products are baked off.

4.2.5 Sugar

Sugar is essential for the nutrition of yeasts over the entire cycle of thawing and leavening (sucrose, glucose or high-fructose corn syrup at a level of 2 to 10 %).

4.3 Dough freezing

4.3.1 Proofing interruption

Straight dough process is used in dough preparation, with an increased proportion of yeast (4 to 5 % to flour). The final dough temperature is +4 ºC. After kneaded, the dough goes into forming machines and the belt conveyor will transport them into the shock freezing device. This device has a very high velocity of cooling air with temperature up to minus 40 °C. In the shortest possible time, the dough must reach a temperature of minus 7 °C, which provides a change of state of water into very small crystals of ice. The yeast activity stops and simultaneously the activity of enzymes is reduced. Thus the unleavened products are stabilized

Next, the dough is wrapped in foil and stored in the freezer box. It is stored packed at minus 18 °C for several days to months without loss of sensory properties. It is thawed in a refrigerator at +4 °C. Then the dough can finish rising in the proofer (temperature of 20 °C, relative humidity of 70 %). Proofing interruption is particularly used in plunder doughs.

4.3.2 Freezing of unleavened (green) dough pieces

- The dough is processed by straight method. If doughs are made for special kinds of frozen bread and are prepared by the sponge-and-dough method, the yeast quantity should be doubled in comparison with the straight process recipe.
- Lower temperature during kneading of 18 to 21 °C is achieved by addition of ice in the form of granules or flakes, or by production in refrigerated premises.
- Unleavened dough pieces are shock-frozen at a temperature of minus 30 °C to minus 35 °C). The dough piece temperature of minus 7 °C must be achieved within 30 minutes.

Dough pieces are shock-frozen and stored in special freezers, packed in polyethylene bags.

- Thawing and proofing phases must not take place too rapidly, because the dough piece is a poor thermal conductor and may incur thermal losses between the core and outer part.
- Storage temperature is from minus 18 °C to minus 22 °C, relative humidity of 90 to 95 %. Maximum storage time is 2 weeks. The main disadvantage of this method is a long time elapsing between the moment of taking the product out of the freezer and obtaining of baked product.
- Dough pieces are thawed at a room temperature for 60 minutes and then they spend about 30 minutes in the proofer.
- During the transportation of dough pieces the cooling chain must not be interrupted.

4.3.3 Freezing of leavened dough pieces

- Proofing takes place from 50 to 70 % in the proofer, then the products are wrapped in polyethylene bags and transferred to a freezing device.
- They are frozen as quickly as possible; after 20 minutes the temperature at the centre of the product should be minus 5 °C.
- Storage temperature is between minus 18 °C and minus 22 °C, relative humidity is 90 to 95 %. Maximum storage time is 2 weeks.
- Increased demands are placed on the storage (to avoid deformation) and special baking technique.

4.4 Freezing of bakery products

4.4.1 Freezing of half-baked products

- Products are baked for half (50 %) of the specified baking time, then the products having a temperature of about 70 to 80 °C are shock frozen.
- Storage temperature is from minus 18°C to minus 22 °C, relative humidity 90 to 95 %. Maximum storage time is 2 weeks.
- Only for common bakery products (baguettes), cannot be used for puff pastry and plunder products.

4.4.2 Freezing of half-baked pastries

- Baking process is finished after about 2/3 of normal baking time, when the protein denaturation is finished and the shape of pastries is stable. The crust is very lightly coloured and pastry has higher water content.
- Baking temperature is 180 to 190 °C, baking time 12 to 14 minutes.
- Pastry is allowed to cool down to 40 to 45 °C.
- It is packed, then cooled or shock frozen.
- Storage at room temperature of 20 °C – 1 day, in the refrigerator +5 °C – up to 4 weeks, in the freezer between minus 18 °C and minus 20 ºC – up to 3 months.
- Thawing for 15 to 20 minutes.

- Baking off at the temperature of 190 to 210 ºC, for 8 to 10 minutes.
- Suitable for common bakery products.

Frozen products after the first baking phase can be distributed as a final product for the market.

4.4.3 Freezing of partially baked pastries

Pastry produced by this method is often called *"par-baked";* it just requires ***thawing and baking at the point of bake off***.

- Baking process is interrupted after about 90% of normal baking time. Protein denaturation is completed, the crust has a brownish tint.
- Baking temperature is 220 to 230 °C, baking time is 10 to 12 minutes.
- Hot pastries are packed in PE bags (condensation occurs) and immediately frozen.
- Storage temperature between minus 18 °C and minus 20 °C for up to three months.
- The product does not need to be defrosted, it can be simply thawed, but to enhance its flavour and sensory characteristics, it is appropriate to heat it at 160 °C for 6 to 8 minutes.
- Intended for the production of common and fine bakery products.

Bake-off bakery products are usually characterized by a shorter shelf life. The products are intended for baking off at the consumer.

Costs are associated with the acquisition of high performance freezing technology. These are mainly devices for shock freezing, which is needed for cooling down the product from the high positive temperatures in the core (80 to 90 °C) to temperatures well below freezing point in the core (minus 20 °C). Because after freezing the cooling chain must not be interrupted (minus 18 °C), the manufacturer must guarantee both the proper storage and transport, resulting in significant financial investment. Therefore, this method is particularly interesting for large industrial bakeries.
Deep-frozen products do not permit reducing the price (investment, high energy intensity of production).

Not frozen pre-baked pastries

Improvers for pre-baked pastries are used. After the first phase of baking and cooling the pastries are packed in PE bags and bags are placed in plastic crates (durability about 2 days), or packing under protective atmosphere with a shelf life up to 6 weeks is used; it is intended for baking off by the final consumer (investment in packing technology). Products packed under inert atmosphere are suitable for small consumer packs.

In this production method, ***cold storage*** is not necessary. The goods are stored at dispatch and baked off at the point of sale and sold hot throughout the day, again without demands on storage space. At present, this product range represents about 30 types of products from common bakery products to sweet Christmas breads (this concept is practiced in Germany, Austria).

4.4.4 Freezing of fully baked products

This process is often referred to as "***thaw and sell***". The products are fully baked, then frozen, and thawed immediately prior to the sale.
Products baked at 70 to 80 °C are shock frozen. Frosting of the outer layers of crust takes place. In the first 5 minutes the products are wrapped by 0.3 to 0.4 millimetres thick icy layer. The goal is to achieve a reduction in temperature at the centre of the crumb from the original 70 to 80 °C to minus 7 °C (at this temperature the retrogradation process completely stops).

- Freezing time – bakery products with lower weight max. 60 min, bread and bakery products with higher weight max. 90 min.
- Storage temperature from minus 18 °C to minus 20 °C, relative humidity of 85 to 95 %.
- Shelf life is up to three weeks.
- Suitable for all bakery assortment, both common and fine bakery products, bread

The aim of freezing of finished products is the preservation enabling their long-term storage and operational deliveries to stores.

