Cereal processing and cereal based foods

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TÁMOP-4.1.1.C-12/1/KONV-2012-0014
„Élelmiszerbiztonság és gasztronómia vonatkozású egyetemi együttműködés, DE-SZTE-EKF-NYME „ projekt segítségével jött létre

SZÉCHENYI 2020

MAGYARORSZÁG KORMÁNYA

Európai Unió
Európai Szociális Alap

BEFEKTETÉS A JÖVŐBE

Contents

1. Baking technology

In the past the simplest baking products were made from flour and water. Today all baked products are made from a few main ingredients. They are the flour and the water. We also added some other ingredients for example: milk, fat, eggs, sugar, salt, flavoring, sweeteners, liquid and leavening agents. The difference is the amounts of the ingredients. The other difference is the combine of the ingredients and the production (different mixing, different baking).

The baked goods are basic nutrition, but many goods are high sugar, fat content. The main product is the bread, for example:

- Yeast bread (yeast produces carbon dioxide gas through the fermentation process)
- Quick bread (this type of bread leavened with air or steam, and we use baking soda or baking powder)

Famous bread types are:

- Baguette (France)
- Balady (Egypt, Syria)
- Chapatti (India)
- Man-tu (China)
- Tannouri (Iran)
- Pan (Japan)
- White bread (Hungary)

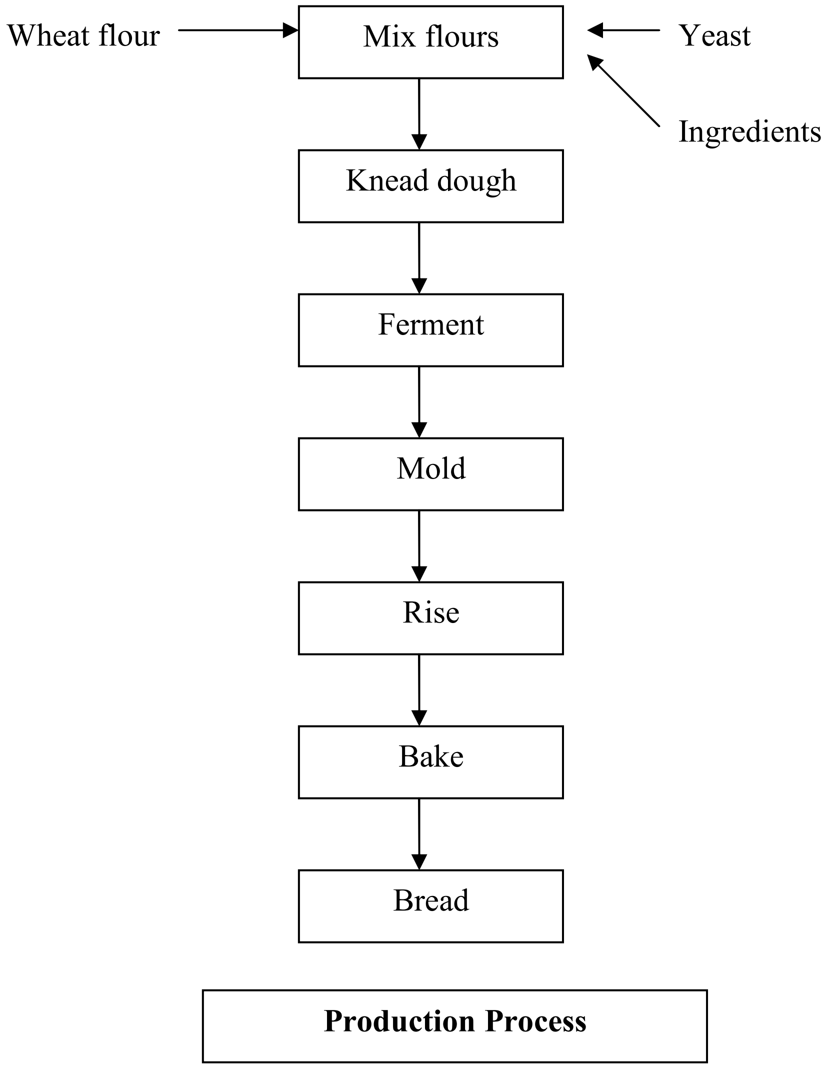

Figure 1. Flowsheet of baking technology

The short technology are the following: scaling the ingredients; mixing and kneading the dough; fermentation; punching down the dough; portioning the dough; rounding the portions; make-up: shaping the portions; proofing; baking; cooling; storing.

1.1. Raw materials

1.1.1. Flour

Flour is the main and most important ingredient, every baked product contains it. It determines the dough and the end of products texture (hold and expand with leaving agents), flavor, nutrition, and binding all ingredients. We can talk about wheat flour, and non-wheat flour. The millers work together with bakers to produce the right flour for the baker's products.

The wheat flour contains insoluble proteins (this is gluten), which determine the texture of a baked product (elastic characteristic), and the volume of the products. The other main content of the flour is the starch. This is an important compound in flour that strengthens the baked products through the starch gelatinization. It determines the crumb, and the products interior.

Types of Wheat Flour

Whole-Wheat Flour: weak gluten (combined with all purpose flour)
White Flour
Durum Flour (Semolina)
All-Purpose Flour: the wild spread flour
Pastry Flour
Cake Flour: less gluten content (it causes the tender structure of cake)
Gluten Flour

The classifications are the following:

wholemeal (whole wheat grain)
wheatgerm (10 % wheatgerm added during the milling process)
organic (it is grown to organic standards)
brown (85 % of original grain, only the bran and germ are removed)
white (75 % of wheat grain, most of the bran and germ are removed)
malted wheat grain (malted grains are added)

The typical gluten free flour is the rice flour, maize flour, potato flour (cooked and dried potatoes). The non wheat flour types, for example the soy flour, which has a higher protein content (high lysine content); triticale flour, which is a hybrid of wheat and rye; rye flour; buckwheat flour, etc.

Figure 2. Flour storage

The different types of end products need different types of flour. The First Patent Flour is good for baking cakes, the Short Patent Flour is good for baking excellent, premium bread.

Chemical ingredients of flour:

- Starch: 70%
- Moisture: 14%
- Protein: 11.5%
- Mineral (ash): 0.4%
- Sugar: 1%
- Fat (liquid): 1%
- Others: 2.1%

Starch is the greater part of the wheat flour, which is broken down by enzymes. It will be the yeast food. When the temperature of the dough increases, the starch absorbs water, and it is called gelatinize.

The flour proteins have two groups: soluble and insoluble protein. The insoluble protein is the most important, because these proteins absorb the water in the dough. It causes the elasticity and extensibility of the dough. The insoluble proteins give the gluten network, the gluten structure, which holds the carbon dioxide gas back.

Figure 3. The gluten

The chemical and physical analysis of the flour is very important:

- Moisture content: Average moisture content is about 14 %.
- Ash content: It determines mineral matter in flour
- Pekar test: colour test
- Protein: the quantity of proteins
- Valorigraph: it determines the absorbent capacity of the water

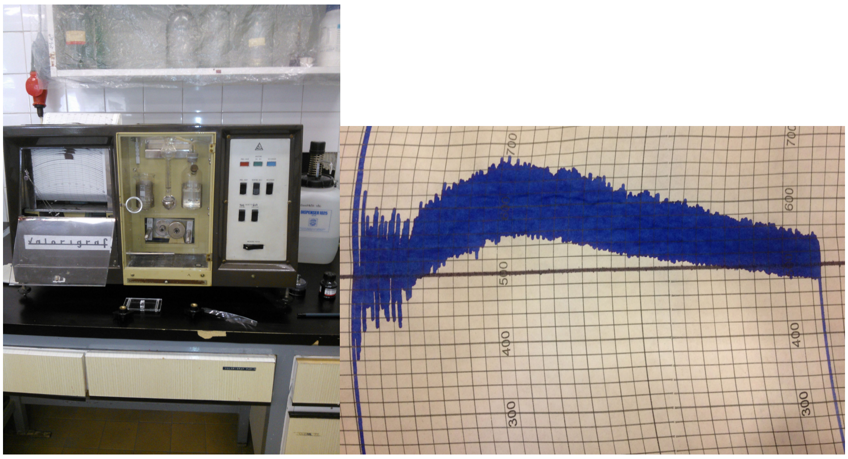

Figure 4. The valorigraph and the curve

- Automatic gluten test apparatus: This machines tests the gluten quality and quantity. The dough is made (and the gluten) by the Glutomatic unit. The gluten is separated from excess water in centrifuge and then dried in Glutork unit. Parallel two samples can be tested.

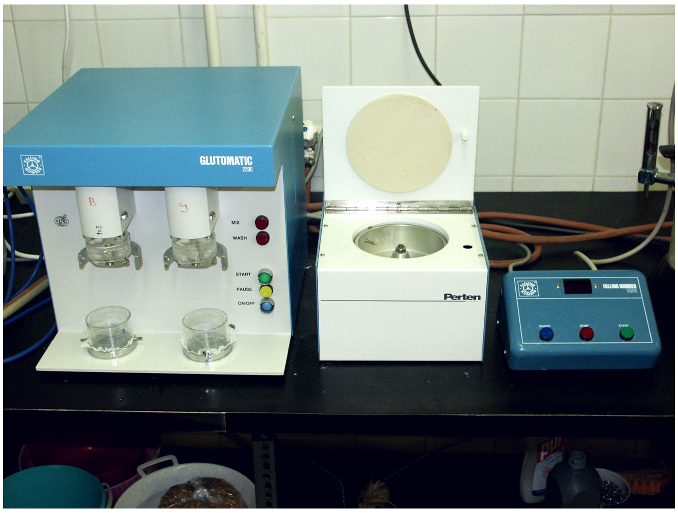

Figure 5. Glutomatic machine (Perten)

- Amylograph: Measure the amylolitical state of cereals. Amylograph is a rotational viscosity meter measuring the viscosity in dependence of time and temperature, designed for testing the gelatinization properties especially of starch containing cereal products and the α-amylase liquefying effect on the starch. The results obtained by the instrument give information on the expected crumb structure of baked products. The viscosigraph is drawn by pen-recorder.

Figure 6. Amylograph machine (Brabender)

- Rheofermentometer: Measure the quality of the flour, the fermentation potential, and the protein network strength. The instrument measures simultaneously the CO2 production, CO2 retention in dough, the % dough permeability and the increase of the volume of dough, tracking of volume evolution during the time of fermentation. It has temperature control to 45°C. Test duration can be varied between 10-180 minutes. The analyses are computerized with spreadsheet.

Figure 7. Rheofermentometer (Chopin)

- Do Corder and developer kneader and measure system: Not only the quality of flour can be tested, but also the processing behavior of dough and large variety of recipes may be examined. With the stepless variable speed (5-250 rpm) of the Do-Corder any desired mixing intensity and energy input into the dough can be simulated. The dough-cup can be tempered. The pen-recorder records the torque /time relationship.

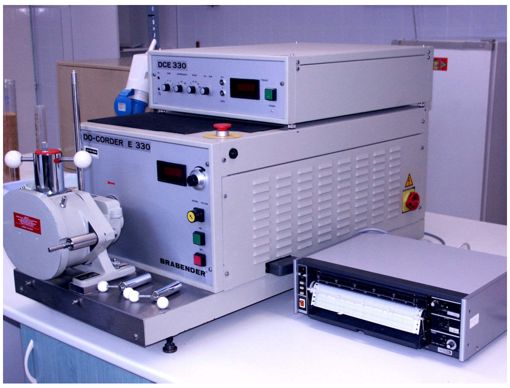

Figure 8. Do Corder machine

- Alveograph: Wheats, flours, grits quality control. The alveograph consists of four main components: the mixer, the actual dough-bubble blowing apparatus, the recording manometer and the dough sheeting assembly. The instrument allows measuring the stretching capabilities of the flour-water dough quickly, precisely and reproducible resistance to extension and extensibility.

Figure 9. Alveograph (Chopin)

- Elastigraph: Measure the quality of the bread crumb. The instrument measures the compressibility of bread crumb under fix strain and the elasticity after putting-off the weight. The change of sample-volume is drawn by recorder on diagram.

Figure 10. Elastigraph

- Falling Number Test Apparatus: Results can be applied to monitoring the ripening process of the grain, to segregation of grain into good quality for bread making, to determine the quality of the flour supplied and to optimize flour blends. The method is for the rapid determination of α-amylase in starch containing products (wheat, rice). The method is based up the rapid gelatinization of a suspension of flour in a boiling water-bath and the subsequent measurement of the liquefaction by α-amylase of starch contained in the sample.

Figure 11. Falling Number machine (Perten)

1.1.2. Yeast

Yeast is a raising agent in a baking technology. It is a Baker's yeast, Saccharomyces cerevisiae. This a Fungi, which produces ethanol and carbon dioxide gas (alcohol fermentation). This gas causes the bread rise (yeast feeds the flour sugar and the added sugar). They are facultative anaerobes and a single cell plant fungus.

The yeast has enzymes, which hydrolizes the starch (to glucose, fructose), and the flour enzymes (α, β amylases) break down, the starch to maltose.

In the food industries, they are classified the yeast on their activity: baker's yeast; brewer's yeast; dried brewer's yeast, etc. In the bakehouse there are three types:

- Fresh yeast (compressed yeast)
- Dry yeast
- Instant yeast (powered dried yeast)

The fresh yeast is better, but we have to keep in cold place (it must be kept refrigerated). It is firm, moist, cream-coloured, and a mixture of yeast and starch with approximately 70% moisture content;. The yeast is a small granular form of yeast (it need water to rehydrate before we use). It can be stored without refrigeration for months. The instant yeast is a dry ingredient in a bread formula without rehydrating (the other name is rapid rise or quick rise yeast. If we use too much instant yeast, it will cause the dough to rise too quickly, but it is easy to use, because we sprinkle straight into a bowl of flour.
The temperature effects the yeast, if it is too high, it will kill the yeast, if it is too low, it will slow down or stop the activity of the yeast (see table). Yeast is very sensitive to temperature and moisture.

Table 1. The temperature effects to the yeast activity

Temperature (^oC)	Yeast development
2	Inactive
16-21	Slow action
24-43	Best temperature for yeast (instant, dry, fresh)
59	Yeast dies

During the mixing (hydration) the yeast is activated in warm water.

Yeast + carbohydrates = alcohol + carbon dioxide

The carbon dioxide gas is trapped in the dough, while the alcohol evaporates. The salt inhibits the yeast from growing, so determines the dough's rise (place the shaped dough in a warm humid environment). So the carbon dioxide generated by growing yeast makes dough rise.
The Saccharomyces cerevisiae has close "wild" relatives, the natural yeast starters (sourdough is a type of natural yeast) used prior to the development of commercial yeast

The other types of the leaving agents are the air (air is trapped in the mixture), the steam (this leavens products contain more water, and it turn into steam and it expands, which causing the products rise); Baking soda; baking powder.

1.1.3. Salt

Salt is a mineral composed of sodium chloride (NaCl), which has different types:

- Solar mining salt, sea salt (the sun evaporate the see water),
- Rock mining salt (from the underground),
- Solution mining,
- Vacuum salt, refining (this is the table salt, which is evaporated, it has chemical and sulfuric acid treatment).

Salt is the oldest preservative, widely used in the food preparation. It slows down the microbal growth.

In the bakehouse the main type which used is the table salt (it is made up of sodium and chloride). But we know that there is little difference in these salt types, so we can also use the other types. The sodium is a mineral, and used by the human body. The chloride is an other important nutrient.

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

The table salt is the best, because it is completely soluble in water and it has a clear solution. This salt is free from biting taste and lumps and it is pure.

The salt determines the flavouring of the products, volume, texture, shelf-life and the evenness of the cell structure. The salt regulates the yeast activity (inhibits the yeast action – the enzymes) and the yeast fermentation, so determines the aroma, the colour and the texture of the products (without salt the dough is hard to handle).

The future is finding the substitute for salt, it can be the potassium chloride. It has a salty flavour, but it has bitter aftertaste. (Iowa State University)

1.1.4. Water

The water has several sources, the sea water is from oceans and seas, the deep water is from geysers and volcanoes, and the third type of water is from rain and snow, this is the natural water. The other classification will be the hard water and the soft water. The hard water contains a lot of dissolved minerals; the soft water contains loss minerals.

The water is the best to control the temperature of the dough (warming or cooling of dough) and the water controls the consistency of dough (elasticity, plasticity, stability).
The main task of the water to solvent the dry ingredients (dissolve salt, suspend and distribute the non-flour ingredients) and allowe gluten to be formed (flour proteins are hydrated). The water is required to hydrate the flour, activate the yeast and gelatinize the starch (wets and swells starch). The water contains minerals and natural impurities. In the baking process it provides steam for leaving and in the bread baking process we need to use steam in the first part of the baking.
When baking soda or baking powder are used, the water reacts with them and produces carbon dioxide gas.
We can talk about the contributing water (in the milk, other ingredients), which determines the texture, the crumb and the crust.

1.2. Secondary raw materials

1.2.1. Fats, improvers including emulsifiers

In the bakehouse, we use fats, which are extracted from plants (vegetable oils) or animals (butter). The functions of these fats are the following: add flavor to the products; moisturizer; tenderizer; determine the heat transfer, the structure of the dough and the shelf life. These fats contain carbon, oxygen and hydrogen.

Butter

Butter is a dairy product, it is the fat of the milk. The fine bakery products contains a lot of butter and in the baking process we use sweet or sour cream to fill the products. The butter must contain more than 80 % of milk fat.
It has some different types, for example sweet butter (this is the traditional butter, we use it everyday); cultured butter, which contains bacterial culture; flavoured butter with different spices and herbs; whipped butter is softer and easier to spread, because it contains innert gas (air).

Margarine

Margarine is the other dairy product, which is a mixture of vegetable oils (hardened vegetable oil), animal fats (for example fish) and water/milk. The margarine has a similar appearance to butter, so it is used as a butter substitute (and the margarine is cheaper).
It determines the volume of the products, because it coats the flour and prevents the gluten. The products crumbs strength is effect by margarine – lower margarine has velvety crumb.
The product, which contain margarine, is richness, tenderness and flavor. In the bakery products we can use the traditional, regular margarine, not the whipped, and liquid types.

1.2.2. Sugars

The sugars have a lot of function in the baking technology. The main function is the sweetening. The browning reaction reducing the sugars, when heated with proteins, reacts to form dark compounds called melanoidins. The sugars help in the yeast fermentation, from glucose, fructose, sucrose and maltose are fermented by yeast. This is the alcohol fermentation, where the yeast produces carbon dioxide and alcohol from the sugar. Sugars are hygroscope materials, so absorb and retain the moisture. The solubility of the sugars control the crystallization of the products. The sugars have hydrolysis properties, when the maltose and the sucrose are hydrolyzed by the enzyme (the yeast has this enzyme). This is an important reaction in the dough before the sugars are fermented. The sugar has a heat sensitivity (the pH determines these properties – low pH, less sensitive), it is the caramelization. Fructose, maltose and dextrose are the most sensitive and lactose and sucrose are the least.
In the baking technology, the sugars help to brown the crust (the crust color is darkened by addition sugar), increases the volume (source of energy of yeast activity) and the moistness (moisture retention and the tenderness (the texture become smoother and finer).

Types of sugars:

- table sugar
- sanding sugar
- molasses
- corn syrups
- brown sugar
- granulated
- honey
- malt syrup

The sugars are the following: monosaccharides; glucose, Fructose; disaccharides ; Lactose (glucose and galactose) –milk; maltose (glucose and glucose); sucrose (glucose and fructose – table sugar; reducing sugars.

1.2.3. Milk products

Milk is a very important ingredient in the fine bakery products. The main nutritions are the water (87 %) and the solids (13 %). The solids are: carbohydrates, protein, water-soluble vitamins and minerals, fat and fat-soluble vitamins. The carbohydrates, the fats provide energy, the protein builds muscle. The calcium builds strong teeth and bones and regulates the muscle. The phosphorus strengthens the body cells.
The milk contains vitamin A, B and D, the vitamin D helps the calcium and the phosphorus to build strong teeth and bones.

Evaporated Milk:

This type of milk is produced from whole milk, is made by removing ~ 60 % water from whole milk. After the evaporation, this milk is homogenized, and fortified with vitamin D and viamin A (it is optional).
It has two types, which depends on the fat content, the fat free evaporated milk content (maximum 0.5 % fat), the sweetened condensed milk content (maximum 8 % fat) (it has been sugar added, which is sucrose). And we can talk about the mixing of the two types, this is the sweetened condensed fat free milk, it contains the same fat content like evaporated fat free milk and it contains sweetener.

Dry milk:

The liquid milk needs refrigerator, and when we once open we can use in a week. Dry milk has longer shelf life and it doesen't need refrigerator. This is powder, made from dried milk soids and we can reconstitute it with water. The bakers like it to use.

1.2.4. Malt products

The malt is made by barley grain germination (by soaking grains in water). The temperature of water is between 10 – 15 ^{o}C. The water enters in the grain and 24 hours later, we can sign the germination. During this process the enzyme activated the embrio developing. We can talk about green malt in 5 days. After the germinating we dry and ground the barley seed into malt power. This malt power is used in the baking technology. The brittle malt roorlet is used in the animal feeds.

These products contain amylase enzymes, which help in the starch break down (into sugar, which sugars are needed the yeast). We use malt extracts in the bakehouse.

They are used to raise baked goods, because they produce gas. The baking (when heated), causes the rising of the dough (the gluten matrix retains the gas, the gas is trapped in the gluten network). The baking soda is stronger (~ 4 times) as the baking powder.

The baking soda is a sodium bicarbonate ($NaHCO_3$). When we use acidic liquid (sour milk, butter milk, yogurt, lemon, cocoa, brown sugar, etc.), the baking soda produces carbon dioxide. It needs an acid to work (to produce CO_2). The baking soda is better, than the powder, but in high amounts it causes soapy.

If we use acid to neutralize baking soda:

$$\text{baking soda + acid} \xrightarrow{\text{water}} \text{salt + carbonic acid} \longrightarrow \text{water + carbon dioxide}$$

The baking power contains acid, is made of baking soda, powered acid and inert filler (as corn starch), so it is a mixture. It releases gas, when the first time meets with liquid and released when it is heated.

1.3. Processing

There are a lot of different types of processing. The traditional method (Combine the yeast with the liquid mixture, and add some of the flour . beat the mixture until smooth.), the batter method (less flour and two rising – in the mixing bowl and in the baking pan), the mixer method (use active dry or fast rising yeast), the one rise method, refrigerator dough method, are well known process.

1.3.1. Scaling

The first step of the production is the scaling. The scaling is very important to keep the recipe and the product's quality. All ingredients must be weighted before using. The corrects weight is necessary to bake good products. We can use electric scaling to measured the amount of flour, salt, water, yeast, milk, egg, etc.

Figure 12. Scaling the ingredients

1.3.2. Mixing

The aim is to mix the fundamental ingredients (flour, water, salt, yeast, sugar, etc) to be a homogenous dough. The dough will be smooth and elastic. Some of the gluten develops during the mixing, but most of the gluten developes during the kneading. Yeast bread is prepared by mixing the ingredients into a dense, pliable dough that is kneaded, allowed to rise by fermentation.

The main ingredients determine the dough. The flour, with high protein content has more gluten potential. Liquids are hydrated the solids and important in the gelatinization. The salt controls the yeast growth, becasuse, without salt the fermentation will be to rapid. The yeast is the biological leaving agent. The yeast is a one celled fungus, which are leavened with carbon dioxid gas.

There are some best known methods:

- Straigh dough method
- Sponge method
- Batter method
- Rapid method

Straigh dough method

In the straigh dough methods, we mix and knead the all the ingerdients in one step. First we have to soften the yeast, the compressed yeast should be activated in warm water, it is 25 oC (the dry yeast needs more temperature). After it, the other ingeredinets have to be combined with the yeast. Combine with the liquid and the other dry ingerdients, and mix util it reach a smooth dough. This methd is a fast mixing method.

Sponge method

First we mix the liquid, the yeast, the sugar and the part of the flour. This is a sponge. This method need more time, these breads take even longer, requiring about six – ten hours to make and fully develope their flavor. It is important, that adding too much flour to the sponge, will make the dough stiff.

This method is a pre-fermentation menthod, where the dough ix mixed in two steps.

When the sponge is ready, it means it becomes bubbly and light, we add the other ingerdients (fat, salt, and the rest of the flour) to form a dough.

Batter method

Some recipe is prepared by the batter, it means to use less flour and so the yeast. This method is the other type of the straigh dough that eliminates kneading (no mix method).

The aim of the mixing are:

- Flour, yeast, salt, etc mixed with water
- Formed flexible dough
- Stretch and elastic dough kneaded.

There are some other well known methods, for example the frozen dough method.
The frozen dough process means, when the process is stopped after the forming/shaping. It needs to reduce the product temperature to -20 ^{o}C. The problem with it, that the yeast activity (the gas production) decreases and the gas retention of the dough is not enough. To this process we need yeast (which is good to this process), because in the water there will be ice crystals during the freezing and it can damage cells wall of the yeast. We need increase the yeast dosage.
To this process we need low protein flour, but with higher protein quality and the water temperature should be close to 0 ^{o}C. More salt helps to strengthen the gluten (and adds flavor), sugar quantity should be reduced to compensate for reduced fermentation. The emulsifiers help the development of the gluten structure.
The technology changes, the mixing have to give the maximum development for gas retention. The fermentation time must be as short as possible, the dividing must be carried out as soon as the mixing has finished. The reting time will be short, maximum 10 minutes, it is enough for the dough to relax. For the freezing we use blast freezer, where the temperature is in between -30 to -35 ^{o}C. The requrement of the packaging:

- Waterproof
- Air tight
- Flexible and resistance to low temperature (polyethylene)
- Sealable

The storage temperture is -20 ^oC. The time is maximum 6 months. It requires cold chain transportation, where the products must be kept at -20 ^oC.
Before using we have to thaw. It can be in a proof box, in a room temperature in a proofer. For the baking we need deck oven or convection oven.

The mixing time is very important, it depends on the mixer type, the dough method, the dough volume, the dough temperature, the water absorbant capacity of the flour, the amount of shortening, the amount and type of oxidizing agents and the amount of other ingredients (for example: milk, eggs, etc.). During the mixing we can talk about different stages. The first is the pick up stages, where the dough is cold and lumpy and getting smoother and drier (absorb the water). The second step is the clean up stages, when the dough reaches the maximum stiffness and the color change (will be whiter). The third is the final development, the gluten is ready, the dough has good temperature.
After these stages, the dough reaches the letdown and the breakdown stages. It is an overmixing period, where the dough is too warm, becomes lack elasticity and will begin to liquefy.

The remaining time is necessary to develop the gluten. Overmixed and undermixed doughs have poor volume and texture. In practice we have to learn, when the dough is ready (sight, feel). The dough is smooth and elastic and not sticky. Too much flour will make the dough stiff, if we add a little more flour if the dough hasn't lost its stickiness after most of the mixing time has passed. The developing depends on the mixer, slow speed at first and fast speed second. The knead work: mix ingredients and develop gluten. Too much pressure at the beginning of kneading can keep the dough sticky and hard to handle. Too much pressure at the end of kneading can tear or mat the gluten strands that have developed.

The mixing and kneading are determined by the mixers. There some types, which operate like the hand mixing. The difference among these mixers is the mixer arm rotation. The quicker mixer is practise and the dough is mechaniccaly developed within 3 minutes.

Table 2. Types of the mixers

Mixer types	Speed (rot/min)	Mixing/kneading time (min)	Specific kneading work (kJ/kg dough)
Low speed mixer	<40	15-20	7-10
Quick mixer	50-250	5-8	10-20
High speed mixer	250-600	<3	30-45

Low speed mixer:

This mixer needs more time (20 minutes) to develop the dough. This operates like the hand. This was the first mixer type all over the world. The rotation is 20-40 rotation per minutes, but the capacity of these mixers were fom 100 to 300 kg. It is a gentle mixing.

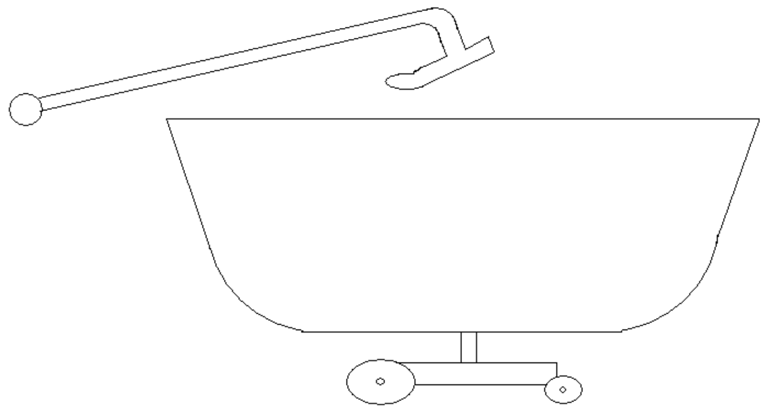

Figure 13. Low speed mixer

Spiral mixer:

This is the main mixer in the bakehouse. The mixing takes 8 minutes. It has a spiral-shaped mixing hook, which rotates. It has slow and fast speed function too. The slow speed is good, when we use flour with weak gluten content, the fast speed is good, when we have with strong gluten content. The capacity of the bowl is ~100 – 200 kg dough and the bowl is rotated.

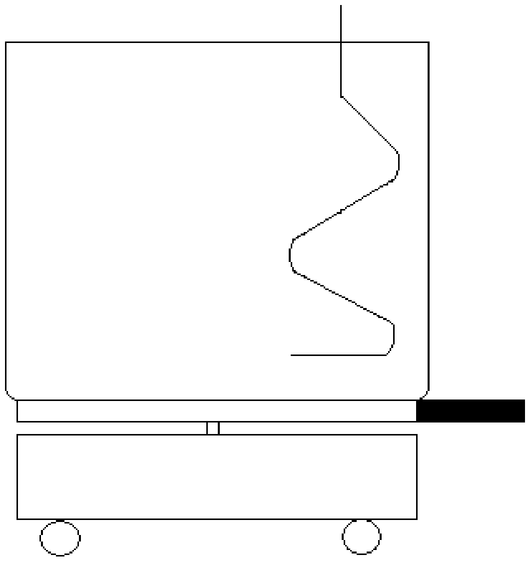

Figure 14. Spiral mixer

High speed mixer (intensive mixer):

The mixing time of this type is 3 minutes, but it needs high level of mechanical energy. It is required cooling, because the temperature of the dough increases rapidly. The capacity is from 50 to 300 kg dough. Here the bowl don’t rotate.

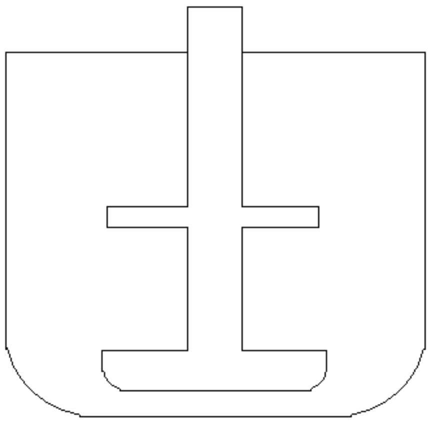

Figure 15. High speed mixer

After the mixing if we use the dough immediately, it will be fresh dough. It should be completely cooled before being wrapped and stored in a dry, cool place at room temperature. In the tropical regions we can find refrigerated dough and frozen dough. The frozen dough can be frozen for two or three months.

1.3.3. Fermentation

After the mixing and kneading, we allow the dough (which contains yeast) to rest. This is a rest time, when the yeast acts on the sugars and starches in the dough. This is the fermentation, where alcohol (ethanol) and carbon dioxide gas produce.

The yeast converts the sugar to carbon dioxide that enables dough volume expansion. In the same time the pH decreases and the enzymes change the characteristics of dough (the gluten) to allow more gas retention. If we use dried yeast, we have to hydrate with water.

During this process the dough should double in size. Therefore it we have to contoll the temperature and the humidity. The humidity is about 75 %, the temperature is between 25 – 30 ^{o}C.

During the fermentation the structural and rheological properties change the dough, it will be soft and expanded. The gluten becomes smoother and more elastic.

The ingredients, the dough temperature and the room temperature control the fermentation (warm and humid environment). The other ingredients (fats, improvers) determine also. The fermentation is in the kneading bowls, which is covered with cloth (it allows to double in size).

The underferment dough has little volume increasing and the texture is coarse. The overfermented dough is sticky, and it is hard to work with it. In this case the the cell walls break and collapse. The carbon dioxide gas goes away and it causes the low volume of the end products.

The good fermented dough is doubled, and if you press fingers into the dough and if indentation remains, the dough is ready, it has risen enough. A dent will remain after the hand or finger is pressed into the top of the dough.

We can talk about straight dough method and sponge dough method. In the bread making technology the traditional process is the sponge dough process.

The alcohol evaporates during the baking, the carbon dioxide gas increases the bread volume (it causes the bread rise)

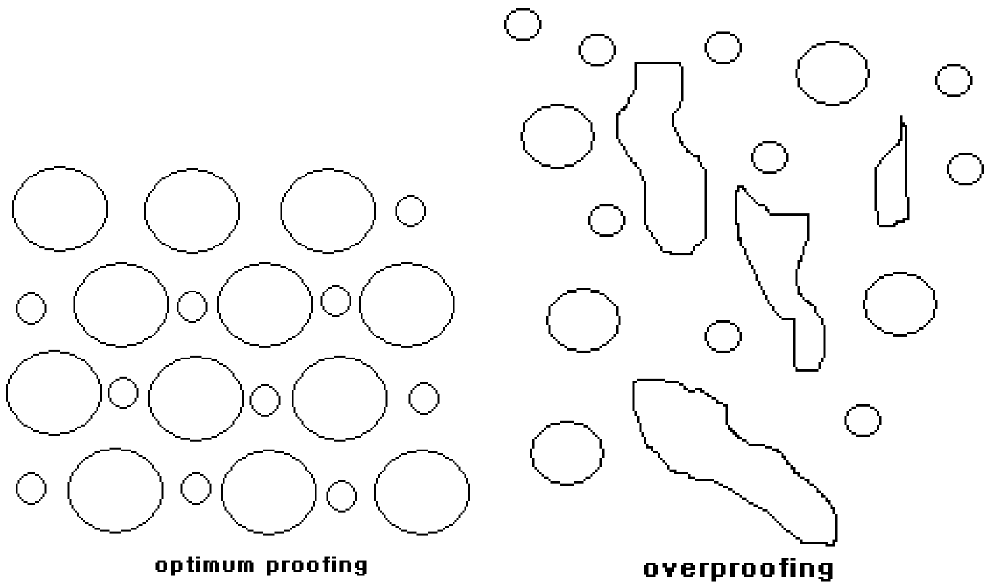

Figure 16. CO_2 gas bubble

To make good bread, we have to keep the following: precise measuring, good mixing and kneading, controlled fermentation temperature and humidity, correct baking temperature.