4. 5 Basic methods of freezing

The current offer of manufacturers of refrigeration and freezing techniques is very wide. In essence, three basic methods are used, i.e. freezing by circulating air, plate freezing, and cryogenic freezing

Freezing by circulating air (conventional method)
In freezing, the product is exposed to a stream of ice-cold air with temperature between minus 29 °C and minus 40 °C. Fans provide the air circulation. On the downside is that the cold air flowing at high speeds draws the moisture from the dough pieces, which leads to their drying. Removed moisture then condenses on the evaporator, where it freezes and thus worsens the entire course of freezing. So there may be differences in quality of frozen products. The air velocity is 4 to 10 m/s, higher speed can adversely affect the products (drying).

Plate freezing

These freezers are made up of a set of horizontally arranged plates, around which a coolant circulates. Products intended for freezing are placed between these plates so that each product is with its upper and lower surface in direct contact with the plate, there is therefore a very efficient heat transfer. There are channels in the plates through which the evaporating refrigerant flows. The advantage is minimal space requirements, while the disadvantage is lack of flexibility for the processing of products of various sizes as well as higher operating costs. These devices are used solely to freezing packed products with a flat outer surface.

Cryogenic freezing

In cryogenic freezing, the food is usually exposed to temperatures lower than minus 59 °C. The basic principle is a direct contact between the liquid cooling agent and product. The cryogenic process uses cryogenic gases in liquid form. Much preferred is the use of liquefied nitrogen. The gases are inert and do not affect the taste or other quality parameters of the final product.

One of the main advantages is the considerable reduction in freezing time. The method can be used in three ways as follows:

- dipping the product into liquid nitrogen,
- spraying of liquid nitrogen onto the products,
- circulation of cold vapours in the space where products are placed.

4.6 Freezing technology

Today, freezing the dough is carried out mainly in **shock freezers** at temperatures from minus 20 °C to minus 45 °C, where the temperature of the core reaches minus 6 °C or minus 7 °C after 20 to 30 minutes. Thus frozen products are then transported to the freezing chamber where they are stored at minus 20 °C.

Another possibility is freezing in **conventional freezers**, which, however, due to their insufficient performance and long time necessary to overcome the critical temperatures, cause defects in products.

A separated shock freezer in combination with a freezing chamber is maximally usable for rational and inexpensive preservation of dough pieces or even hot pastry (Hromádka, 1999).

After freezing, the dough pieces must be protected before further drying by their packing into bags impermeable to water vapour. Thus produced semi-finished products can be stored for several weeks without loss of quality of future products.

The performance of freezing technology is highly variable. For example, freezing the product to 0 ºC: conventional freezers – 50 minutes; freezers with greater velocity of circulating cold air – about 25 min; shock freezer – under 20 minutes.

5 TECHNOLOGY OF DURABLE BAKERY PRODUCTS

The history of handicraft production of durable pastries begins in the 19th century, but the gingerbread has been known since the Middle Ages. These pastries are used for fast refreshment. In addition to the energy values they usually do not have any nutritional benefit. They have a longer shelf life.

According to the implementing Decree of the Ministry of Agriculture no. 333/1997 Coll., as amended by Decree of the Ministry of Agriculture no. 182/2012 Coll., durable bakery products are classified and defined as follows:

Durable bakery products are products made from flour and other ingredients and additives, with a water content of less than 6 %, with the exception of sponge biscuits (less than 8 %), and gingerbread, pretzels and durable sticks (less than 16 %), or filled with various fillings, dipped, coated, or with a modified surface.

Biscuits are products obtained by baking the dough, particularly leavened by chemical agents.

Durable pastries from whisked (foam) masses are products exclusively loosened by mechanical methods, whose basic ingredients are egg contents and sugar.

Wafers are products obtained by baking a thin layer of dough or mass by contact method between iron plates (a wafer iron).

Gingerbreads are products made from chemically loosened dough with added spices and neutralized invert sugar solution or invert sugar or honey**.**

Rusks are products made from chemically or biologically loosened dough; after baking they are cut to slices and toasted**.**

Pretzels and durable sticks are products made from chemically or biologically loosened dough, which must be dried throughout their entire volume during baking.

Crackers are products made from laminated doughs, loosened either chemically or biologically.

The extruded product is a product made from grain mill products using the extrusion technology by action of pressure and temperature.

The puffed product is a product made from abraded and moistened cereal grains of one or more botanical species of cereals, rice, or buckwheat, in an expansion mould of the baking device by action of pressure and temperature**.**

Matzos are thin, brittle unleavened products of round or square shape, made from water and wheat flour by heat treatment.

Knäckebrot is a product of fragile consistency made from grain mill products and other ingredients, usually in the shape of a rectangle, by heat treatment**.**

Durable bakery products are always marked by their respective group: biscuits, products from whisked (foam) masses, wafers, gingerbread, crackers, pretzels, durable sticks, Knäckebrot, crackers, extruded products, puffed products, matzos, and sponge biscuits.

5.1 Biscuits

Biscuits are among the most widespread types of durable bakery products. They are characterized by the type of raw materials used, method of processing and properties of the dough and final product.

The dough is usually loosened only by chemical means. For the biscuits to be brittle during consumption, the dough is kneaded with less water and less intensively than in case of leavened doughs. Biscuits and wafers need wheat flour with instable gluten protein to prevent the development of a spatial grid from swollen gluten protein. Sometimes the protein is even attenuated by adding proteolytic enzymes.

Biscuits are cereal products with different contents of fat (between 0 and 35 %) and sugar (between 10 and 20 %) in the recipe. Assortment of biscuits is wide.

Division of biscuits

by the fat content to soft with fat content between 15 and 35 % and hard with fat content between 0 and 15 %,

by dough processing method to cold-processed and warm-processed

by the method of shaping to cut out (fat content 0 to 20 %), pressed (fat content 15 to 30 %), extruded (and cut, fat content 15 to 30 %), and sprayed (fat content above 30 %),

by treatment before packing to plain, filled, half-dipped, coated, decorated on the surface,

by taste to sweet, salty, and specially favoured.

Raw materials

Fine wheat flour for baking purposes, weak (gluten content of 22 to 28 %, stretchable, less elastic, protein content of 7 to 8 %, 8 to 9 % for pressed biscuits),

sugar - sweet taste and fullness of flavour (sucrose, abroad sucrose is replaced with fructose or fructose syrup),

fat - impact on technological and textural properties, reduces the development of elastic gluten structure of the dough,

eggs, dried milk, leavening agents, aromatizing and flavouring substances. Sodium bicarbonate and ammonium bicarbonate (ratio 1 : 1) are used as leaveners.