PUNCHING

Punching is a method of the deflating the dough. Expels the carbon dioxide gas, and relaxes the gluten, if the temperature is good.

PROCEDURE

The procedure is when we pull up the dough on all sides, fold over the center, and press down. Then turn the dough upside down in the bowl.

1.3.4. Dough make-up/shaping

The first step is the scaling with bakers scale. The aim is to divide the dough into pieces (uniform scaling, pan flows, texture). Sharp knife is used for a dough cutter to divide into pieces. There is weight loss during the baking, so the scaling weight is more, than the final weight of the products (the moisture, the alcohol will evaporate). This weight loss is between 10 and 20 percent of the weight of the dough. It depends on the final weight of the bread

required (generally 12 % extra dough). Dividing should be done within the shortest time in order to ensure the uniform weight.
After the scaling the next step is the rounding, when the pieces of dough is shaped into round balls. Roll the dough into 10 rectangles. The rounder is good to impart a new continuous surface skin. The width of the dough depends on the length of the bread pan.
After these steps, the dough needs a rest (it is about 10 minutes). It is an intermediate proofing, the machines cause that the dough is like a rubber and it will not mould easily. After the intermediate proofing the dough will be flexible, extensibility and tears easily. It will be easier to handle, and rise again after the scaling and rounding.

Figure 17. Rounder machine

After it, the moulding will be the next, it has three steps: sheeting, curling, scaling. The sheeter degasses the dough, so the dough will be manipulated easily. In the curling section, the rolls into a cylindrical form carries the sheeted dough.

Figure 18. Different bakery products form

1.3.5. Proofing

After the forming the next step is the second fermentation, where the gas production gives the final volume of the product. Here continue the yeast fermentation. It is the same process as the mixing dough fermentation, but the proofing is the final fermentation before baking.

We need proof box, where the average temperature is 80° to 95°F (27° to 35°C). This temperature is higher than fermentation temperature. The humidity is important (keep the crust moist), it is 80-85 %.

Figure 19. Proofing chamber

Under the proofing the volume of the products increases, without proofing the results will be poor volume and dense texture (it is a young dough). When you over proof the product, it will have coarse texture and there will be loss of flavor (old dough).

This step is needed to a developed of gluten, because the mechanical forming destroy it.

Figure 20. Volume changing (increasing) during the proofing

1.3.6. Baking

After these steps, the loaf has to be baked. This process is determined by the size of the loaf and the kind of the dough. The two important parameters are the baking time and the baking temperature.

During the baking the following reaction will happen:

- In the first part of the baking the dough volume will rise quickly, because the gas cell expands. It is called oven spring.
- At first the yeast is very active, but when the temperature reaches the 60 oC, it is killed.
- The protein coagulation.
- The starches will gelatinization.
- The crusts will formation and browning.

After it the cells in the bread will become rigid.

There are two baking techniques:

- HTST (high temperature short time): if the baking is too quick, the crust will be good, but the crumb structure is not.
- LTLT (low temperature long time): it causes a thicker rigid skin without browning.

Figure 21. The baking process

The aim is nicely browned crust and good crumb. Crumb is the cell structure, when the products are sliced. The size, the shape, and the thickness of the cells are important parameters. The size of the cells will be large (open) and small (close), the thickness of the cell will be thin in the fine crumb and predominate in a coarse crumb.

The bread crust is dry and the breadcrumb contains moisture up to 40 per cent after the baking.

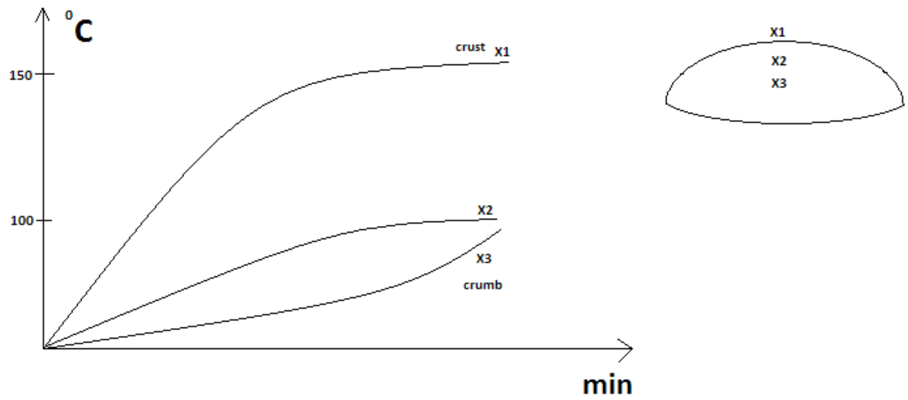

Figure 22. The temperature increasing in the loaf

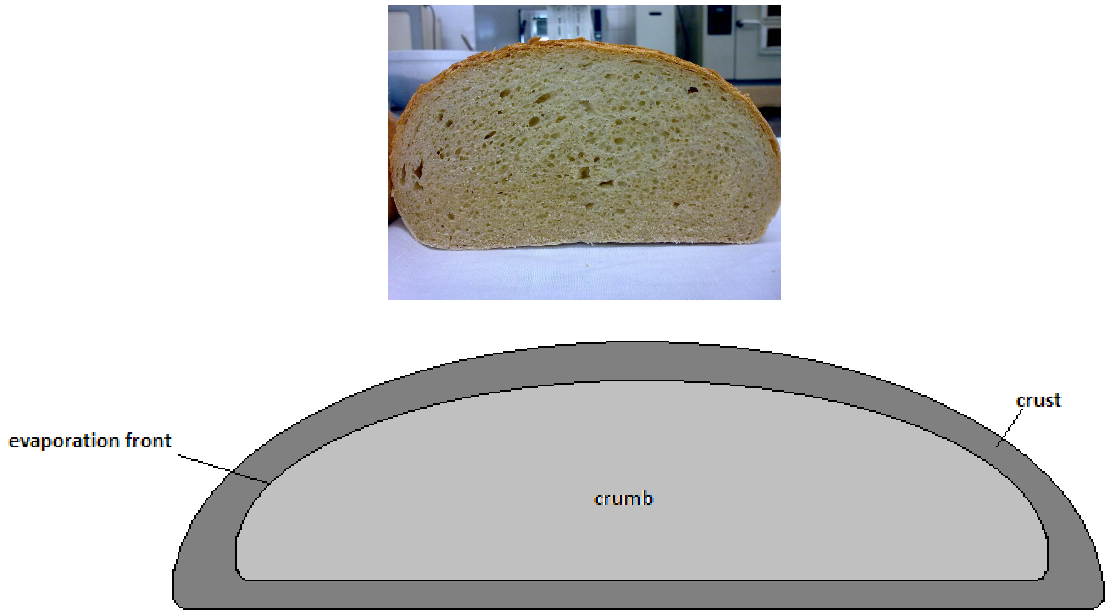

Figure 22. The bread crust and crumb

The temperature depends on the types of the products. The rolls are baked at a higher temperature than the larger products. It causes, that they become browned in the short time it takes to bake them. The average baking temperature of the fine bakery products is between

200°C to 245°C. The products which contain a lot of sugar, need lower temperature (175°C to 200°C), because their fat, sugar, and milk content makes the crust brown faster. The bread baking temperature is higher (250 °C to 300 °C). In the bread making process after the oven spring, we have to reduce the oven temperature, this prevents the over browing on the surface of the product. The dough is ready, we check for doneness, it means to remove the loaf from the pan and tap bottom and sides. Well baked bread sounds like the hollow.
The modern oven is the tunnel oven.

Figure 23. Tunnel oven
(http://apple722722.en.ec21.com/Tunnel_Oven_Baking_Oven_Bakery--3046298_4255665.html)

Figure 24. Etage oven

The baking time is very considerably depending on the products type.
After the baking, the bread is removed immedietly from the oven (and from the pans) and placed on a cooling racks.
After the cooling, it is easier to slicing.

Figure 25. The products volume after normal proofing (left products) and without proofing (right products)

Characteristics of good yeast bread loaf are large volume, the loaf is smooth, the surface is golden brown, the crumb texture is fine, uniform, tender and elastic.

The baking equipments are the ovens. The ovens have different types. The traditional was the direct fired brick ovens. It was not less than 75 centimeter thick at the top of the dome. Nowdays the oven is operated by firing. When firing , we have to open the door just enough to allow sufficient air to enter for proper combustion.
We can use cold ovens and hot ovens. The cold oven is good, when the loaf is underproofed, when we have a large loaf and if we have a sweet bread. The hot oven is good, when we have a good ferment loaf, with less sugar. In the hot oven the baking time is shorter than in the cold oven.
After the baking, the bread will be fresh, but somewhere the bread will be frozen. This bread is expeciallity in a warm.

1.3.7. Cooling

After the baking we have to cool rapidly the products. The aim is to reach as soon as possible the room temperature (20 ^{o}C). To help it we use evaporated water on the surface of the bread and circulation air around the products. In a big factory, where the capacity is huge, they use refrigerator (to help it the bread must be removed from pans). The aim is to allow the escape of excess moisture and alcohol created during the fermentation.

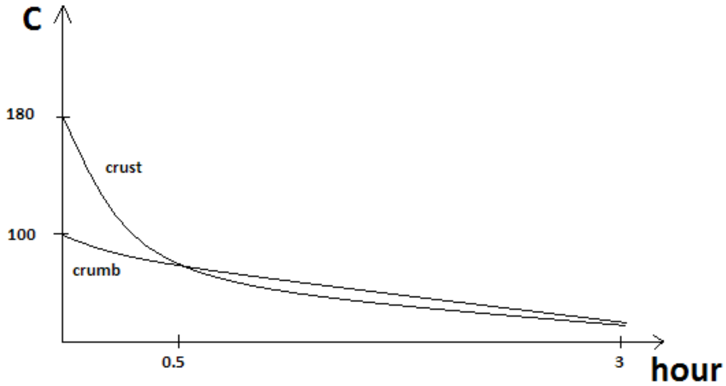

Figure 26. The crumb and the crust cooling

The bread temperature of the oven is 100 ^{o}C in the crumb and 160-170 ^{o}C in the crust. The moisture is about 50 % in the centre. The crust is hotter, but much drier (5 % moisture) and cools rapidly. The moisture is moving from the crumb of the bread outward towards the crust and goes away into the atmosphere. The moisture content in the crust rises greatly the bread loses the crispness and the attractive appearance.

Figure 27. Cooling in the bakehouse

Figure 28. The final bread product

1.3.8. Storing

The bread storage in the bakehouse will be a short time (few hours). For longer storage, we have to wrap the cooled bread. It is very important, that we have to wait until the bread cools down before wrapping, if we don't wait for it, the moisture is collected in the bag. The storage temperature is between 15-20 ^{o}C.

After the cooling, and storage, the baked goods will be packaged. The main functions of a package are:

- to contain the product;
- to protect the product;
- to help with selling of the product.

In the bakehouse we can use plastic materials, which have strength properties, protect from humidity, oxygen, heat and light. These materials are machinabile and printable. The packaging of bread must ensure hygiene and barrier against contaminating agents. It has optimum water vapour transmission rates and requisite physical strength property to provide some physical protection. It has printing surface, and should resist the effect of creasing and folding. The cost of the packaging is also very important.

Figure 29. The bread transport

2. Pasta production

Pasta is a traditional product. It is eaten all over the world. The pasta product technology is very easy:

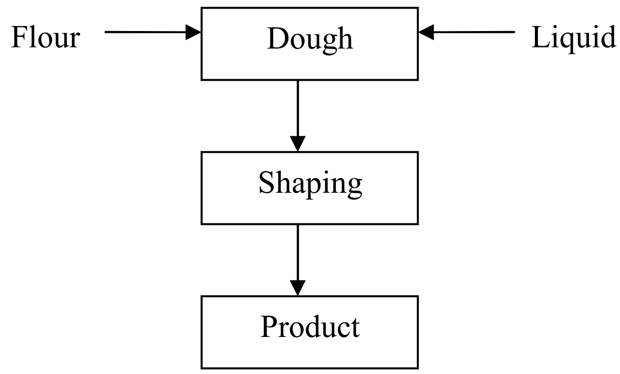

Figure 30. The pasta process flowsheet

The difference among the pasta is the shape, the colour, the use, the storage requirement and the composition and there are different production technologies and techniques. The pasta has a basic technology, when mixing the flour with liquid (for example: egg) and process the final shape. There are three groups: fresh pasta, frozen pasta and dried pasta.

The fresh pasta has high water content, 30 %, it determines the fresh pasta shelf life. There are a lot of micro-organisms which can easily grow in the product and they have difference enzymatic activities. Somewhere chemical preservatives are used in the fresh pasta.

The main component of the pasta is the following: flour, liquids, supplements and nutrients, etc.

We can talk about conventional (plain, stuffed) and non conventional pasta (dietetic, pre cooked, pre-gelatinized). The stuffed pasta is filled with meat, dairy products, vegetables, etc. The plain one contains flour, eggs, natural flavourings, additives, etc.

Figure 31. Pasta products (http://www.bigoven.com/article/recipe/choosing-pasta-shapes)

The behaviour of starch and gluten determines the dough, especially the water absorption capacity and the action of the hydrolytic enzymes (amylase, protease). The best "flour" is the durum wheat semolina; it has different granules in shape and in size. These granules have a specific behaviour in connection with water absorption (the smaller granules absorb water faster).

In the pasta technologies, we can find the cold technology. These are the refrigeration and freezing techniques in the pasta industry. In the refrigeration, the temperature is between 0 – 7 oC, it is enough to slow down the vital function and biochemical reaction of the micro-organisms. The freezing temperature is -18 ^{o}C, it causes the water crystallize. The speed of the freezing must be quick, because the water will have small ice crystals, and it isn't break the cell walls.

2.1. Raw materials of pasta products

The basic raw materials are the semolina (durum wheat semolina) or the flour (soft wheat semolina) and the liquids (water). After the scaling, the next step is the mixing, the dough making. The secondary raw materials are the eggs (or powered eggs), dehydrated vegetables and some other additional ingredients (food additives). The precision scaling and the materials characteristic guarantee the quality of the pasta.

2.2. Mixing

The ingredients must be measured out and the flour or semolina and the liquid must be mixed. The partical size of the semolina or flour determines the mixing, because these particles absorb or do not absorb the liquids. The aim is the homogeneous absorption; it needs time for a liquid to be absorbed by the particles. The size of the particles (average size) and the temperature of the flour and liquid determine it. Fine granulometry flour is preferred. The flour or semolina has lower temperature the liquid has higher temperature.

Today the modern mixing machines make the dough in 3 minutes (the old machines make the dough in 20 minutes). This short time decreases the pasta technology, but for it we need fine flour (it has more starch damage, which absorbs the water quicker). In the quick dough making process, we reduce the press size.

The mixing is under atmospheric pressure, it increases the enzymatic acivities, and it determines the colour of the product (loses the yellow color). To avoid this, there are vacuum mixers.

2.3. Extruding

Extrusion is the process when the raw materials are forced through a cylindrical barrel in order to form, shape and sometimes cook.

The pasta industrial extrusion is similar to the meat mincer. This extruder works continuously, heats and cools, and produces different products with different shapes and texture (these machines operate with viscous materials). Low temperature and pressure are needed to the pasta production. High temperature and press are needed to the snack production.

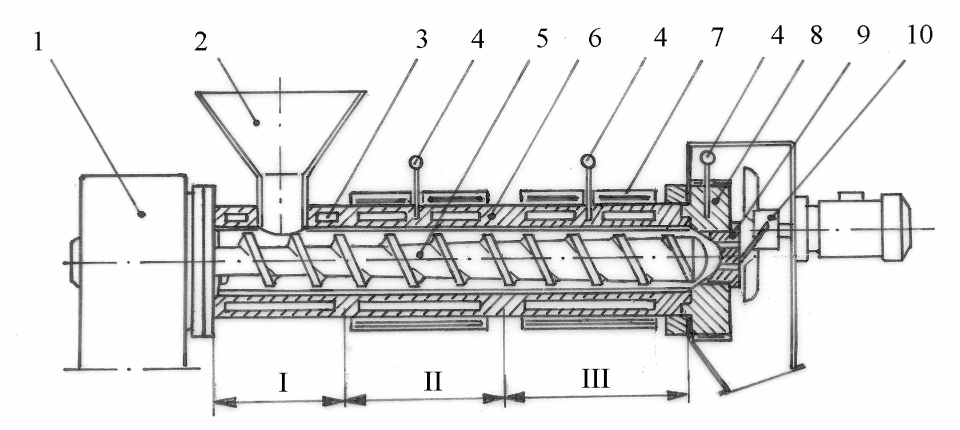

Figure 32. A cross-section of a single-screw extrusion-cooker (1 - engine, 2 - feeder, 3 - cooling jacket, 4 - thermocouple, 5 – screw, 6 - barrel, 7 - heating jacket, 8 - head, 9 - net, 10 - cutter, I - transport section, II – compression section, III –melting and plasticization section (Mościcki et al., 2009).