Production process technology

Production process technology involves blending of loose materials, dough mixing, dough rolling, biscuits shaping, baking, cooling, filling, sticking together, decorating, sorting, and packing.
Process for the preparation of dough depends on the recipe and subsequent shaping. Fat is added in an aqueous emulsion and processed at 26 to 28 °C for its consistency to be pasty. The dough is mixed in special kneading machines to prevent formation of continuous gluten structure so that biscuits are not hard and fragility is achieved.

Dough shaping

There are four basic methods:
Cutting out – a thin sheet of dough is rolled out, which then moves along the production line under a rotating cutting cylinder or cutting die. The belt transports the cut-out shapes into the oven for baking. The cutting device is equipped, besides blades of corresponding shapes, also by spikes for perforating the dough. The purpose of this perforation is to ensure removal of steam not to raise the dough surface during baking and thus ensure an even thickness of biscuits after baking. This type of biscuits has the lowest proportion of fat and biscuits are harder. Biscuits have smooth and flat surface.

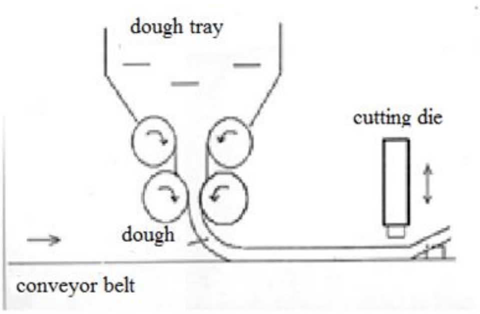


Figure 5.1 Scheme of cutting biscuits

Spraying - thin dough is sprayed by nozzles in equal portions on a conveyor belt, which transports biscuits directly into the oven. Sprayed biscuits contain most fat in the dough, more than 30 % to the weight of flour. Their compositions corresponds to the short-crust pastry products.

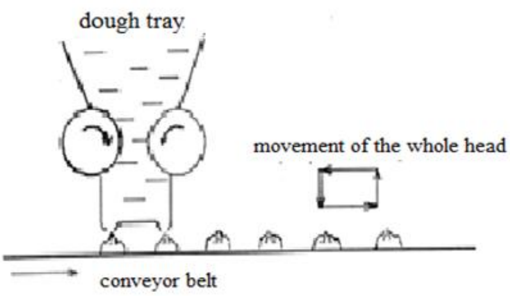


Figure 5.2 Scheme of spraying biscuits

Extruding, cutting - the dough is extruded through an opening, which has an outer contour of a biscuit. Slices, corresponding to the thickness of a biscuit, are cut off from the extruded dough by wire, fall onto the belt and are transported directly into the oven. Biscuits have flat, roughened surface due to the cut by wire. The dough has a higher fat content (30% to the flour content).

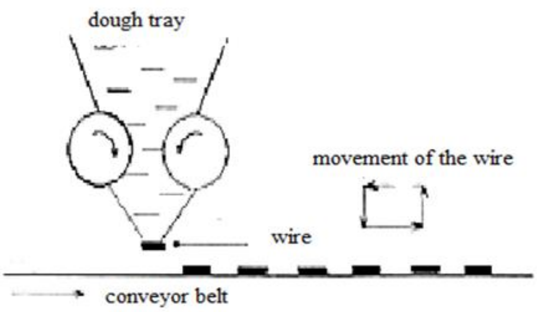


Figure 5.3 Scheme of extruding (cutting) biscuits

Pressing – the dough is pressed into the milled shapes on the surface of the shaping roller. The finished shapes fall out from the holes onto the conveyor belt and are transported directly into the oven. Pressed biscuits may have a higher percentage of fat (15 to 30 % to the weight of flour) than the cut-out biscuits. Their surface is plastic with protruding design given by the shape of moulds on the roller surface.

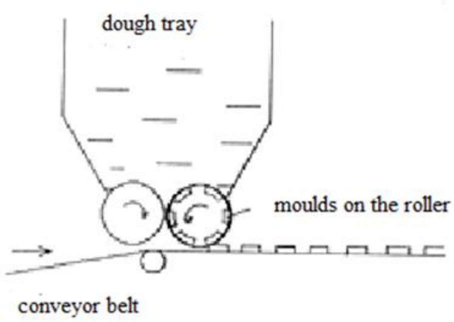


Figure 5.4 Scheme of pressing biscuits

Baking

Baking of biscuits takes place in belt-type ovens at a temperature of 240 to 280 °C for 4 to 5 minutes depending on the type. Baking reduces the moisture content to 1 to 4 % and colours the surface.

After baking, the biscuits are cooled down. At a temperature below 30°C, they can be filled and stuck together, coated or variously decorated. Then they are sorted and packed in plastic foils with print.

5.2 Products from whipped (foam) masses and sponge biscuits

These products are exclusively loosened mechanically. Basic raw materials are egg contents and sugar, flour to about 37 % of the mass. Whipped masses are semi-finished products prepared from foams.

According to the raw materials used and method of making, we distinguish light whipped masses, heated whipped masses, heavy whipped masses, and special whipped masses.

Bases are used for making gateaux, cakes and cuts in confectionery production.

5.2.1 Light whipped masses

Technological process of preparing a light whipped mass

It is prepared by the cold process, when the whites and yolks are whipped separately. After mixing of both these foams, the flour or other ingredients are added, sometimes including fat.

The production of the round sponge biscuits dominates in this area; they are produced on a large scale.

Round sponge biscuits ("children" sponge biscuits)

Raw materials

Egg contents, fine wheat flour (weak gluten), sugar (cocoa, food colouring).
A similar composition have also sponge fingers (or ladyfingers) that are produced on a smaller scale from fresh eggs by mechanical whipping. They are more loosened. In terms of definition they belongs among durable bakery products.

Production process technology

Sponge biscuits are prepared from a light whipped mass. Firm foam is mechanically whipped from egg whites (after a short whipping of whites the caster sugar is added) and egg-yolk foam is prepared (from the yolks and powdered sugar). Foams are mixed with flour, dosed on a baking belt, baked, cooled and packed.

Air is whipped into the mixture in a mixing machine. By mixing, all the ingredients perfectly blend together and uniform air bubbles are formed. Whipped mass is sprayed onto the baking belt through nozzles. The baking belt is smeared with oil and sprinkled with edible starch. Baking lasts 2 to 4 minutes at maximum temperature of 320 °C. Air bubbles expand during baking and create a fine structure without the addition of loosening agents.

Featured products

Round sponge biscuits, sponge fingers, “golden dessert” round sponges (with apricot, orange, raspberry and other flavours) and so on.

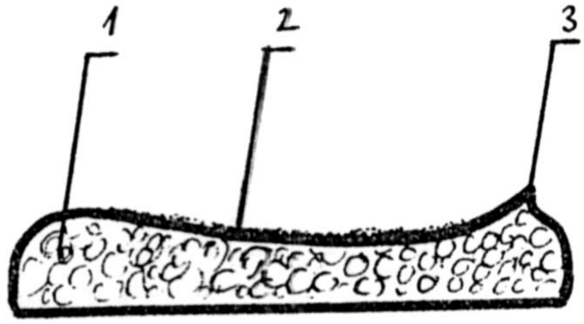


Figure 6.6 Cross section of quality whipped mass sprayed into the shape of sponge fingers (Skoupil, 1997)
1 – evenly porous crumb, 2 – surface strewn with powdered sugar,
3 – sign of quality, stable foam

5.2.2 Heated whipped masses

They are also known as "sandy" masses. Egg mass is heated up with sugar to 45 °C, then it is poured into a mixing machine bowl, cool down and whipped until foamy. Then the flour and condiments are added as well as liquid fat, if needed.

Featured products

Bases for gateaux and cakes and bases for rolls, cuts, tunnels, and so on.

Bases are used for making gateaux, cakes and cuts in confectionery production.

5.2.3 Heavy whipped masses

They are prepared by cold process, without heating the eggs, and contain a large portion of fat. Whites are whipped with half the sugar to the consistency of “firm snow peak”, fat is whipped with egg yolks and the other half of sugar. Both foams are combined with flour and flavouring ingredients. Bases are less porous, but pliable due to the addition of fat. They are among the best cake bases.

Bases are used for the production of gateaux, cakes and cuts in confectionery production.

5.2.4 Special whipped masses

We divide them to masses from egg whites or egg yolks with a higher content of sugar, which do not contain flour. The exception is the beze or meringue mass, which in addition to nuts contains small amount of flour.

Featured products

Snow pastry – shaped by spraying
Yolk coffin pastries
Coconut or walnut meringue cookies ("laskonky") and bases for cakes and rolls – shaped by spreading, less by spraying

Bases are filled and decorated in confectionery production.

5.3 Wafers

Wafers are products obtained by baking a thin layer of dough or mass by contact method between iron plates (a waffle iron). They are the second most common type of durable bakery products. The beginnings of wafer making date back to the 9th century. Wafers were originally prepared only for church purposes. The only raw materials were water and wheat flour.

Raw materials

Wheat flour for baking purposes (optimal protein content is 8.3 to 10.5 %, weak gluten - up to 28 % of wet gluten),

water (up to 140 % to the weight of flour),

other ingredients - sugar (up to 3.5 %), butter, fat (shortening, cooking oil, in the liquid state up to 5 %), dried milk (max. 3 %), emulsifiers (0.3 %, in a solution; lecithin in soybean oil, or in dried egg yolks), starch, caramel, salt,

leaveners - water vapour, chemical leavening agents only rarely (mixture of sodium bicarbonate or sodium carbonate and ammonium carbonate in 2 : 1 ratio)

Between 94 and 97 % of the wafer mass is the mixture of flour and water (flour 42 %, water 58 %), the remainder being other ingredients.

Sugar favourably affects the taste, smell, colour and texture; the addition of more than 6 % to the weight of flour causes sticking to the mould. To increase the fragility or if the flour is strong, maize starch can be added. Addition of coarse flour increases the brittleness, but reduces the yield (the weight of the wafer plates is higher).

Production process technology

Wafers are produced by whipping a very fluid batter and baking it in a thin layer between the plates, the so-called wafer baking tongs or wafer irons.
Preparation of emulsion, dosing of loose materials, whipping, straining, dosing batter into baking tongs, baking, cooling of wafer sheets, spreading of filling on the sheets, cooling of wafer bases, cutting, dipping, cooling and packing.

Preparation of wafer batter

Normal conditions* – *pre-mix - emulsion from warm water, milk and egg yolks, and sugar, if necessary, after mixing a solution of lecithin in fat is added. Then it is whipped for 35 to 45 minutes. In the mixer, the emulsion is added to the cold water (15-20 °C) along with leavening agents, and finally flour. It is mixed for 1 minute, then it is pumped through a sieve into the tank at the baking station.

Continuous preparation – turbo mixers (500 to 3500 rpm), the mixture is done in 45 to 100 seconds. Before baking, the batter rests for 10 to 20 min to remove air bubbles, because owing to the low temperature of the batter, gluten lumps could form without the resting phase.

Wafer baking

The batter is dosed into the baking mould (forceps) in several stripes (usually 5). The normal size of sheets is 290x465 mm. It is necessary to ensure that the specific gravity of batter is same all the time. The temperature in the first part of the oven is 150 to 180 °C, 270 °C in the second part, and 240 to 250 °C in the third part. Moulds must be pre-heated. Baking time is between 1.5 and 3 minutes.

The output temperature of sheets is 160 to 200 °C, moisture 1 to 3 %. They are allowed to rest in order to equalize the moisture. Moisture content before spreading is 2.5 to 4 %. If dipping in chocolate follows, the moisture content must be adjusted to 5% not to cause the coating to be broken.

Production of fillings

Raw materials - sifted sugar, fat, milled processable fragments, ingredients (dried milk, sweet whey powder, starch, soy flour, cocoa, cocoa or chocolate mass, nuts and flavouring agents). Newly, roasted wheat germs are used.
For smaller shops, it is possible to buy ready-made fillings. In larger plants, the fat is stored in liquid state in tanks and before processing it is necessary to make it plastic by gradual cooling, whilst constantly stirring (24 h).

Filled wafers are cooled (for 10 minutes at 5 °C), then cut, and dipped in chocolate, where appropriate.

Plastic reliefs on the surface of plates of baking tongs improve the firmness of the wafer sheet and better capture of filling. After baking, filling (usually fat-based) is spread on the wafer sheets, several filled sheets are then compressed and cut to final shapes.

Brown wafers

are products from brown wafer batter. They are flat rectangular, square or round sheets

Hollow wafers

are wafer products, which are used for ice cream - wafer cones, shells, baskets, bases for wafer waves

White wafers

They are made from potato, maize or wheat starch of the best quality, or mixtures of these starches. Sometimes they are dyed. We divide them to flat wafer sheets and hollow wafer sheets.

Commercial types of wafers

Unfilled (tort wafers, ice cream containers, cheese wafers etc.)

Sintered wafers, which are sprinkled with sugar and various additives and baked together (Hořické trubičky), ***filled with different fillings***, which are based on sugar and fat, supplemented with various condiments (Zlaté oplatky, etc.).,

dipped and half-dipped in chocolate (Minonky, Horalky, Tatranky, and so on).

The assortment includes wafers with reduced sugar content and wholegrain wafers.

5.4 Gingerbreads

Gingerbreads are baked products from chemically leavened dough with added spices and neutralized invert sugar solution or invert sugar or honey. Traditional group of durable bakery products with a longer shelf life. Production of gingerbread dates back to the times of ancient Egypt, Greece and Rome.