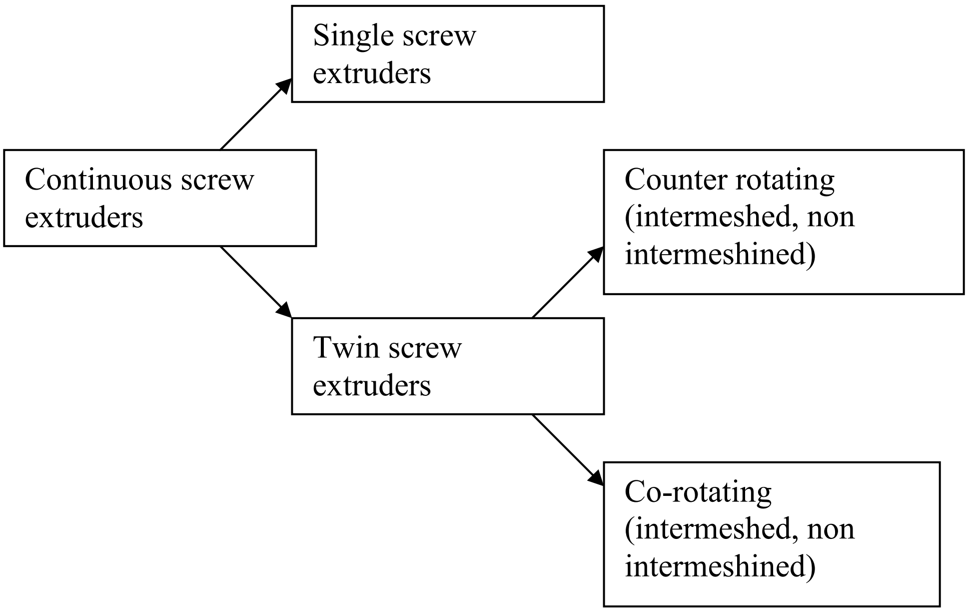

Figure 33. The extruder group

The dough is mixed and the dough is transferred to the extruder. The well known extruded pastas are the macaronu, the spaghetti, and the shell. The extruders are adiabatic, isothermal and polytropic. The machines have two functions, through the dough across the die and knead. And make the dough a homogeneous mass. There are different types of dies (Figure 34.). Variances in the flow rate of the dough through the die cause the pasta to be extruded at different rates. The inside surface of the die also influences the appearance of product.

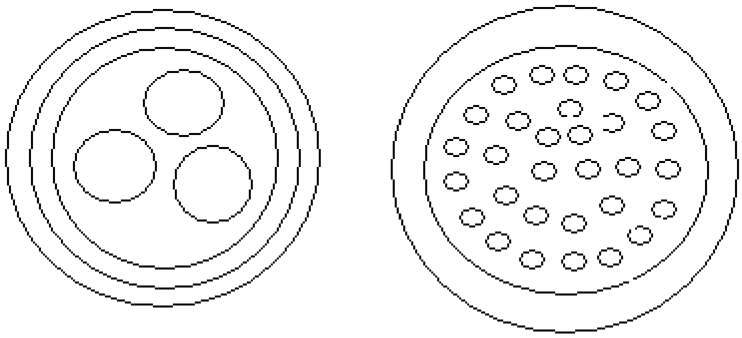

Figure 34. Different types of die

The screw in the extruders rotation and push the pasta dough towards the head press, where is the die. The die function is to give the chosen shape of the product. The die must be checked in the temperature and pressure. There are different varieties of pasta kind and they need specific dies. The main pasta types are:

- long round pasta with hole and without hole,
- long oval pasta,
- flat straigh pasta with simple/double festoons, or with rectangular section.

Main parameters of the pasta are: diameter, width, length and thickness.

The dia materials is bronze or teflon, directly holed by profiles, which suitable for the required shapes. The average life of the teflon is longer than the bronze. The teflon is better, these die inserts have to be built with extreme precision and made of special materials to assure not only the die life but also its efficiency, with concern to both of the product quality (even surface, colour, etc.) and the press output capacity.

We use pressure in the extruder and this pressure destroys the dough structure/texture. The pressure is about 110 bar, and it damages the texture.

The other problem is the rotation screw, because it can cause the dough heating, it will be a thermal stress, we need keep the temperature under 40 ^oC. To reach it we circulate cold water in the extruders cylinder.
The part of the extruder requires control.

2.4. Drying

In the pasta process the drying is the main step, because it is very difficult. Out of the die, pasta has about 30% moisture. This moisture content will be reduce by 13-13 %. It causes that the products will be hard. During the drying the water gradients are created very strong as regards the moisture between the pasta centre and the outside of the pasta. The hot and humid air ventialtion cause the first reduction in the pasta surface moisture. So in the continuous drying lines there is a pre-dryer section and a dryer. In the pre-dryer section the speed of the air is different.

The results in pre-dryer, that the pre drying hardens the outside surface of the pasta, while the inside is soft and plastic. The final dryer removes the most of the moisture from the pasta.
In the pre-dryer the moisture reduces by 17-18 %. The products is heated to such temperature as to cause the quick evaporation. It causes the liquid diffusion, the surface diffusion and the hydrostatic pressure differences, when internal vaporization rates exceed the rate of vapor transport to the surroundings through the solid.
We have to calculate to determine the balance with the temperature and the relative humidity of the air. It is important because the outside of the products have greater moisture decrease (and it is quickly), while in the internal zone of the pasta has slow diffusion of the water and it is reduced less. It causes that the internal parts tend to be submitted to tension, since the outside surface zone dries more; as a result it is blocking the spread of water toward the surface.
The pre-dryer for a long cut pasta is usually a unit made of single tunnel, which is separated from the dryer line zone. The mechanical characteristics of the pre-dryer vary according to adopted technologies. The drying differs from the pre-drying phase for a more gradual moisture reduction and, particularly for the alternation of water particles evaporation and their even distribution inside the product.

During the drying we have to check the physical state of the pasta, the temperature of the air and moisture rate determine it. The water extraction by evaporation and water particle redistribution are different in the pre-dryer and dryer.
After the drying, the dry pasta temperature is high, we have to cool it back to room temperature. This cooling place is a separate unit, where the air temperature and humidity is checked and controlled by modifying the water flow in the cooling batteries or by sending steam inside the cooler.

2.5. Packaging

The pasta packaging materials are: plastic (polythene, plastic cartons or plastic boxes, PET (polyethylene terepthalate) bottles, polystyrene). Plastic is good, because it is:

- moisture proof,
- strong,
- flexible
- light,
- heat sealable,
- low cost,
- printable,
- and these have variety of weights, size, shape, thickness.

In the pasta industries the filling system are manual, semi automatic, alternate automatic and continuous automatic. The problem is that these products are breakable, so the packaging of these dry products is influenced by various factors such as:

- the weight precision
- the kind of the pack,
- the products cost,
- the speed of the packaging
- the filling system flexibility.

The continuous filling system is the best, the average capacity of these machines is about 400-500 pack per minutes. The basic of these machines are the volumetric filling system or the net

weight filling system. The volumetric is measured by the volume and the criteria, so that the pasta density must be uniform. The net weight filling machines weigh the pasta before put into the pack. The volumetric machines are cheaper, but to increase the production speed, several times these systems are used together. The aim is that the weight can achieve ±1 %.
These machines are controlled by computer.
After the packaging we can use the cartoning unit, which is used for packaging products that are packaged in bags. They are pushed horizontally inside the box and after it; it will be closed and sealed. It will be semiautomatic and automatic, the automatic system provides automatically for the carton forming to the carton sealing.
Palletizing units have two different versions (with top loading or with ground level loading). These machines with loading from the top offers the advantage of leaving the surface underneath clear. The feeding of cartons or products and the complete pallet are placed on the ground level. A palletizing unit with loading on the ground level excludes the necessity of hoisting the cartons to the upper level. The palletizing units can be equipped with automatic devices for the pallet feeding. The speed of the palletizing unit depends on:

- the number of carton boxes in each layer,
- the number of layers,
- the position of layers,
- the dimensions,
- the weight of each single carton.

3. Asian noodle

Noodles are a basic nutrition in Asian countries. The main ingredient is the wheat flour, this will be mixed with salt (alkaline salt). The salt determines the flavour, the texture and decreases the boiling time (Kubomura 1998). The dough will be compressed between rolls.
The protein content affects the brightness of the dough (increasing the whiteness). The gluten network is developed during the sheeting process and it gives the noodle texture.
The texture will be determined by the starch too. It affects the texture, when there is salt in the noodle, affects the viscosity (Hou and Kruk 1998).
The starch during the steaming process will gelatinize. The alkali salt gives them a yellow colour and a firmer and more elastic texture. The alkaline solutions or kan sui (a mixture of sodium and potassium carbonates) cause the changes of the polysaccharides of the flour to allow the manifestation of the yellow color. β-carotene is often used to adjust the creamy yellow colour of udon.
The colour is determined by the flour ash content and the flour particles too. High extraction gives duller noodles, low extraction gives brighter noodles.
The bread wheat (Triticum aestivum) with water and salt, alkaline salt is enough to produce noodle. The water absorbant capacity is about 30 %. If the capacity is under this value, it will be a dry mixture and we haven't got good dough. Too much water will make the noodle dough soggy (hard to work with it) (Miskelly and Moss 1985).
Some noodle contains emulsifiers (lecithin, glycerin fatty ester), which help to prevent the starch retrogradation and increase the cooking quality.
Then the sheeted/cutted noodles dough is slit to produce noodles and it is ready for sale (Miskelly 1984).
When the noodles are ready for sale, there are different ways of consuming, there are different recipes. In the Asian countries, the noodles are consumed hot in soup, as a pasta plate or stir-fried with meat, shrimps and vegetables. Chinese birthday parties always contain noodles, in Japan consumed cold dishes, the name is soba. In a lot of countries people eat it together with boiled rice (Corke and Bhattacharya 1999).

3.1. Processing

There are two main processes: the hand made process and the machine made process.

The main products of the hand made process are the Chinese noodles. It is manual, which includes the stretching and the swinging by hand. It has been used traditionally.

The hand swung noodles have flour, water and salt. They are mixed intensively by hand; it helps to develop the gluten. After it the dough is rolled into a rope, which is held in hand. These types of noodles are cooked immediately.

The hand cut noodles are fresh, smoothness and firmness, it contains also flour, water, salt (100:40-45:3-5 ratio). The water contains the salt and we give the flour to this and formed by hand. Small dough balls will be made continuing the kneading to develop the gluten matrix. The kneading has got two steps. Between the two steps (it is a rest period) the hydration is finished. After the kneading, the dough is divided into a hand workable piece, and the dough is formed into balls prior to a second rest period. After the second resting time, the dough is rolled, dusted, folded and compressed before being cut with a specially designed knife.

The third type is the hand stretched noodles, it is the same as the hand cut noodles, but it contains more water. The other difference is the dough sheet being cut in an internally spiraling manner.

This process is repeated until the dough achieves a thickness of 1 cm.

The process time is very long with the hand made noodles, sometimes it lasts 30 hours.

Figure 35. Hand made noodle (http://twistedsifter.com/2009/09/la-mian-art-of-chinese-noodle-making)

The machine that makes noodles is made by using machineries. The whole process from the mixing to the cutting are made by machines. These machines mixes the flour, the water (30-45 %), the salt and the kan sui. In some countries gelling agents such as food gums, alginates, and potato starch are added to control the texture of the finished products. The salt and the kan sui are dissolved in the water in some products. During the mixing the gluten develop, and after the minxing the dough is allowed to have rest time. The rested dough is divided, and formig with rolls. Then two sheets are combined and pass though the second roll. The noodles can be about 2 to 4 mm for Japanese noodles and 1.3 to 2 mm for Chinese noodles.
The machine that makes noodles has got less cooking loss (Chen Pmt, 1993).

Figure 36. Machine made noodle http://slowclubcookery.blogspot.hu/2012/12/vegan-fresh-pasta-dough.html

Generally we can say that the correct amount of water is between 30-35 %. The mixing time is less than 20 minutes. The dough temperature is important, the dough has to be soft and sticky. The starch gelatinization assists the flour hydration, like the gluten. During the compression stage of sheeting the gluten is developed and becomes more uniform in nature. To the sheeting they use waved rollers, or multi roller system. These machines increase the capacity, but the aim is to improve the development of the gluten network to achieve noodle quality approaching the hand-made noodle (Wu, et al., 1998).

We can sort the noodles on processing. Fresh noodles, like Chinese raw noodles, udon noodles, chuka-men, Thai bamee, Cantonese noodles and soba noodles. They are cut and packaging fresh. The shelf life is maximum 5 days in refrigeration.

Noodles, like Chinese raw noodles, Cantonese noodles, chuka-men, udon noodles, and soba noodles, are dried (by machines or only the sunlight). The result is long shelf life.

The boiled noodles basic is a fresh noodle, it will be pre-boiled or cooked fully. These products like, Chinese wet noodles, hokkien noodles, udon noodles, and soba

Noodles, are rinsed in cold water, and coated with vegetable oil. These boiled noodles need 2 minutes to cook (Azudin, 1998).

The steamed noodles are alkaline noodles, which are steamed. These are the Yaki-Soba noodles.

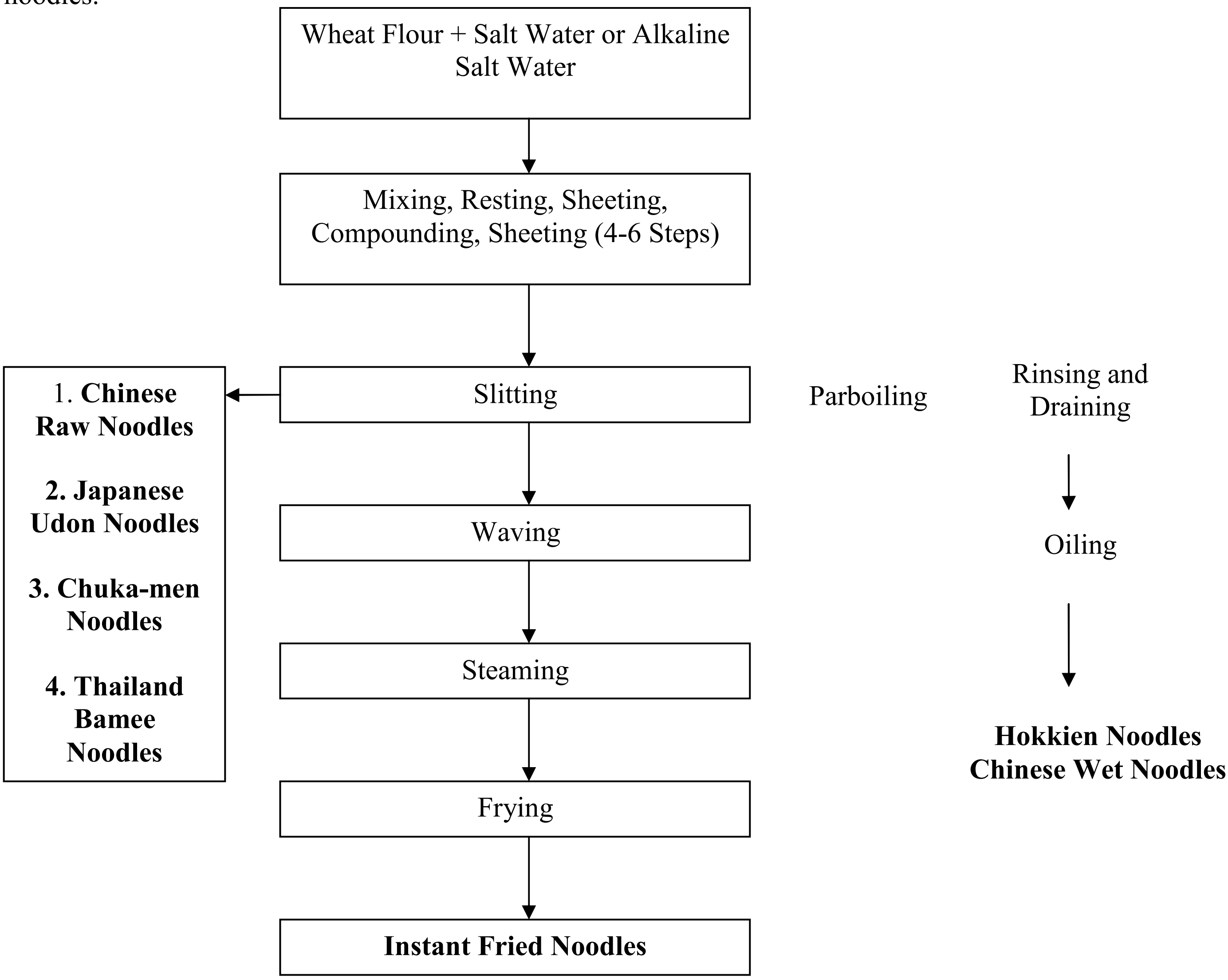

Figure 37. Noodle process flowsheet

The sort technology is the following: mixing the flour, the salt and/or kan sui, and water. The mixing time is from 5 to 20 minutes (it depeneds on the water amount). The next step is the rolling, which forms the dough. There are different numbers of rollers that determine this process time. It can reach the 20 minutes. The final thickness depending on the noodle type, but the average is 1 mm. The last step is the cutting, the generally width is between 1.3 to 2.0 mm (Wu, Aluko, & Corke, 2006). After the process, the colours of the dough sheets are good, the shape is uniform, and the texture is strong (Hou and Kruk 1998).