Flour for the production of gingerbread

Rye flour was previously used for the production of gingerbread, which is now only rarely used. Gingerbread products from rye flour had smaller relative volume, and were denser, but not hard (because rye flour does not contain gluten). Earlier concentrations work with 70% sugar solutions (30% of water), now we work with solutions, which contain only about 20% of water. In the first case, the hydration of proteins was larger, more gluten was formed, which in the case of stronger flours often resulted in "gumminess" of the basic gingerbread dough. Cookies were deformed with large blisters on the surface. Therefore, these basic doughs were allowed to mature for several months before further processing, which led to disintegration of gluten and change in the rheological properties of doughs, from which quality products were obtained as a result. Best flour reported was the flour containing 8 to 9% of protein in dry matter, with a moderate gluten strength and stretch.

With today's technology, the binding of water by flour (gluten formation) is strongly limited, thereby changing also the rheological characteristics of the basic gingerbread dough (reduction in stretch and elasticity). The consequence is the insufficient resistance of gingerbread doughs prepared from "weak flour" to pressure of leavening gases (NH_3, CO_2 and water vapour) during baking. In the first phase of baking, the bread volume increases, but at temperatures above 150 °C the higher pressure of gases "breaks" the not so strong gluten and bread goes down.

Therefore, we recommend using **“stronger” flours** when preparing basic gingerbread doughs from concentrated sugar solutions. As an example, see the technological parameters of suitable wheat flour referred to as ***fine wheat flour, half-light, "gingerbread" (T 700):***

- Maximum moisture content 14.5 %, maximum ash content in dry matter 0.700 %, wet gluten content in dry matter 29.5 to 32.0 %, minimum swelling capacity 12, falling number 230-260 s
- ***Alveograph parameters*** - W (deformation energy of 1g of flour) - optimum 200 to 220 x 10^4J, P/L ratio 0.7 to 1.0
- ***Farinograph parameters*** – water binding capacity of flour 57 to 60 %, development of dough min. 120 minutes, dough stability min. 6.0 minutes, decrease in dough consistency max. 80 FJ (Skoupil, 2003).

Raw materials

Fine wheat flour, half-light, with strong and elastic gluten (30 to 36 %), invert syrup, chemical leavener, spice mix.

Production process technology

The invert syrup is prepared directly in the production by sucrose hydrolysis by boiling with hydrochloric acid (from 0.03 to 0.35 % to 70 % of sucrose at 105 °C). Mixture of glucose and fructose is formed. After 5 to 10 min the solution is neutralized with sodium bicarbonate and the flour is added to the solution while hot, or after cooling. For better quality, it is possible to add the egg mixture. The resulting stiff dough is allowed to rest (for several days). **After resting** the chemical leavening agent ix added to the dough in a small amount of water - ammonium bicarbonate and finely ground gingerbread spices. Next the dough is **shaped** (by cutting or pressing), baked, cooled, coated, and filled, Filled gingerbreads are cooled down and packed.

Gingerbread products are **baked** immediately after shaping. Baking temperature and time depend on the size and thickness of shapes. Small shapes are baked for about 7 minutes at 200 °C, larger shapes for about 18 to 20 minutes at 180 °C.

Commercial types of gingerbreads

Undipped gingerbreads (gingerbread for grating, the surface is smeared by solution of dextrin or gelatine),

dipped and half-dipped gingerbreads (filled gingerbread, gingerbread hearts in chocolate, Jahodový dortík, etc.)

glazed gingerbreads (gingerbread with sugar icing, gingerbread with whipped topping, Rumové perníčky, Zlaté bochánky),

decorated gingerbread (gingerbread fairings).

5. 5 Rusks

Rusks are products made of chemically or biologically (yeast) leavened dough. Loosely laid loaves or shapes of pan bread are baked. The baked product is cut to slices, which are dried by toasting.

Raw materials

Wheat flour rich in gluten, yeast (2 to 8 %), salt (1 to 1.8 %), sugar (2 to 10 %, lower doses of sugar are combined with 1.5 % of malt flour), fat or butter (2 to 10 %), sometimes 1 to 2 % of dried yolks or eggs is added.

Production process technology

They are made from well matured leavened doughs of looser consistency. Method for producing is either conventional (trough, proofer, oven) or industrial lines. Matured dough is divided and formed into loaves, which are placed to metal pans greased with fat. They proof about 45 minutes. Proofed loaves are baked for about 30 to 40 minutes at 210 to 220 °C. Inter-mediate product called “krudon” is obtained by baking, which is allowed to rest for 12 to 24 hours in a conditioned space. Maturing is needed so that the moisture of baked product is uniformly spread by diffusion throughout the cross section of the loaf. If not sufficiently matured, the slices would have higher moisture in the centre than at the periphery and would lack uniform colouration. After resting, the krudons are cut to 5 to 8 mm thick slices and toasted on both sides at a temperature of 190 to 210 °C. After cooling, the rusks are wrapped in cellophane or paper bags. Packaging has to protect the rusks against moisture.

Commercial types of rusks

***Diet rusks* –** from wheat dough without fat,

***delicate (luxury) rusks* -** beyond basic raw materials the dough contains eggs, fat, coarsely chopped nuts (hazelnuts or peanuts), candied fruit, etc., they are coated in sugar**.**

Featured products

Karlovarské suchary, Lomnické suchary, diabetic rusks.

5.6 Pretzels and durable sticks

Pretzels and durable sticks are products made from a stiffer dough, loosened chemically or biologically (yeast). They are baked until completely dry throughout.

Raw materials

Fine wheat flour “special”, baking powder, improver, water, fat and complementary ingredients such as caraway seeds, cheese, wholemeal flour, various seeds and others.

Production of pretzels and sticks

Pretzels have a low water content. Originally they were produced manually in the shape of rings. When produced by machinery, the rings are extruded. The production of sticks is much higher than that of pretzels. Sticks are produced from yeast dough, but also from dough that is chemically leavened.

After mixing, the dough is allowed to mature. Then it is shaped either by using grooved rollers or extrusion through nozzles. Shaped sticks are cut to appropriate length and are baked. Baking time and temperature depend on the type of a stick; the thinner the stick, the higher the temperature (240 to 300 °C) and shorter baking time (5 to 10 min).

- Thicker sticks, more fluffy, with a diameter of 10 to 12 mm, are baked on metal plates with grooves to maintain straight shape. Today the sticks are manufactured with various additives - cheese, spices, tomato paste, and so on.
- Salty sticks called “soletky” (fine thin sticks having a diameter of about 5 mm), before baking they go through a lye baths for obtaining colour and gloss. The 3.5 % KOH solution is applied with temperature of 26 °C.

Commercial types of pretzels and sticks

Traditional salty sticks and pretzels (Salty sticks, Soletti - salty pretzels, lightly salted pretzels, and so on),

thin sticks and “soletky”,

thicker Italian breadsticks of grissini type and variants derived from them with savoury taste (Opavské tyčinky, Graham tyčinky).

5.7 Knäckebrot

This crisp bread is imported from Germany. It is made from both flours and whole grains of rye, wheat or other cereals.

Knäckebrot may be leavened by yeast, sourdough or leaven by air through whipping. The flat bread is baked until completely dry; the moisture content may not exceed 10 %.

It is hard, but also brittle. Not to confuse it under this name with extruded crisp slices.

5.8 Crackers

Products made with chemically leavened laminated doughs with a small amount of yeast added because of better taste.

Raw materials

Fine wheat flour with a high content of strong gluten, fat, malt flour, sodium bicarbonate and yeast. Gluten properties are adjusted by proteolytic enzymes (proteases). Previously also chemical reducing agents (sodium sulphite) were used.

Production process technology

Sponge-and-dough method with a pre-ferment (flour, water, yeast, malt flour), maturing at temperature from 27 to 28 °C, 12 to 20 hours. Dough is kneaded from a mature sourdough starter and other raw materials, dough resting time 3 – 5 h,

In the production of crackers, **leavening** is usually accomplished by a combination of yeast and chemical leavening agent. Yeast is added in very low doses. This results in a long time needed for the *dough resting*.

Straight dough method - loose raw materials are ***mixed***, yeast is added in part of water. After the first stage of kneading, tempered water with leavening agent and enzymes is added to the dough. Then follows the dough ***kneading***, ***proofing***, ***rolling, laminating (folding), short resting (****only on the belt****), shaping (cutting out), wetting, sprinkling, baking (3 to 5 minutes, 290 to 360 °C), cooling (35 to 40 °C), packing***.

A characteristic feature is the dough ***lamination***, i.e. after rolling out to a thin sheet, the dough is repeatedly folded and again sheeted, thereby achieving a characteristic, very fragile and flaking consistency. For folding, a device is used where the dough sheet is folded out using either a vertical or horizontal feeder, which performs a periodic reciprocating motion. The dough sheet is thus laterally transferred on the conveyor belt, where it creates several layers depending on the ratio between the two speeds.

After repeated rolling out of the dough, again sheet is created with equal thickness. During ***baking*** the lamination manifests itself in higher rising of the dough between the developed micro-layers. After baking, some types of crackers are sprayed with hot oil and sprinkled with salt or other flavours when leaving the oven.

Featured products

Piknik, Telka, TUC, and so on.

5.9 Expanded bakery products

Expanded products include **extruded and puffed products**. Loosening proceeds as a thermo-mechanical process. Partially gelatinized material at a high temperature and with a small amount of water is closed under high pressure and subsequently discharged into the surrounding atmosphere. Gases and water vapour enclosed in the material immediately expand and loosen the product, which instantaneously solidifies in normal atmosphere and temperature. The product is fragile.

Extrusion takes place in an extruder, which is a closed tube with a screw inside. The material moves through whilst being compressed under high pressure and temperature. The material is then pushed out through a narrow opening at the end of the extruder and expands. Fine materials can be processed, which form a homogeneous dough.

Depending on the nature of the final product and processed raw materials, the extrusion process parameters are within the following ranges: temperature from 80 to 250 °C, pressure from 2 to 20 MPa, moisture content from 5 to 40 %, the residence time of material in the extruder from 5 to 100 seconds (Doležal, 2003).

By construction type, extruders can be divided into single-screw and twin-screw machines, with short or long screws. By pressure, we distinguish low, medium and high-pressure machines. High-pressure twin-screw extruders can handle a wide range of raw materials.

Puffing (name of this process is derived from puffy, swollen grains) takes place so that moisturized and gelatinized grains are placed in a tube or mould under a high pressure and temperature. Material is expelled from the tube into a grid in a normal atmosphere, where it expands and loosen up. The whole grains are processed by puffing. Burisons (puffed rice) are produced from rice grains. Puffed sandwiches of different cereals can be produced using moulds.

The wetted grains are fed into the expansion mould of a baking machine. Due to the high temperatures (300 °C) and pressure the moisture quickly evaporates (10 s), the grains swell (expand) and are shaped into sandwiches. After sorting out damaged pieces, the sandwiches are flavoured in a spraying or dipping machine, and then their drying is accelerated in a drying or cooling tunnel. Then they are packed in a foil wrap and labelled with expiry date, placed into cardboard boxes, palletized and dispatched. .

Raw materials for extrusion and puffing:

- ***maize*** the most common is maize semolina, more suitable than the flour
- ***wheat (flour)*** worse expandability than maize due to higher protein content
- ***rye*** worse expandability
- ***triticale*** needs higher temperatures
- ***rice*** suitable raw material
- ***oats*** worse expandability due to carbohydrates and fats

Advantages of extrusion and puffing

- Increases the digestibility by disrupting starch and proteins
- Increases the nutritional value of products
- Increases the hygienic value, the product is microbiologically clean
- Damage to thermo-sensitive materials is minimal (the process takes only a few seconds)

Products

Extrusion products belong to a group of products intended for fast refreshment. They are high in fibre, suitable for diabetics and various diets, and durable. Due to physical conditions during extrusion, they are boiled and so extruded products are instant.

Small, shaped pieces, sticks, salty or otherwise flavoured slices, flat products of crisp bread type, all of these products can be further treated (toasted, dipped in chocolate or coated) or flavoured (spices, natural flavours, and so on). Shaped extruded products such as shells, tubes, or pads can be also further filled with a variety of fillings.

5.10 Matzos

Matzos are special bakery products. This product is made with unleavened water-based dough. The dough is formed into thin perforated sheets and briefly baked at a higher temperature.

5.11 Quality and sensory evaluation of durable bakery products

In sensory evaluation of durable bakery products we assess the product's **overall appearance and shape,** surface, its colour, aroma and taste, and consistency (whether it is fragile, stiff or tough). For filled products we evaluate the consistency of filling (softness, granularity) and uniformity of spreading. For dipped and half-dipped products, the uniformity of coating application and its appearance (colour, gloss) is monitored.

Surfaces must be clean, not stained with filling or topping. Wafer sheets must be complete, not cracked, integrally dipped, where appropriate, the topping must hold, without cracks.
The colour should be light brown to brown, depending on the type of wafer sheets used**.** **Consistency** of sheets must be fragile, not tough, with soft filling**. Aroma and taste** must be pleasant, typical of wafers, with the flavour and aroma of the fillings and raw materials used**.**

Bases and products made from light whipped masses are characterized by high porosity and low density. Bases made from sandy masses (heated whipped masses) are generally smoother than the sponge masses.

Table 5.1 Requirements for the quality of durable bakery products (Decree of the Ministry of Agriculture no. 182/2012 Coll.)