3.2. Classification

There are some classifications for the Asian noodles. The classification is the following:
Based on raw material noodles:

- wheat flour (hard wheat flour – Chinese noodle, it is creamy white, or yellow color, the texture is firm; soft wheat flour – Japanese noodle, it is creamy white color, the texture is soft and elastic)
- Wheat flour with buckwheat flour (brown, gray color, unique flavor and taste).

Based on salt:

- Salt (white color)
- Alkaline salt (yellow color)

Based on size:

- Small size (softer faster in hot water)
- Large size.

Based on the processing:

- Hand made (it has favorable texture, stretching noodles by hand)
- Machine made (Noodle processing operations include mixing raw materials, dough sheeting, compounding, sheeting /rolling and slitting).

3.3. Mixing

The noodles are mixed by horizontal or vertical mixer. The main mixer is the horizontal, the results (the noodle dough structure) are better with this machine. In the mixing, we use a little amount of water, it results that the gluten development is minimal. The flour protein, the starch and the pentosans determine the water absorbent capacity of the flour. The low water slows down the discoloration, and it determines the drying and the frying steps. The water absorption is between 2-3 % (the large particle size of flour needs more time to absorb water). The result of the mixing is the sheetability of the dough, the smoothness and the uniformity of the sheeted dough.

3.4. Resting

After the mixing, the dough has to be rested; it is 30-40 minutes. This resting time is important to absorb the water, and the dough will be smoother and less streaky. The resting is in a container. Different resting time and number of folding applied when instant noodle samples is made for the purpose of investigating. These factors impact on the end quality of the final product.

3.5. Sheeting

The rested dough is divided into two pieces that pass through a pair of sheeting rolls. These gap reductions the dough thickness is about 30 %. The final types of the noodle determine the thickness of the dough. The sheeted dough is passed through the second pair of sheeting rolls. The temperature and the humidity are controlled, so there is a cabin with conveyor belt, where the dough relaxes. It is kept for 40 minutes.

The sheeting is controlled by the rolls diameter, the rolls rotation speed. After the sheeting slitters the noodle dough is cut in various type. Main types are the Chinese raw noodle, Japanese udon noodle, chuka-men and Thailand bamee noodle.

3.6. Cooking noodles

The cooking time depends on the type of the noodles. The Japanese noodles are boiled for 13-15 minutes; the Chinese noodle is parboiled for 70-90 seconds. There are three cooking types: boiling, parboiling, and steaming. In some cooking techniques, it is used oil to prevent the sticking. During the cooking the starch gelatinization (somewhere reach ~ 90 %).

Parameters, which determine the cooking and the products qualities:

- Size of the pot
- pH of the boiling water (~ 6.0)
- Cooking time
- The water temperature (~100 ^{o}C)
- Amount of the water

When we use steam for cooking, we have to determine the steaming time, which depends on the size of the noodle. The important parameters are the same as above (steam temperature, steam pressure, and steaming time).

The parboiled noodles have got sort shelf-life (3 day) and the boiled noodles have got long shelf-life (6 months to 1 year).

3.7. Drying noodles

The other type is the drying noodle. In this method, we use air, deep frying or vacuum drying. The air drying lasts 7-8 hours, the frying lasts a few minutes. The temperature in the air drying machines is low in the first stage, it is ~ 20 ^{o}C, it is enough to reduce the noodle moisture content by 20 %. In the second stage the air temperature 40 ^{o}C. The other important parameter is the relative humidity, which is ~ 70 %. The dried noodles are cooled prior to packaging. The air dried noodles have got low fat content.

These types of noodles are steamed for 20 minutes at 100 ^{o}C, and then dried for 40 minutes with hot air (80 ^{o}C).

The deep frying process is a fast process, when the water is vaporized quickly from the surface of the noodles. The water migrates from the interior to the surface. The noodles is dipping into hot oil, and some water is replaced by oil.

Drying noodles types are as Chinese raw noodles, Japanese udon noodles, steamed and airdried instant noodles,

White salted noodle:

The white salted noodle is a very famous product in Japan. The mixing time is 15 minutes (expeciallity with vacuum mixer). The salt content is 2-3 percent. The water content is between 30-45 percent. The dough is divided and sheeted. The dough are laminated. The resting period is 30-60 minutes. The cutting rolls form two types of edges: a rounded versus is the more popular square cut noodles (with the thickness being 75 percent of the noodle's width).
The last step is the dryin stage, which is significanty influences the quality of the noodle. In the beginning of the drier the temperature is 20 ^{o}C and it lasts 5 hours, in the end of the drier the temperature is 40 ^{o}C and it lasts another 5 hours. The result is lower than 14 percent moisture content. It needs longer cooking time, than the fresh noodle (Nagao, 1996).

Instant noodles:

This is another very famous product. The cup shape noodles need rapid cooking and a little water. The main ingredients are the flour, but the protein content of the flour only 7-9 percent. The ash content of the flour is between 0.4-0.54. The dough must be elasticity; the gluten must have strong viscoelastic behaviour (Kim, 1996).
In the processing alkaline salt (0.2 %), and common salt (1.5-2.0 %) is used. The water content is lower, it is ~30 % (it determines the salt, and the alkaline salt – strengthens the gluten). These products need two stages of mixing; it depends on the quality of the noodle. Common noodles have got much shorter mixing time due to a reduction in the slow mix phase. The mixing is under atmosphere pressure, but in Japan they use vacuum mixer (here the moisture is ~ 40 %).
The gluten matrix/network is essential for a high quality product. These noodles have got unique waved shape, which allows more efficient steaming and frying as the noodle strands are separated. The noodles are cut and steamed for 100- 250 sec. The conveyor belt goes under the cooling fans, which reduce the noodle temperature rapidly. The noodles are then placed in single serving molds on a weight basis before being conveyed to a frying chamber (Moss et al., 1987). The temperature (oil temperature) during the frying is 140-155 ^{o}C and the

time is only maximum 2 minutes. The aim is to form the internal spongy structure. The spongy noodle structure is hydrationed rapidly. The low protein content and the high starch content retain more frying oil, so the final products have more oil content (it can reach the 40 %). It determines the shelf life of the instant noodles, because the oil is a rancidity material (Wu et al., 1998).

Figure 38. Wave shape noodle http://norecipes.com/mie-goreng-recipe-indonesian-fried-noodles/

4. Tortilla technology

Tortilla is the basic food in Mexico, Venezuela, Columbia and Central America. (Guo et al 2003). It is a flat, thin pancake, which is made from corn meal and flour. The tortilla name means ‘small cake’ in Spanish.

In the process the corn is ground with gaps (in the past stone grinder – this was the metate) and make corn meal. This flour is mixed with water and kneaded, after it the dough is rested for several minutes. After the setting, the dough is kneaded until the dough reaches soft texture. The small masa is formed by hand into flat cake, which is baked on a flat stone.

The full technology is transmitted from generation to generation expeciallity in Mexico, where the tortillas are consumed daily.

Today the technology of the tortilla production contains modern machinery, which works automaticly. Tortillas are produced by hot-press, die-cut or hand-stretch procedures. The baking temperature is low (Waniska et al., 2004). The die cut tortilla has lower moisture content , less elasticity, higher density. The diameter of tortillas is about 20 centimeter and each corn tortilla weights 25-40 grams.

The hand stretch tortillas have got different diameters and the quality is changing (Guo et al 2003).

In the world we can find wheat flour tortilla, which is an unfermeted flat bread. It is made from whole wheat flour, which contains more dietary fibre, minerals and vitamins Liu 2007.

The tortilla chips are a famous products all over the wolrd. It is made from corn flour, sugar, salt, starch and water. These ingredients are mixed and kneaded. The dough is broken into small pieces and spread out. Then the dough is pressed into thin sheet and cut (triangular shapes). The chips are pre-cooked in the oven, and it is finalized by frying. There are different flavorings, which are added by spraying the chips surface (Cepeda et al., 2000).

Figure 39. Metate (http://www.liveauctioneers.com/item/9523401)

4.1. Main ingredients

The main ingredients are:

- Flour
- Fat
- Emulsifier
- Baking powders
- Preservatives

The wheat flour is the main ingredient, which has got 10-12 % protein content. Weak flour with low gluten content determines the quality of the tortilla (it will be easily cracked and split). The strong gluten flour determines the mixing time and the resting time before the pressing. The water absorbant capacity depends on the flour type and the other ingredients. It is about 45 % (weak flour) and 55 % (strong flour).

The fat reduces the stickiness of the tortilla dough. The high level of shortening results that the dough will be less elastic and more extensible. So the shortening improves the dough machinability (as lubricant and interacts with the starch and protein during the whole process). The amount of the shortening is between 5 – 15 %.

The emulsifiers help to stabilize the dough.The emulsifiers types for example: sodium stearoyl lactylate, mono- and diglycerides.

The baking powders like monocalciumphosphate (MCP), sodiumaluminumphosphate (SALP), or sodiumaluminumsulphate (SAS), are puffing the tortillas during the baking. These ingredients determine the pH of the tortilla. A high pH improves dough consistency and tortilla quality, but a low pH is required for extending the mold-free shelf life of tortillas. (in some tortilla there is yeast, but in this case it determines the taste and the flavor of the final product (Serna-Saldivar et al 1988).

Some tortillas contain salt, which determines the strengthens, toughens of the gluten and determines the flavour and the shelf life of the products. The amount of salt is 2 %.

The leavening agents (like sodium bicarbonate and sodium aluminum suflate change the colour, the density and the texture of the tortillas. They change the pH, the optimum pH is about 6.

This pH is very important in connection with the preservatives, which extend mold free shelf life. The optimum pH of these materials are between 5.5 and 6.5 (Serna-Saldivar et al 1988).

The reducing agents (L-cysteine, bisulfites, sorbic acid, fumaric acid) are used to improve the tortilla dough machinability by increasing the dough extensibility and reducing the dough elasticity. These agents inhibit or prevent the formation from disulfide between the chains of the protein. The fumaric acid allows controlling the release of CO_2 in a more uniformed manner and the tortilla has got higher quality. Fumaric acid with baking powder is better, because the tortilla has got better flavour, less translucency and improved texture.
In the modern nutrition the tortillas has got low fat or contains no fat. In this case we use fat replacers. These fat replacers are based on wheat gluten, fibers, starches, gums, or nonleavening yeast, that help to increase water absorption and prevent from loss of excessive moisture during the baking.

4.2. Mixing

The aim of the mixing is to have smooth dough with a right consistency. The water absorbant capacity determines it. If the capacity is lower the dough will be stiff and causes difficult press. The high capacity resuts soft texture and it will be silky.
The mixing time is an important parameter. The undermixing dough will be blisters; the overmixing dough will be sticky. We have to know that the temperature of the dough also determine the mixing, and the mixing time.

Table 3. Tortilla recipe

Ingredient	Amount
wheat flour	100,0
water	53,0
shortening	10,0
salt	1,7
sugar	0,8
baking powder	2,7

In the mixing the important materials will be mixed. The flour, the fat, the emulsifiers, the preservatives, the baking powder, etc. will be a homogenous mass (which have about 6 pH).

4.3. Dividing

After the mixing, the next steps are the dividing, the rounding and the resting. The dividing depends on the diameter of the tortilla. The scaling weights are between 30-50 g. After the dividing the tortilla is transferred to the overhead proofer, where it has got a short resting time. After the resting period the dough pieces will be elastic and extensible. After the dividing the next steps are the short intermediate rest, and the scaling.

4.4. Pressing/moulding

In the pressing step, the characteristic of the dough is plastic and it is shaped in a tortilla press. These machines have different size, and move with hydraulic press. The pressure is 1.75 kg/cm^2 (400 pounds) to 7.5 kg/cm^2 (1100 pounds). The dough is placed, to the tortilla press centre, and closed. During the pressing a thin skin is formed. The temperature is about 170-230 ^oC. This result the tortillas to expand and puff.

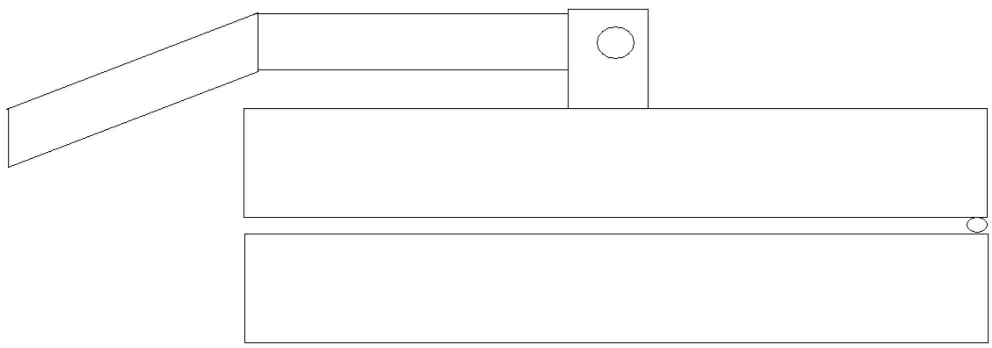

Figure 40. Pressing machine (hand made)

The other operation, when pair of smooth rollers rotate and press the dough towards the gap between them. With this method we can make with different thicknesses products. The average size of a tortilla is 15 cm diameter, and ~ 30 grams. The cutter (under the rolls) cuts various products. Plastic bands surrounded the rolls help to reuse the excess mass.

4.5. Baking

The tortilla baking is a short time, because it is only 20-40 seconds (it's depend on the temperature – 190 ^{o}C - 315 ^{o}C, which depends on the volume of the tortilla). The baking place is in the tortilla oven, which operates with gas fired.

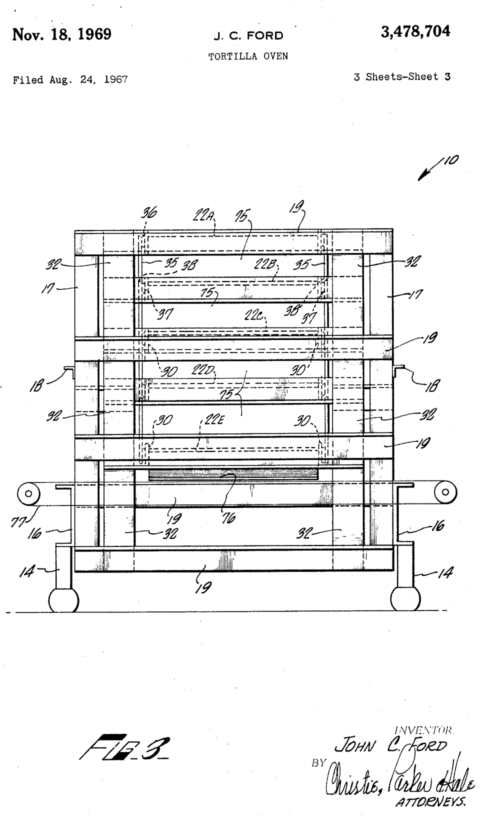

Figure 41. Tortilla oven

Figure 42. Tortilla oven (http://www.ammfg.com/tortilla_LT1800BHT.html)

4.6. Cooling

After the baking the tortilla is cooled to 25 ^{o}C. The aim is to reach this temperature is about 4-5 minutes. This cooling determines the shelf life of the tortilla. After the baking the tortillas are sterile, and during this process it can be contaminated by microbial contamination. Before the packaging, the tortillas have to be cooled, because the moisture can be condensed in the package (and the tortillas can be stick together. So the controlling of the tortillas is important in connection with the shelf life.

Figure 42. The tortilla products http://www.dunbarsystems.com/baked-unbaked-products/tortillas/default.html

4.7. Packaging

The finalized product is then ready for weighting, packaging and distribution. We package the tortillas in plastic bags. There are three types of package, it depends on the size:

- Small commercial scale
- Medium commercial scale
- Large commercial scale.

The tortilla is sterile, when come out from the oven, and we have to save it during the packaging.

1. PREFACE: General structure of cereals

Members of the grass family (Gramineae), which include the cereal grains, produce dry, one-seeded fruits. This type of fruit is, strictly speaking, a caryopsis but is commonly called a *kernel* or *grain*. The caryopsis consists of a fruit coat or *pericarp*, which surrounds the seed and adheres tightly to a *seed coat*. The seed consists of an *embryo* or *germ* and an *endosperm* enclosed by a *nucellar epidermis* and a seed coat. In general, all cereal grains have these same parts in approximately the same relationship to each other.

The chemical constituents of cereal grains are often compart-mentalized. This plays a large role in grain storage stability. Grains often contain degradation enzymes and their substrates. Certainly if the two come in contact, the degradation process can easily start. However, if the enzyme or the substrate is protected from coming in contact with the other, the system is stable. An example of compartmentalization is that the lipids of wheat occur in deposits that are protected from the enzymes in the rest of the endosperm.