	Appearance and shape	**Crust, surface**	**Crumb**	**Aroma and taste**
Durable bakery products, except biscuits, wafers and gingerbreads	Characteristic colour		Fragile, layered breakage with laminated products	Pleasant according to the ingredient used
Biscuits	Regular shape imparted by the mould	Light brown	Fragile	Delicate
Wafers	By the mould	Brittle, design embossed by the mould	Fragile	Pleasant according to the ingredient used
Gingerbreads	By the mould	Compact, clean	Pliable	According to the ingredients
Extruded products	Regular shape imparted by the mould	Typical, corresponding to the ingredients used	Fragile, porous	Typical of bakery products, pleasant, with flavour of added ingredients, without foreign odours and flavours
Puffed products	Regular shape imparted by the mould	Typical, corresponding to the ingredients used	Fragile, consisting of individual puffed grains	Typical of bakery products, pleasant, with flavour of added ingredients, without foreign odours and flavours

6 PRODUCTION OF PASTA

Pasta is universally recognized food with versatility, easy preparation (even in terms of energy) with excellent nutritional profile that meets the current requirements of proper nutrition, i.e. low-fat, minimal amounts of cholesterol and sodium, and a corresponding proportion of complex carbohydrates and proteins. ***Pasta contains*** on average 12% of proteins, 72 to 76 % of carbohydrates, 12 to 13 % of water, 0.5 to 0.7 % of fat, minerals (Fe, Ca, P), and vitamins B_1, B_2 and PP.

Pasta consumption has a steadily upward trend, both in Europe and in America. The highest consumption in Italy is around 30 kg per person per year. In the Czech Republic, this value is about 6.5 kilograms of pasta per person per year. Most consumers in the Czech Republic consumes pasta at least once a week. There are new methods of treatment, use and consumption of pasta. Also the assortment expands. Pasta is made from different raw materials, in different shapes, colours and flavours, as well as frozen and filled pasta with long-term durability.

6.1 Classification of pasta

Pasta is produced by shaping of dough, which is neither leavened nor chemically loosened, prepared especially from the mill grain products or mixtures thereof.

According to the Decree of the Ministry of Agriculture no. 182/2012 Coll., **pasta is divided into groups as follows:**

- ***egg pasta***, in the production of which, in addition to mill grain products, chicken eggs are used in the amount of at least 2 eggs per 1 kilogram of flour
- ***eggless pasta*** made without the addition of eggs,
- ***semolina pasta*** made solely from semolina from durum wheat (*Triticum durum)*, without the addition of eggs,
- ***wholemeal pasta*** made from whole wheat flour,
- ***homemade pasta*** made by hand from mill wheat grain products and fresh chicken eggs in an amount of at least 6 eggs per 1 kg of wheat flour, and
- ***other.***

Above groups are further divided into:

- ***dry pasta*** that is dried after being shaped to reduce the moisture content to less than 13 percent by weight,
- ***fresh undried pasta*** that is slightly dried after being shaped to have the total moisture content at least 20 and not more than 30 percent by weight,
- ***stuffed pasta,***
- ***frozen pasta,***
- ***pasta packed under either vacuum or inert atmosphere.***

Pasta is also divided according to **shape** into:

- *long-cut* - spaghetti, bucatiny, macaroni,
- *medium-cut* - cut macaroni, smooth and grooved rigatoni, large and medium-sized pasta in various shapes (square-shaped, seashell-shaped, and many more),
- *short-cut* – small-sized pasta in various shapes (seashell-shaped, letter-shaped, ring-shaped, flat-shaped, rice-shaped, and many more);

according to the **method of shaping** to *pressed* (extruded) and *rolled* (cut); and

according to its **use** to *soup pasta* or *side dish.*

6.2 Raw materials

Flour is the main dough raw material affecting the mechanical and sensory properties of the pasta. Pasta is best made from a special coarse flour called **semolina** (from the Italian word semi-milled), which is obtained by milling durum wheat (*Triticum durum*) grown in the USA, Canada and the states of the Mediterranean. Since the carotenoid and flavonoid pigments are distributed also in the endosperm, semolina has a yellowish colour. The grain has a high water core, high bulk density, and hard endosperm. It is rich in proteins, 12 to 16 %, therefore also in gluten (above 34 %), which is rigid, low stretch, little swells in water and provides a rigid and pliable dough, which is slowly pressed. Under proper drying process, the produced pasta does not crack, is smooth, firm, and elastic, achieves large volume while cooking, retains its shape and does not boil to mash.

Durum wheat cannot grow in our conditions and must be imported, so pasta is also produced from medium coarse flour made from *bread wheat Triticum aestivum* (var. hard) or a mixture of flours from durum wheat and bread wheat.

An important indicator of the quality of flour for making pasta dough is its **granularity**. Balanced granularity is the condition of uniform water absorption, which favourably influences the pressing and drying of pasta. Where there is a difference in granularity, fine mealy particles absorb the bulk of the water and moisture cannot be equalized before compression. Then pasta lacks a continuous smooth surface and has ***marbled internal structure***.

The second basic raw material, which makes the dough formation, is water that must meet requirements for drinking water. Water amount is 24 to 30 % to the weight of flour, with temperature of 22 to 50 °C. The higher the gluten content of flour, the warmer water can be used.

Other raw materials are an essential part of the basic recipe. They improve the nutritional value, increase protein content, reduce cooking losses, and improve sensory qualities when eaten.

Eggs are added in a dried form, 2 to 5 pieces per 1 kg of flour (1 fresh egg corresponds to 10.425 g of the dried mixture). They increase the volume of pasta during cooking, reduce the tendency of overcooking, and improve the colour and flavour.

Dried milk, vital gluten, colourings (turmeric, carotene), vitamins (B_1, B_2), dehydrated vegetable powder and many others are added to improve pasta properties.

Additives can be divided into 4 groups:

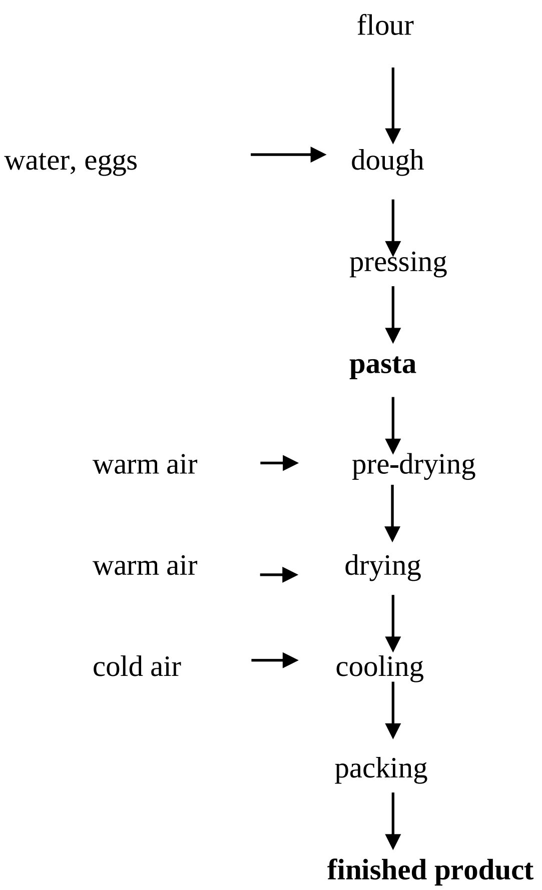
- substances increasing nutritive value (eggs, milk, soy, gluten)
- flavouring substances (fruit and vegetable juices, pastes, aromatizing substances)
- improvers (antioxidants preventing degradation of carotenoids in the flour)
- biologically active ingredients (vitamin preparations, vitamins B_1, B_2, PP)

6.3 Pasta making process technology

Production of pasta is relatively simple and involves the following operations:

- preparation of flour (sifting, mixing, pre-heating) and other raw materials
- preparation of dough and making pasta (mixing, kneading, pressing, shaping, and cutting)
- pre-drying and drying
- quality control and packing

Pasta making scheme



Dough making and pressing

The pasta dough is the easiest of all kinds of doughs that are used in cereal technology, both in composition and method of preparation. It is prepared from flour and water, or eggs and other ingredients.

The whole process of dough preparing and shaping is carried out in a ***dough press*** under pressure. All raw materials are continuously fed to the mixing chamber of the press on a weight or volume basis. At first, the dough is rather stiff, with disparate consistency. After vigorous kneading it gets the appearance of a lumpy mass and only after further processing it becomes stiff and plastic. When processing semolina, water is added about 1 to 1.5 % more. The absorption ability of flour varies according to the nature, granulation, quantity and especially quality of gluten. Soft wheat flour absorbs more water than semolina, which, after hydration, has greater ability to retain this state (this feature of semolina is one of the main reasons why pasta is produced mainly from hard wheat).

The kneading time is 10 to 20 minutes, modern presses are bale to prepare dough in a shorter time. The dough temperature (43 to 45 °C) affects the quality of the pasta.

Modern continuous manufacturing processes use two-stage mixing machines, wherein the flour is mixed with water, usually 40 to 50 °C warm in an amount up to 30 % to the weight of flour, and optional additives to make a stiff dough. Water warmer than 50 °C is used when processing gluten-rich flours.

Kneaded dough is brought by a robust auger into the chamber of the press, where it is kneaded under pressure of up to 15 MPa. This is a low pressure extrusion. The dough is advanced into the discharge worm, where it is forced through a die. Openings of the die determine the product’s shape. Dies are made of stainless steel and the openings are lined with Teflon liners, thereby reducing friction and achieving smooth surface of the pasta made. There are knives behind the die, which cut the extruded pasta to the appropriate length. In order to remove air bubbles and prevent oxidation of the dough, which deteriorates the appearance and colour of the finished product, the workspace is connected to the vacuum station. Kneading under vacuum facilitates the dosing of raw materials and improves the appearance of pasta (prevents the formation of strips).

Considerable amount of heat generates during pressing, therefore the working area should be cooled down so that the temperature in the press head does not exceed 48 °C. Otherwise it has a negative effect on the gluten structure and cooking properties of the pasta. Pasta leaving the press head is pre-dried by warm air of 40 to 50 °C, thereby reducing the pasta moisture by about 5 %, water is removed from the surface and pasta then do not stick together.

Pasta drying

Drying is among the most important and most complex operations. Moisture from pasta must be removed gradually. Therefore, drying should proceed in **three stages**:
Pre-drying – reducing the moisture content by 1 to 2 %; ***drying*** – reducing the moisture content by 7 to 8 %; and ***cooling*** – removal of 6 to 7 % of the moisture content, whereby the moisture of original pasta of about 29 to 32 % decreases to the desired 13 % and the temperature declines to 25 °C. Different systems are used for

drying, which differ from each other mainly in the temperatures used. Generally, the drying time for long-cut pasta lasts seven hours, with 2 to 3 hours for short-cut pasta.

It is also possible to use a **two-stage process**: ***quick pre-drying*** (air temperature 36 to 45 °C, relative humidity 85 to 90 %, time 20 to 90 min, the moisture content is reduced to 22 to 24 %) and ***slow final drying*** (air temperature 32 to 45 °C, relative humidity 70 to 80 %, time 6 to12 hours, the moisture content is reduced to 12.5 to 13 %).

The most radical **shortening of pasta drying** process came with the introduction of ***drying at very high temperatures (thermos-hydro-treatment or THT)*** of 80 to 120 °C. This technology allows drying of long-cut products in 4 to 5 hours and short-cut products in two hours. Studied is also the possibility of using preheated water vapours for drying, which would enable to shorten the process further. In addition, high temperatures inhibit or destroy some microorganisms. Made pasta tolerates cooking process very well, it is possible to produce in this manner also pasta from soft wheat. For the drying process to be correctly regulated, the drying room is divided into different climate zones, providing pre-drying, final drying, cooling, and stabilization of pasta.

Long-cut pasta is most often dried on poles, the length is adjusted by cutting to 230 to 250 mm. Short-cut pasta is firstly pre-dried in a shaking drying chamber, conveyors then convey it into the first drying zone. Manufacturers of the equipment for drying pasta at very high temperatures (THT) include companies such as Bühler, Bassano, and Pavan.

After drying, the pasta is ***cooled, ventilated and collected*** by receiving hoppers of automatic packaging machines.

A special technological process is used to produce *instant pasta***.** For consumption it is prepared by rehydration in water or other liquid.

Storage and packing

Pasta is **stored** in bins in areas with relative humidity not exceeding 75 %. It is packed in plastic bags, which can be stored for 1 to 2 years. ***Undried pasta*** must be stored at temperatures not exceeding 5°C, while pasta packed under vacuum or inert atmosphere must be stored at temperatures not exceeding 10 °C. Fresh undried pasta is transported in isothermic packages or isothermic vehicles.

Pasta must not be packed in a coloured transparent or translucent package, under which the colour of product is visually distorted.

6.4 Quality and sensory evaluation of pasta

Appearance and shape must match the commercial type, and the consumer package must not contain more than 1 % of impurities made by other pasta shapes. The **surface** is smooth, compact, without cracks. For rolled pasta and pasta products, where most of the surface is formed by cutting, the surface may be slightly rough and mealy. The proportion of fragments may not exceed 10 %. When conditions from the cooking recipe are observed, pasta **does not overcook, is not sticky** and retains its shape after cooking.

The point of fracture of pressed pasta must be vitreous, that of rolled pasta may be even slightly mealy.

The colour is bright, even, in various shades of yellow; for egg pasta it corresponds to the number of eggs used, for semolina pasta the colour is amber or in various darker shades of yellow, for other types it corresponds to the raw materials, additives or flavourings used.

Aroma and taste are pleasant and correspond to the raw materials, additives or flavourings used.

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