The caryposis of all cereals develops within floral envelopes, which are actually modified leaves. These are called the chaffy parts or *glumes*. In rice and most cultivars of barley and oats, the floral envelopes cover the caryopsis so closely and completely that they remain attached to the caryopsis when the grain is threshed and constitute the *hull* of those grains. In wheat, rye, corn, sorghum, and perl millet, the grain and hull separate readily during threshing, and the grains are said to be naked because they have an uncovered caryopsis. (HOSENEY 1998.)

1.1. Wheat

The flour miller is the first wheat user who is affected by the quality of wheat. It is estimated that 25 % of the flour quality is determined by the milling technology, mill adjustment, and environmental conditions in the mill, and 75 % by the quality of the wheat. The miller evaluates incoming raw material for its price and quality. Price is dependent on factors such as supply, demand, and transportation costs. In the trade, quality is mainly based on wheat grading and factors such as protein level and any demage to the wheat. Following the wheat purchase, the miller has the power to evaluate, select, segregate, prepare, and blend wheat mixes for milling. The miller has two ultimate aims: first, to supply the customer with the specified product quality and, second, to efficiently separate the three main parts of the wheat kernel (*bran, germ*, and *endosperm*) the economic values of which are related to their purity. (POSNER-HIBBS, 2011.)

1.1.1.The Wheat Kernel

A kernel of wheat is a dry, one-seeded fruit. Its color is one of the most constant variety characteristics; length and endosperm texture are the other two. Wheats are classed as white or red, with the exception of some Abyssinian and durum varieties. The dark color of the red wheat is primarily from pigments in the seed coat, but it is influenced also by the texture and vitreousness of the endosperm and the level of pericarp transparency.
The unique morphology of the wheat kernel presents a technical challenge in the process of grinding it to flour. This is because the kernel has a *surface crease* that, in commonly grown varieties, extends inward nearly to or beyond the center of the kernel. (POSNER-HIBBS 2011.)

1.1.2. Endosperm

The wheat endosperm contains, on average, about 30,000 cells that vary in size, shape, and composition of strach granules and protein depending on their location in the kernel. Starch, protein, and bran content are all important in determining the potential *flour yield* from the wheat. The amount of flour that can be extracted from the kernel depends mostly on the percentage of endosperm. Heavier kernel with large endosperm contain more starch and protein and have the potential to yield more flour. The protein and mineral contents of the endosperm follow a pattern. For protein, distribution in the endosperm is the lowest in the center, with a gradient of increase in protein content through the endosperm to the bran coat. The gradient in mineral content (analytically named „ash" because it is what is left after incineration of the endosperm or other parts of the wheat kernel) also increases from the center to the outer layers of endosperm, but it is not indentical in all wheats. (POSNER-HIBBS, 2011.)

1.1.3 Bran

The pericarp and the outermost tissues of the wheat kernel, including large portions of the aleurone layer, compose what is known commercially as „*bran"*. The *pericarp* (fruit coat) consists of two layers. The outer pericarp is made up of the epidermis (epicarp), hypodermis, and remnants of thin-walled cells. The inner pericarp is made up of intermediate-cell, cross-cell, and tube-cell layers. The pericarp envelops the seed and is fused with the *seed coat*, which consists of the *testa* (or episperm), the pigment strand, and the *hyaline layers*. Together, they form two protective layers around the kernel's interior components, the endosperm and the germ. When tissues beneath the seed coat are exposed, moisture, *mold*, etc. gain access to them more readily than when the seed coat and fruit coat are intact.

In the classical milling process, using rolls to separate the endosperm from the bran, the miller tries to achieve minimal abrasion or damage to the bran layers. The goal is to keep the bran as whole as possible and in its original thickness, so that certain spots are not weakened and likely to split during milling.

1.1.4. Germ

The germ is structurally a separate entity of the kernel; therefore the separation of germ from endosperm should require no breaking of the endosperm cell walls. The wheat germ contains the *embryo* and the *scutellum*, which are separated from the endosperm by the epithelial layer. The emryo draws materials for intitial germination and growth from the endosperm, through the epitheial layer. Germination is intitated by the activation of the germ enzymes via heat and moisture. These enzymes are of two main types proteolytic, or protein-liquefying, and amylolytic, or sugar-producing. Due to the action of the latter type, some of the starch in the proximity of the germ is changed to sugar and is use to feed the germ and permit growth. The germ, usually about 2-3 % of the kernel by weight, is partly embedded in the endosperm at the base of the kernel. It is rich in oil and protein.

The „germ" separated in the commercial mill is actually the embryonic axis of the wheat kernel; the softer and less-rigid scutellum is left attached to the bran.

1.1.5 Brush

At the kernel and opposit the germ, there is a „brush" or cluster of hairs. Wheat varieties differ materially in the size of the brush. The kernel hairs, which are extensions of the pericarp, are about 10-15 μm in diameter and 0,5 mm long. Undesirable materials are sometimes entangled in them. Depending on the milling practices used, the hair might end up in the flour. Intensive scouring of wheat during cleaning stages usually removes the kernel hairs. (POSNER_HIBBS, 2011.)

1.1.6. Wheat Quality Parameters

Wheat Moisture

Wheat moisture is not a grade factor, but some countries indicate a maximum allowed moisture content in wheat. Red spring wheat, for example, is straight grade if its moisture content is 14.5 % or lower; though if its moisture content is between 14.6 % and 17.0 %; and damp if its moisture content is over 17 %. Proximate data such as protein content are corrected in the United States to 12 % moisture basis and in European countries to dry basis. The logic behind the usage of 12% as the moisture basis for wheat is that, in general at about 25 ^{o}C and 60% relative humidity, wheat moisture will equalize to 12 %. Under the same conditions, flour moisture would equalize to about 14%. Accordingly, wheat farmers, traders, inspectors, and millers recognize wheat moisture determination as one of inspectors, and millers recognize wheat moisture determination as one of the major parameters. (POSNER-HIBBS, 2011.)

Wheat Ash

Ash is the residual inorganic material left after incineration and is expressed as a percentage of the original sample. The ash value is corrected to *dry basis* or any *moisture basis* for comparison. Ash is another quality factor used to evaluate wheat flours and other mill products in the trade. Millers are always looking for wheats that will produce *low-ash flours*, but there are unusual instances that affect this objective. Certain wheats produce relatively low-ash straight grade flour, but, regardless of the amount of *clear flour* that is taken out, it is difficult to produce a low-ash *patent flour*. Other high-ash, straight-grade flours lose ash rapidly as clears are removed. These examples show that inorganic material is not always produced in the same way in the bran and endosperm of different samples of grain.

Thousand-Kernel Weight

Thousand-kernel weight (TKW) is determined today using semiautomatic counting instruments. The weight of 1,000 counted kernels is determined, or the number of kernels is counted in a preweighed sample and the weight of 1,000 kernels is calculated from it. The count includes sound, whole kernels from which all foreign material and broken kernels have been removed. The weight of 1,000 kernels can be corrected to a dry basis or any moisture basis. TKW can give the miller important information about the wheat's *millability potential*. If two samples have the same size distribution of kernels but different TKWs, that indicates that the *heavier* kernels have a *higher* percentage of endosperm than the lighter ones.
TKW is one of the wheat quality parameters highly correlated with flour yield.

Kernel Size

One of the major wheat physical characteristics that influence processing in the mill is kernel size. In a given mill with fixed corrugations and sieves apertures, change in kernel size affects grinding performance. Wheat kernels break up differently when acted upon with different corrugation specifications. Accordingly, the miller should consider the parameter of kernel size distribution and strive to be within a certain tolerance for optimum results.
The behavior of different sizes of wheat kernels in the milling process was studied to examine the influences of kernel size on *water absorption* during *tempering* and *break release* in the *break system*, the relationship between kernel size and the intermediate stock distribution in the milling system, and the *rheological properties* of flours from different sized kernels.
Uniformity of wheat kernel size plays an importent role in *milling stability*. From the miller's standpoint, wheats that are uniform in kernel size are desirable because they allow the use of *technical specifications* for milling equipment and produce consequent *economic benefits*. Each mill has an optimum specific kernel size distribution. It has been suggested that wheat kernel size distribution should become one of the *wheat-grading criteria*. (POSNER HIBBS, 2011.)

Kernel Shape

Kernel shape is a physical characteristic that is of interest because of its use in classification. It is used to classify wheat as hard or soft buti n the future probably also will help in refining the technology of milling. *Image analysis* is used to determine kernel shape. Algorithms have been produced to characterize shape parameters of entire grains and the germ.

Kernel Hardness

Kernel hardness is regarded mainly as a segregation parameter used in the trade, where the main parameters influencing different end uses of *soft* and *hard* wheat are the level of *protein* and its *quality.* Some new hard wheats function as hard wheat but have the kernel appearance traditionally associated with soft wheats, and vice versa. The importance of the distinction in marketing and use is commonly acknowledged. *Hardness* plays a very important role with regard to *quality* and the *suitability* of grinding a certain wheat on a mill.
The deficiency of the current practice of segregating hard and soft wheat is that the determined hardness value is not related to the processing quality of the wheat. Mill flows of soft and hard wheats differ substantially in their roll surface and sieving area, and therefore wheat should be classifield to reflect millability in addition to protein specifications. (POSNER-HIBBS, 2011.)

Price is a major factor in wheat-buying decisions. However, experience has shown that suitable quality for producing the desired *flour characteristics* and *maximum flour extraction* is, in the long run, more significant than low price for economical operation of the commerical mill. Kernel hardness and protein quantity and quality are among the most important parameters affecting wheat usage.

Protein Content

Protein quality and *quantity* are two parameters that the miller considers in the preparation of a wheat blend for milling. Those two values are adjusted by wheat mixing to reach the flour end user's specifications. However, the milling process affects both the quantity of protein recovered in the wheat flour and the protein's quality.

If sample of wheat meets the standard for protein quality and can be fit into the scheme of mill mixes, than acceptability of the milling properties must be determined. Scientists are continuously trying to accommodate plant breeders by developing a standard test with which to select promising samples from several thousand lines that may vary widely in protein and quality characteristics. Such tests sometimes don’t have the standards of acceptability of promising wheats during the breeding program and of wheats entering the trade system are of *prime importance* to those developing new varieties.

Falling Number Value

The falling number (FN) value represents the time in seconds required to stir a hot aqueous flour gel undergoing liquefaction in a viscometer and then to allow the viscometer stirrer to fall a measured distance through the gel (Method 56-81B, AACC, 2000). The stirring takes 60 sec, so the absolute minimum FN value is 60 sec. Wheat that starts to germinate (i.e. has sprout damage) undergoes morphological and chemical changes in which enzymatic activity converts the carbohydrates into complex sugar compounds. This activity of *α-amylase* is measured by the FN value.

Flour Yield

Flour yield is the most important technical and economic factor of milling and should play a major part in wheat buying decisions. In some cases, a lower price is paid to offset potential lower extraction levels. At the going price, if a sample of wheat fails ti produce a satisfactory yield, it should be rejected regardless of its other virtues. Even in early civilizations, those grain kernels from which the outer coat was more easily removed, providing higher flour extraction, were selected for further planting. The percentage volume of starchy endosperm (which is affected by size and shape of grain, thickness of bran, and size of germ) has been thought to influence the flour extraction. (POSNER-HIBBS, 2011.)

1.1.7. Durum Wheat

Durum wheat is milled to flour or to a granular endosperm product called semolina, which is used for the production of pasta products. Semolina differs from farina in that the latter can be produced from any wheat but semolina is made only from durum.

Semolina is defined similary, except that it is made only of durum wheat, and its maximum dry ash content is 0,92%.
Durum wheat, which originated in the Mediterranean Basin, is also used in many of the surrounding countries for other local foods.
The durum kernel is usually vitreous and much harder than that of common hard weat. When reduced to four, the percentage of damaged starch from the endosperm is higher than for kernels of other wheats.This can be a very important factor in quality control, especially where durum flours are blended with other wheat flours.
It is more critical to achieve balance of the load to the different machines, especially the purifiers, when milling durum than when milling other varieties of wheat. Therefore, the miller must have a thorough understanding of the fallowing basic factors: the pasta manufacturer's specific requirements; good wheat selection and handling procedures; efficiency int he cleaning house, conditioning and blending; grinding techniques; efficient stock classifications, sifting, and purification; and control of the environmental conditions int he milling facility. While these factors are important in processing all wheat flour, they are especially so in milling durum.
Therefore, durum wheat protein levels for semolina milling should be between 13 and 16%, taking into account an estimated loss of about 1 % in protein between wheat and semolina. The above difference between wheat and semolina protein content should be determined for each mill. Other wheat characteristics such as test weight and 1,000-kernel weight, sprout damage, gluten strength, kernel color, and kernel vitreousness or discoloration are important factors in the determination of durum quality. White spots in the pasta are the result of using yellow berry kernels; the endosperm particles of such kernels cause inadequate hydration and mixing of semolina. The percentage of vitreous kernels in the wheat is negatively related to fine flour produced during milling and is positively related to the protein level. (POSNER-HIBBS, 2011.)

1.2 Rye

The rye kernel is a caryopsis 6-8 mm in length and 2-3 mm in width. The kernel threshes free of glumes, has no hull, and is creased like wheat. Its color is grayish yellow. Like the other cereals, rye has a caryopsis consisting of pericarp, seed coat, nucellar epidermis, germ, and endosperm; the endosperm is surrounded by a single layer of aleurone cells. Scanning electron micrographs of the outer area of the grain and of the endosperm show that they are similar to those of wheat. The starch in the endosperm cells is embedded in a protein matrix. The starch, like wheat and barley starches, has large lenticular and small spherical granules. (HOSENEY, 1998.)

1.3 Triticale

Triticale is a new cereal produced by crossing wheat (*Triticum*) and rye (*Secale*). In general morphology, the grain closely resembles its parent species. The caryopsis threshes free of glumes, is generally larger than wheat (10-12 mm in length and 3 mm in width), and weighs about 40 mg. It consits of a germ attached to an 0endosperm with aleurone as the outer layer; outside the aleurone are a seed coat, a pericarp, and the remains of the nucellar epidermis. Thus, triticale closely resembles the other cereal grains in structure.

The kernel has a crease that extends its full length. The yellowish brown grain is characterized by folds of the outer pericarp, apparently caused by shriveling of the grain.

Grain shriveling is a major problem with triticale. It leads to low test weight, poor appearance, and unsatisfactory milling performance. The aleurone layer in triticale is more irregular in shape than is that in wheat. The cells vary in size, and the cell wall tends to vary in thickness. In grain that is shriveled, the aéeurone cells are badly distorted, and lesions have been noted in which complete sections of aleurone and associated endosperm cells are missing. (HOSENEY, 1998.)

1.4. Rice

The caryopsis of rice is harvested with the *hull* or *husk* attached. This is called *paddy* or *rough rice*. The hull which constitutes about 20% of the weight of rough rice, is made up of the floral envelopes, the *lemma* and *palea*. The hulls are high in cellulose (25%), lignin (30%), pentosans (15%), and ash (21%). This ash is unique in contaning about 95 % silica. The high amounts of lignin and silica make the rice hull of rather low value both nutritionally and commerically.

Brown rice (rice after the hull is removed) has the same gross structure as that of the other cereals. However, the caryopsis does not have crease. It varies from 5 to 8 mm in length, and it weighs about 25 mg. Brown rice consists of a pericarp (about 2 %), seed coat and aleurone (about 5%), germ (2-3%), and endosperm (89-94 %). As with the other cereals, the aleurone is the outermost layer of the endosperm but is removed with the pericarp and seed coat during milling.

In general, the endosperm of rice is both hard and vitreous. However, opaque cultivars are known and some cultivars have opaque areas (called *white belly*); these are similar to yellow-berry in wheat. The opacity is caused by air spaces in the endosperm. The thin-walled endosperm cells are tightly packed, with polygonal compound starch granules and protein bodies. The protein bodies are more numerous in the cells just inside the aleurone than in cells near the center of the endosperm. The polygonal starch granules may be formed by compression of the starch granules during grain development. Rice and oats are the only two cereals *with compound starch granules* (i.e. a large granule made up of many small granules). The individual rice starch granules are small (2-4 μm). (HOSENEY, 1998.)

1.5. Oats

Oats, like barley and rice, are harverested with the caryopsis enclosed in a floral envelope. The caryopsis itself is called a *groat.* The aot groat is similar in appearance to kernels of wheat or rye expect that it is covered with numerous *trichomes* (hairlike protuberances). The germ extends about one third of the length of groat, being larger and narrower than the germ of wheat. The oat groat consists of pericarp, seed coat, hyaline layer, germ, and endosperm. The aleurone makes up the outer layer of the endosperm. The strachy endosperm of oats contains more protein and oil than do those of the other cereals. The starch is found as large compound granules made up of many small individual granules. The small granules are polyhedral in shape and range in size from 3 to 10 μm. (HOSENEY, 1998.)

1.6. Pear Millet

Pearl millet consits os small (average about 8.9 mg), tear-shaped kernels that are threshed clean of their hulls. They vary in color, with slate gray being most common, although yellow, white, and brown varieties are also known. The caryopsis is similar to those of the other cereals. Millet pericarp does not contain starch, as the pericarp of sorghum does, nor does pearl millet contain a pigmented inner integument. The germ in pearl millet is large (17%) in proportion to the rest of the kernel. Its endosperm has both translucent and opaque endosperm, as do those of sorghum and corn. The opaque endosperm contains many air spaces and spherical starch granules. The matrix also contains protein bodies ranging in size from 0.3 to 4 µm. The protein bodies have a well-defined internal structure. (HOSENEY, 1998.)

1.7. Corn

Many types of *corn* (or more accurately, *maize*) are grown around the world. *Dent corn* has a large, flattened seed. It is by far the largest of the common cereal seeds, weighing an average of 350 mg. The kernel is made up of four principal parts; *hull or bran* (pericarp and seed coat), *germ, endosperm,* and *tip cap*. For corn, „hull" is a misnomer; it is not synonymous with the hull of barley or oats but more akin to the „bran" of wheat milling terminilogy. However, the term „hull" is strongly ingrained in the wet-milling industry and thus will persist. The tip cap, the attachment point of the *cob*, may or may not stay with the kernel during shelling. The corn kernel is quite variable in color. It may be solid or variegated and ranges from white to dark brown or purple. White and yellow are the most common colors. The hull or pericarp constitutes about 5-6% of the kernel; the germ is relatively large, constituting 10-14 % of the kernel, with the remainder being endosperm.

Corn is different from wheat int hat both translucent and opaque endosperm are found within a single kernel. The cells are large with very thin cell walls.

The translucent endosperm is thightly compact, with few or no air spaces, as one might expect. The starch granules, polygonal in shape, are held together by a matrix protein. Protein bodies are quite noticeable in the photomicrograph; these have been indentified as *zein* bodies. Also noticeable are indentations in the starch caused by the protein bodies. In the opaque endosperm, the starch granules are spherical and are covered with matrix protein that does not contain protein bodies. Chemical analysis of the separated opaque and translucent endosperms showed that the two contained equal amounts of protein but that the protein types varied.

In general, corn kernels are quite hard. The large number of broken starch granules, that the bond between the protein and starch must be quite strong. The fact that water alone will not allow a good separation of protein and starc during wet-milling suggests that the bonds are different in corn and wheat. The opaque endosperm in corn is generally referred to as the „soft" endosperm.

While the practicle size of ground corn from a mutant with a completely opaque endosperm suggests a soft endosperm and while photomicrographs of the opaque section of a normal kernel, show no broken starch granules, which is compatible with a soft endosperm, it still appears prudent to call this part of the endosperm „opaque” and not assume that it is soft simply because it is opaque.

The starch granules in the opaque and translucent parts of the endosperm differ in shape. One possible explanation of why a single kernel of grain should have two starch shapes is that during the natural drying process the protein loses water and shrinks.

The adhesion between the protein and starch is strong enough to pull the starch granules closer and closer together. At this stage, the starch granules are pliable and, as they are tightly packed, they become polygonal in shape. Further evidence of their plasticity before maturity are the indentations that the zein bodies make ont he starch granules int he translucebónt endosperm.

In the opaque endosperm, protein distribution and amino acid composition are quite different. During drying, protein-protein bonds rupture, giving intergranular air spaces and maintaining spherical starch granules.

2. STORAGE of Cereals

The cereal grains are, in general, amenable to storage for relatively long periods of time. They are usually harvested at a relatively low moisture content and, when stored out of the weather and protected from insects and rodents, easily store for several years. Under ideal storage conditions (low temperature, inert atmosphere, etc.), safe storage may be measured in decades.

2.1. Basic Types of Storage

Grain is generally harvested once or, in some areas of the tropics, twice during the year. Yet it is consumed throughout the year. Therefore, practically all grain *must* be stored. Storage can vary from the simple expedient of pouring the grain on the ground or on streetsup to storage in large concrete structures equipped so that a rail car can be picked up and shaken empty in a few minutes.

Generally grain is piled on the ground only during the harvest season when tarnsportation equipment is in short supply. In fact, such storage is nota s bad as it sounds. A pile of grain sheds water quite well, and only the top inch or two is damaged with short-term storage. Of course, as storage time increases, the loss increases, because the grain accepts more water from rain and is also exposed to birds, insects, and rodents.

Primitive societies often stored their excess grain underground. The practice continues today in some regions of the world. Underground storage offers a number of advantages. For example, it protects the grain from daily and seasonal variations in temperature; the construction is relatively simple; and it protects grain from insects and molds because of the low oxygen and high CO2 content of the interseed air. Of course, the site for underground storage must be picked to give a dry environment.

The next level of improvement is storage in bags. Bagged grain can be stored in almost any shelter that protects the bags from the weather and from predators. Bags can be handled without any equipment. However, they are relatively expensive, and handling them is expensive unless labor is very cheap.

Bulk storage in bins is the most widely used type of storage today.The size of the bin may very from a few hundred bushels for an onfarm storage bin to tens of thousands of bushels for a bin in a terminal elevator. On-farm bins are often constructed of wood or steel, and the larger elevators are today practically all constructed of concrete.

2.2. Moisture, No. 1 for Safe Storage

Moisture is also of the greatest importance int he safe storage of grain. Microorganisms, particularly certain species of fungi, are the major cause of grain deterioration. Three major factors control the rate of fungal growth on cereals. These are moisture, time, and temperature. Of the three, moisture is the most important. At low moisture contents, fungi will not grow, buta t about 14% or slightly above, fungal growth begins. Between about 14 and 20% a small addition to the moisture level greatly increases the rate of fungal growth and also changes the number and type of species that develop. Thus, if one is going to store cereals for any period of time, it i9s important to know the moisture content in any given portion of the stored grain.

If one area in the grain has a high moisture content, microorganismswill grow at that point. As the organisms grow, they produce both moisture and heat, as a result of their metabolism, which will then lead to greater damage.

The moisture in grain is in equilibrium with the air surrounding the grain. This equlibrium moisture content (EMC) is defined as the moisture content at equlibrium with an athmosphere

at a certain relative humidity. Different lots of grain, even of the same type of grain, may have different EMCs, and various grains in a mixture may have different moisture contents even though they are all at equilibrium with the relative humidity of the interseed air.
The safe storage moisture content of cereal grains is almost completely dependent upon the grain's hygroscopic properties. When isn storage, the grain and the moisture content of the associated air come into equilibrium. One of the most damaging factors in grain storage is the growth of molds. Generally molds will not grow on grain in equilibrium with air of less than about 70% rh. The maximum moisture levels for safe storage of the major grains are generally accepted to be: corn, 13%; wheat, 14%; barley, 13%; oats, 13%; sorghum, 13%; and rice 12-13%.

2.3. Drying of Cereals

Drying has been used since early civilization to preserve food. Cereal grains areddried for the same purpose; however, because grain is usually harvested in a relatively dry state, we do not think of it int he same terms. In years past, grain crops such as corn or sorghum were allowed to stand int he field until dry. Crops such as wheat, oats, and rye were cut, bundled, and shocked, then allowed to stand int he field until dry or until a threshing crew became avaible. The advent of the combine harvester, or the picker-sheller int he case of corn, largely did away with that practice.
Because we cannot predict the weather and because bad weather can destroy the crop left int he field, it is usually wise to harvest the crop as early as possible. In „normal" years, most of the small cereal grains dry rapidly int he field and thus are of a safer storage moisture at the time they are combined. In wet harvest years, however, a considerable amount of small grains must be dried. Even in normal years, most of the corn and rice harvested is dried.
Two major types of drying, low- and high-temperature, are in current use. Low-temperature drying uses air with no heating above ambient conditions. Air, with the heat contained therein, is forced through the grain mass. The system has several obvious advantages. It is relatively energy efficient, requiring only the energy to force the air through the grain. It may also have the advantage of cooling the grain, which is also important for safe storage. Another major advantage of ambient drying is that the grain is not damaged by high heat, as is too often the case with high-temperature drying. The major disadvantage is the relatively long time required to reduce the moisture content significantly. Another obvious disadvantage is that, if the air used has a high relative humidity, that could conceivably increase the moisture contetnt

of the grain. Because of its economic advantages, ambient air drying is used wherever possible. This is usually when the temperature is low enough that moist grain can be safely stored for a period long enough for the ambient drying to be effective.
The drying process can be speeded up by heating the air to higher temperature. This increases the capacity of the air to hold water and speeds the removal of the water from the grain. The major advantage is, of course, the saving of time.
The major disadvantages are the cost of energy for heating the air and the damage the grain may suffer. Such damage may include: stress cracks, increased brittleness and suspectibility to breakage, bulk density changes, discoloration, and loss of germination ability. Less obvious changes also occur and can be seen only when the grain undergoes processing.

2.4. Aeration

In years past, grain stored for extended periods of time had to be turned occasionally. Turning, or simply moving it from one bin to another, was to help control grain temperature and eliminate hot spots. In recent years, turning (which is expensive) has been replaced by aeration. This movement of a small amount of air through the mass was found to maintain the temperature satisfactorily. The amount of air is, in general, too low a volume to reduce the moisture content of the grain mass to any extent.
Grains, like most other foods, store better at lower temperatures. Temperatures below 17C generally prevent insects that attack grains from rapidly increasing in numbers. Microbiological attack is also temperature-dependent. Thus, lowering the temperature of grain that is to be stored is always an advantage.
When a bulk of grain is stored in an area where seasonal temperature changes are large, the temperature changes lead to nonuniform temperatures int he grain bulk. Air convection currents are set up that lead to *moisture migration,* resulting in moisture accumulation at particular points int he mass. Aeration corrects this condition, as the movement of air through the grain mass makes the temperature more uniform and decreases the moisture accumulation.

2.5. Microflora and Mycotoxins

Cereals are hosts to a large number of different types of microflora. These include types that invade the seed as well as those that are surface contaminants. The most important of the microflora as far as grain storage is concerned are the fungi, which grow at a much lower

interseed relative humidity than other microflora. If the sysem gets out of control and the moisture content in local regions of the grain increases, othet types of organisms can become important, but under good storage conditions this does not occur.
The storage fungi are always present. Because their characteristics are well known, the conditions necessary to stop their growth have been established. Prevention of damage is then simply a matter of keeping the conditions under proper control. Storage losses to microorganisms can be controlled under almost any environment.
Only a few species of fungi attack stored grain. These are promarily species of *Aspergillius* that are adapted to living on low-moisture grain. Certain species of *Penicilium* also grow on grain at an only slightly higher moisture content. Other species grow only on grain containing relatively high moisture. The high moisture may occur in pockets around areas of fungal growth.
Certain fungi are capable of producing toxic compounds. Some of these are exceedingly toxic when consumed or, in certain cases, when they come in contact with the skin. Some *Fusarium* toxins have been shown to kill mice or rabbits within 24 hr after being applied to the skin.

2.6. Insects

Insects are a major problem for the storage of grains and seeds. Not only do insects consume part of the grain, but they also contaminate the grain and thereby constitute a major sanitation problem.
Insects that can live on grain can be divided into those that develop inside the kernels and those that live outside the kernels. Those that develop inside the kernels are responsible for the *hidden infestation* found in stored grain (Fig. 12). Five species (granary weevils, rice weevils, maize weevils, lesser grain borers, and Angoumois grain moths) are responsible for that hidden damage. Kernels provide little evidence or moths. Weevils deposit their eggs inside the kernels. Lesser grain borers and Angoumois grain moths lay their eggs outside the kernels, but the newly hatched larvae tunnel into the kernels to feed and develop.
Insects that develop outside the kernels often feed on broken kernels, grain dust, etc. Important species of this group include confused and red flour beetles, saw-toothed grain beetles, cadelles, kharpa beetles, and Indian-meal moths.
Most grain-damaging insects are of subtropical origin and do not hibernate. Thus, ther damage can be limited by low temperatures. Not only is low temperature lethal in itself, but it

also makes insects inactive so that they do not feed. Generally, temperatures below about 10°C limit the growth and developement of most grain-damaging insects.

Even though the grain is stored at a relatively safe storage moisture of 11-14% int he presence of insects, the grain often „heats." The heat is caused by the metabolic heat of the insects. Because of the increased temperature, moisture migration occurs and results in increased moisture of pockets of grain. This leads to microorganisms growing, and the system rapidly gets out of control, with large amounts of grain being damaged.

2.7. Rodents

Next to human beings, rats and mice are probably the most damaging animals known. They destroy (consume or contaminate or both) millions of tons of food each year. Throughout history, rats, mice, and humans have coecisted in an uneasy condition. A popular rule of thumb, which may or may not be true, is that in any given area, the populations of rats and and humans are equal.

Killing of rodents, whether by baits, traps, or otherwise, is effective only over short time spans. These methods are helpful in reducing populations or eliminating small populations. The answer to rodent contol is rodent-proofing of buildings and good sanitation, which make the rodents want to find a better place to live.

3. WHEAT FLOUR MILLING

Milling is an ancient art. In simple terms, its objective is to make cereals more palatable and thus more desirable as food. Milling generally involves removal of the material the miller calls bran, i.e., the pericarp, the seed coat, the nucellar epidermis, and the aleurone layer. In addition, the germ is usually removed because it is relatively high in oil, which makes the product become rancid faster, thereby decreasing its palatability.The bran and germ are relatively rich in protein, B vitamins, minerals, and fat, and the milled product is lower in these entities than was the original grain. Thus, as a result of milling, the palatability is increased but the nutritional value of the product is decreased. What we call dry milling is the attempt to separate the anatomical parts of the grain as cleanly as possible.

In addition to making the product more palatable and increasing its ability to store longer, milling often involves some type of constraint with regard to particle size.

The flour miller is the first wheat user who is affected by the quality of wheat. It is estimated that 25% of the flour quality is determined by the milling technology, mill adjustment, and environmental conditions in the mill, and 75% by the quality of the wheat. The miller evaluates incomingraw material for its price and quality. Price is dependent on factors such as supply, demand, and transportation costs. In the trade, quality is mainly based on wheat grading and factors such as protein level and any damage to the wheat. Following the wheat purchase, the miller has the power to evaluate, select, segregate, prepare, and blend wheat mixes for milling. The miller has two ultimate aims: first, to supply the customer with the specified product quality and, second, to efficiently separate the three main parts of the wheat kernel (*bran, germ* and *endosperm*), the economic values of which are related to their purity.

3.1. Preparation processes of wheat

It is important for the individuals responsible for growing, bying, storing, handling, and processing wheat to know the handling systems in the elevator. Storage facilities, handling system, and athmospheric conditions such as the grams of moisture per cubic meter of air outside and within the storage facility can significantly affect the quality and value of the wheat. Wheat grading systems reflect damage to wheat that occurs during storage and handling. Unsuitable mechanical equipment can cause changes in quality such as an increase in kernel breakage and the amount of fine dust int he wheat. Mold growth creates a penetrating and residual musty odor that is a concern in wheat grading; accordingly, such wheat is designated smutty. Heat damage results from conditions that develop during storage.

The Grain Elevator

Wheat is an important raw material for human food consumption because it can retain good quality from one harvest to the next. Over many centuries., storage systems progressed from the keeping of small amounts of harvested grain in underground pits t ostoring hundreds of thousands of bushels in concrete bins. The main objectives centuries ago was to maintain good quality of grain until the next harvest. In modern times, storage of grain over two or three harvest periods is not uncommon, even in locations with unfavorable climate.

Flour mills located close to wheat-growing areas have exceptionally large storage capacity for harvested wheat. Such mills receive large quantities of wheat during the annual harvest period and usually are technically designed to handle these amounts. Identity-known wheats are accepted, segregated, and kept in optimal storage facilities until usage. The decision to accept the newly harvested wheat directly from the farmer involves significant economic and technical considerations. The costs of wheat storage, and year-ruond delivery can and should be quantified before such a decision is made.

3.1.1. Wheat storage and Blending

Facilities and Equipment

Equipment in the elevator (*silo*)can be divided into categories according to use: weighing, receiving, dust control, sampling, and analysis; cleaning; storage; distribution; *dosing* (blending) at bin outlets; conveying; and preserving wheat quality.

Sampling and Checking

Sampling of wheat upon arrival at the elevator is important for segregating wheat to different bins and for subsequent blending to achieve least-cost product optimization. Sampling can be done manually or with an *automatic sampler.* In either case, the objective is to get th ebest representative sample from the tested load.

The miller checks incoming wheat for its quality characteristics to make sure it is suitable for the expected storage period and intended flour. It should be checked for infestation, amount of impurities that are not millable to flour, and suitability for the specific technical characteristics of the mill. Based on information describing the wheat sample, it is possible to make some decisions and take the necessary measures for segregating to bins, storage, or blending. Wheat that is known to have been subjected to recurring cycles of wetting and drying after maturity or that was exposed to abnormal conditions before or during harvest will exhibit reduced storage quality. Under unfavorable storage conditions, lower-grade or weathered wheat deteriorates more readily.

Blending of Mill Mixes in Storage

The objective of wheat blending is to achieve a wheat mix of specified physical, chemical, and baking characteristics. Such a mix is intended to produce uniform flours within the required specifications. However, the numerous variables in wheat and the processing system influence the accuracy of the resulting flour quality. No procedure is available to determine an optimum ratio by which the qualities of the mill mix and the resulting flours can be accurately predicted. That is why the final mix should be tested to confirm that the quality factors meet specifications. The fact that a wide number of blends can be created with various results, because of natural variation in the wheat, indicates that blending is as much art as it is science. In some countries, the blending of mill mixes is sometimes referred to as „gristing” and the „grist” is the wheat mix that is processed by the mill.

To achieve repeated results within a tolerance limit, blending should be done only with wheats compatible with the particular mill design. Blending of different classes of wheat such as hard in soft or vice versa, usually results in reduced milling efficiency. The main parameters for blending wheat are the protein content, quality, and baking characteristics of the resulting flours. Additional parameters that are gaming importance are kernel size, hardness, and sprout damage. The sizes and shapes of corrugations ont he break rolls are directly related to the wheat kernel sizes. Average dry-wheat kernel hardness affects milling efficienccy and should be considered a parameter in wheat blending and subsequent conditioning procedures. Sprout damage in some of the wheats used int he final blend before milling is related to mill adjustment and the capacity to generate starch damage, especially by smooth rolls.

The method and equipment used for blending wheat vary from mill to mill. Blending of wheat is required when millers must accomodate their customers by producing a large number of uniform flour grades meeting different quality specifications. Some mills formulate the mix out of the tempering bins. The optimum moisture and temper time with the type and hardness of the wheat. Each type can be tempered separately and blenden together out of the temper bins, using gravimetric feeders to obtain an accurate mix. Some mills, rather then changing the wheat mix for each flour type, blend base flours from holding bins to generate the different final products. Uniformity is ensured and can be tested before shipment.

3.1.2. Wheat Cleaning and Conditioning

Wheat arriving in the mill usually contains foreign matter, such as strings, straw, parts of bags, wood, stones, or metal, that must be removed before processing. The contaminants usually become mixed with the wheat int he field and during its transfer through the various stages of the grain-handling system. In addition, wheat always contains some seeds of other plants, even if grown under th ebest conditions. If farming or environmental conditions are poor, the amount of *screenings* is likely to increase. Although part of the foreign material (dockage), or all of it, is discounted int he trade, the cleaning system in the mill should be designed not allow the miller enough flexibility to properly clean any wheat arriving at the mill.

Unmillable Material

The unmillable fraction is treated differently by individual mills. Some use a hammer mill to grind the screeinigs to a fine material, which can then be mixed with the mill feed. Other mills find markets for the separated fractions of the screenings. Some millers feed the separated broken and shrunken wheat kernels to the *tail-end-breaks* in the mill.

Foreign Material

The material separated in the cleaning house from the millable wheat could be poisonous, reduce flour quality and extraction, or damage machinery. Decisions on how to set the flow or the cleaning house and adjust the machines are dependent upon the wheat's physical characteristics and the level of impurities in it. A good, dependable cleaning house in flexible enough to handle all the possible variations in wheat physical characteristics and those of the unmillable materials. A cleaning house designed to separate only some particular contaminants in the wheat, and only up to a certain level, is a technical and economic handicap to the mill.

Damaged Wheat

Wheat kernels that have been damaged mechanically, biologically, by insect infestation, or by disease during growing or subsequent handling also should be removed during the cleaning. Kernels that are unripe at the time of harvest become light, meager, and shriveled after drying. Frost-damaged wheat that has been frosted in the milk stage of growth has meager and shriveled kernels. Insect damage decreases the grain's value. Infested grain is defined as insect-damaged kernels that are visible in the sample.

Methods of Separating Wheat Impurities

Unmillable material is removed in the cleaning system by multiple methods based on different principles because a load of wheat usually contains heterogeneous materials differing substantially in their characteristics. The various machines used to separate impurities from the wheat are based on one or more of the following characteristics of either the impurities or the wheat: 1) magnetic and nonmagnetic properties of metals; 2) size and dimensions (volume, width, and length); 3) shape; 4) specific gravity; 5) behavior during wheat washing; 6) behavior in air currents; 7) surface friction, elasticity, texture, and hardness; 8) *friability* under impact; 9) electrostatic properties; and 10) color differences.

Some modern wheat-cleaning systems include machines that are designed to perform multiple functions by incorporating two or more of the above-mentioned principles. In many instances, such machines are installed in the system to save space and to reduce investment, control by operators, and power consumption. However, some of the multifunctional machines are unsatisfactory in allowing operator access for adjustment during the run. In addition, multifunctional machines have limited flexibility in handling wheat loads with significant variability in physical shape and amount of unmillable material. The professional miller must evaluate the installment of such multifunctional machines in the mill wheat-cleaning section based on the expected variance of quality and the characteristics and level of unmillable material that might be included in wheat loads to the mill.

Magnetic and Nonmagnetic Metals

A magnetic separator is installed as the first machine in the system to separate any free metal pieces in the wheat stream. Magnets are needed not only to remove metal from the wheat but also to protect machines from damage and generation of sparks that might trigger a dust explosion. It is a good practice to install more than one magnet in the system, because additional metal pieces can enter that wheat stream from the operating machines. Permanent magnets or more powerful electromagnets activated by electrical current can be used. If the current supplied to the electromagnet is alternating, a rectifier of some kind must be used because the system requires direct current.

By Size and Dimensions

For separating grain impurities according to size, machines with different mechanical arrangements of sieves are used. The separating media, the sieves, can be made from perforated sheet metal or wire cloth. To achieve a separating action with sieve, it must be in motion. The motion of the sieves varies in machines originating from different manufactures. Machines are constructed with rotary motion, oscillating (reciprocating) motion, and a combination of head-end rotary motion and tail-end reciprocating motion. With flat sieves, the screening process and take place only when the motion of the seed is not synchronized with that of the screen. The relative motions of the wheat and the screen can be obtained by one of two methods: 1) movement of particles caused by their gravity along an incline, static screen and 2) movement of particles caused by the movement of the screen.

In most modern cleaning machines, the screens always move. The material on the sieves moves at a slower velocity than the sieve. The relative velocities depend on the sieve surface and the material's shape and surface. The screens can be horizontal or set at a low angle to the horizontal to ensure that the material moves on top to the lower end. The load should be distributed evenly over the whole surface of the screen to ensure efficient usage of all the sieving area. The relative velocities of the screen and material should allow particles smaller than the screen openings to pass through the screen with ease.

By Shape

Separation based on differences in shape is made in a *disc separator* or an indented trieur cylinder. As the names imply, the disc separator comprises a series of discs rotating in the bulk of the wheat, and trieur cylinder is a rotating metal cylinder in which material is picked up by indentations or pockets and thrown into a centrally located trough.

Another machine that is designed to separate bulk fractions different in shape is the trieur cylinder (indent separator) The cylinder, with indentations on its inner surface, usually is inclined to allow the mass of wheat to move by gravity to the end. Particles small enough to lodge in the pockets are raised to a certain point, after which they drop out into a trough and are removed by a screw conveyor. The rest of the material tails over the end of the cylinder. The maximum capacity of the trieur cylinder is reached when the indented cylinder is rotating at a speed just below that at which centrifugal force would prevent the lifted particles from dropping out at all.

By Specific Gravity

Particles such as stones, dirt (mud balls), glass, or metal about the same size as the wheat kernels flow with the stream of wheat from the sieve separator. The stoned or other materials heavier than wheat may be separated by specific gravity differences, using air or water as segregation aids. Machines in which this principle is implemented are the dry *destoners* and the destining section of wheat washers.

Dry destining based on differences in specific gravity is achieved in a machine in which air current, sieve stroke, and sieve inclination are variables that affect the separation efficiency. The specific gravity separators can remove not only particles heavier than wheat, such as stones and mud balls, but also particles lighter than wheat, such as ergot, rodent pellets, and heavily insect-infested kernels.

By Surface Friction, Elasticity, Texture, and Hardness

Friction on the wheat kernel separates impurities adhering to the kernel's surface. It has a polishing effect and cleans the wheat. *"Beeswings"* of the pericarp can be removed very efficiently by friction after the first tempering of the wheat. This action takes place in a scourer, in which a rotor bounces the wheat against the wall of the machine, which may be perforated sheet metal, a screen of woven steel wire, or an emery surface. The rotor may be made of a drum, on which inclined beater blades are positioned. The small impurities pass through the screen, and the cleaned grain is discharged at the outlet end of the machine.

Cylindrical fine wire brushes mounted on a rotor also are used as a friction mechanism. This type of machine enables the separation of softer seeds, such as garlic, from the mass of wheat by piercing them with the steel points of the brush.

By Color Differences

Color sorting of seeds is a common practice in the rice-milling industry. Its use is growing for whole-wheat products to remove discolored or partially discolored kernels. Development of multichannel high-capacity color sorters (up to 15 t/hr) have made it a common machines in durum wheat-cleaning systems, where discoloration of the raw material result in black specks in the granular products from the durum mill. Color sorters also can be found in systems in which wheat is processed into flakes and other breakfast cereals. The color sorter, with its limited capacity, is used to handle small fractions of the main wheat flow in the cleaning section, sometimes in conjunction with a gravity table that concentrates impurities into smaller fractions.

Although using a method based on color differences for sorting wheat streams is an expensive solution, professional millers appreciate its usage when glass and plastic particles are separated also. A properly adjusted color sorter can be effective in the separation of small glass and plastic particles from the wheat stream. Especially when the mill produces granular products, such as farina, semolina, or whole-wheat products, ground glass and plastic could cause hazardous situations and great damage to the mill’s reputation.

Theory of Conditioning Wheat for Milling

An old slogan of the experienced miller is that having clean, consistent well-prepared wheat at the first grinding stage is at least half the battle toward mill balance, which results in the most favorable flour extraction and flour quality. Part of wheat preparation for milling is conditioning, which involves removal (or, more often, addition) of water, followed by a rest period. Some call this process “tempering”, a term that actually should refer to the rest period, during which the added water penetrates the kernel. The unique feature of wheat that makes milling possible is that the three parts of the kernel (bran, germ, and endosperm) differ in relative toughness or friability. Adding water to the different parts exaggerates their differences and their behavior in reaction to the forces exerted upon them during milling.

Conditioning involves adding cold or warm water to the wheat and allowing the wheat to rest, or temper, in bins until it reaches the optimum moisture distribution and kernel suitability for milling. The objective is to toughen the bran and mellow the endosperm. A too-hard endosperm will function as a hard background in the grinding system and cause the bran to split excessively.

The amount and rate of water uptake by wheat kernels depend partly on the initial water content, kernel hardness, and kernel temperature. An increase in kernel temperature causes the kernel to expand; then, the capillary tubes become distended, allowing passage of a large amount of water in a given time.

Wheat Conditioning Equipment

Today's tempering system consists of an intensive mixer in which the wheat is tumbled with water for about 20-30 sec. During this short period, the objective is to get the maximum dispersion of water within the grain. The modern wheat tempering mixer allows the addition of up to 7% water, which requires less capacity in the tempering bin than multistep methods do and provides a single control point for water addition. An automatic, pneumatically activated water-dosage regulator is used to adjust the addition of water to the tempering mixer, so that the actual moisture content of grain leaving the mixer coincides with the target moisture content. The moisture of the wheat going in or out of the tempering mixer is checked continuously by what are called feed-forward or feedback signals, respectively. A feed-forward system measures the dry wheat moisture dielectrically before it enters the tempering mixer. The system corrects the moisture values based on density and temperature and subsequently controls the amount of water addition. In the feedback system, the moisture and temperature of the wetted wheat are determined after it leaves the tempering mixer. Based on the target moisture level, the system sends back a signal to control the amount of water to be added.

Cleaning-House Flow Sheet

The sequence of machines in the typical wheat-cleaning section follows in general the arrangement shown in Figure 4-18. Magnets to separate ferrous materials are followed by sieved to separate foreign materials that are smaller or larger than the wheat kernel. Next, a gravity table is used to separate foreign materials that are of the same size as the wheat kernel but differ in specific gravity. Separation of sand with sieves and of stones with the gravity

table ensures that the mass of wheat, which subsequently is treated with indentation machines, does not wear out the pockets of these machines too fast.
The cleaning-house flow has changed since the early 1990s, and not for better if wheat cleanliness and capacities are considered. The cleaning system is considerably shorter in its design; the bulk of the stream is separated at the beginning of the flow. The fraction of the total wheat stream containing most of the unmillable material goes through an intensive cleaning system, while the rest of the wheat is diverted to the tempering process.

3.2. *Main Processes of the Wheat Flour Milling*

3.2.1. *Grinding*

The grinding process is the most important step in the milling system. The manner in which the kernel is broken affects the subsequent sifting and purifying operations, both in granulation (particle size distrubtion) and in the amount of fine bran present in the ground material int he reduction and sizings systems.The grinding process can be classified into four systems: 1) the break system, which separates the endosperm from the bran and germ; 2) the sizing system, which separates the small bran pieces attached to the large pieces of endosperm; 3) the reduction system, which reduces the endosperm to flouw; and 4) the tailings system, which separates the fiber from the endosperm recovered from the other three systems. The quality characteristics of the flour particles are infuelnced greatly by the grinding action used in the reduction system. The most obvious effects are the amount of starch damage in the flour and variations in flour color from bran contamination.
In the grinding operation, energy is expended to break apart the bran and endosperm and reduce the endosperm to flour. This uses about 50% of the power connected with the milling system and results in heat generation and moisture loss in the ground material. Early primitive mills consisted only of grinding to reduce the wheat kernel into flour to make a bread product. As the taste for refined white flour grew, so did the complexity of the milling system. It is during the grinding process that the basic work is done. All other operations — conveying, classifying, purifying, and other blending operations — use less energy and could be considered secondary requirements for the milling system.
The principal forces of grinding are 1) compression, 2) shear, 3) friction/abrasion, and 4) impact. Most grinders operate on a combination of these principles. Some of the most common grinding machines are roller mills, attriton mills, impact mills, ball mills, cutters,

disc mills, bran dusters, and pearlers. Each of these machines is discussed in some detail on this chapter.

Roller Mill

The roller mill is the principal grinding machine in a commercial wheat flour mill because of its range of selective grinding action and economy of operation. Manufacturers offer roller mills in a number of configurations. The most popular is the four-roll double-roller mill, which has a pair of rolls on each side of the stand that can operate independently or together or the same stock.

The grinding action of the roller mill subjects the particles to shear and compressive forces, caused by corrugations on the roll surfaces and pressure exerted by the rolls while pulling particles toward the nip (Haque, 1991). The magnitudes of the stresses imposed ont he particles during roller milling vary according to grinding conditions. The rate and uniformity of flow of stock rolls, the roll velocities, the ratio of speeds of the fast and slow rolls (known as the differential), the gap between the rolls, the type and condition of the roll surfaces, and thr properties of particles affect the magnitudes of each type of stress.

The Roll Surface

The term *roll surface* refers to the linear measurement of pairos of roll sin a flour mill. It can be expressed as the total length or, more commonly, as the unit of length per capacity of the mill for a 24-hr period of time. The roll surface required for a flour mill depends ont he type of wheat milled and the specifications of the end products.

The roll surface often is reduced in the middlings and tailing systems by using impact machines in selected process steps. They can be used on break redust (the overs of the break sifter flour screens containing a mixture of fine particles of endosperm and flour) and in combination with rolls on the first and second middling reduction steps that reduce low-ash material to flour. These are usually high-velocity impact machines and sometimes pin mills (machines using counterrotating pins) to produce more flour and keep the starch damage low.

Low-velocity impact machines can be used on tailing stock (mixtires of endosperm and bran) to clean endosperm off bran chips after compression by a smooth roll. This is because the endosperm sometimes is flaked and adheres to the bran. These machines are called detachers.

The detachers are helpful for soft wheat stocks or high-moisture material that is dufficult to grind on a roller mill.

Operation of the Roller Mill

The roller mill is the primary grinder in the flour mill. Grinding is achieved on pairs of horizontal, parallel, iron cylinders (rolls) rotating in opposite directions. They pull the stock down between the rolls into the nip of the rolls, which is considered the grinding zone. (The pair of rolls must be paralell. This is achieved by tramming, the rolls, i.e., adjustin the eccentrics that support each end of the rolls.) The nip of the rolls is the minimum space between two parallel rolls. The roll gap is the distance between the rolls at the nip; it is adjusted to control the severity of the grinding action. The rolls can be set in a diagonal position to reduce the horizontal width of the roller mill; however, this presents more difficulty in feeding the rolls. The newer models are horizontalt o simplify the feeder and increase the capacity of the roll. Roller mills have been made with different roll configurations, such as two or four pairs of roll sin one stand. The roll surface can be smooth or corrugated, with grooves (flutes) running the length of the surface of the roll in a spiral to produce a cutting or shearing action. The grinding action of a pair of rolls is influenced by many factors.

Factors Influencing Grinding

Diameter

Commercial rolls range from 225 to 300mm in diameter. The diameter affects the work of the rolls by changing the area of the grinding zone. The grinding zone starts at the point where a particle first comes in contact with the grinding surface of the two rolls, called „point-of-seizure" and measured by the angle of contact, and ends at the nip of the rolls. The larger the diameter, the greater the grinding effect. A large-diameter roll is preferred for flaking operations. It provides more seizing ability to pull material into the nip of the roll and can exert more compression or flaking action. A smaller-diameter roll sometimes is preferred int he break system to minimize compression in favor of more shear action.

Length

The roll length varies from 450 to 1,500 mm in a commercial mill. The grinding capacity of the roller mill is dependent upon the roll length, which usually is expressed in quantity of material per linear dimension of roll length for given stock. For ecample, the first-break roll can grind 30-50 kg/cm per minute (140-280 lb/in. Per minute) depending on the rolls' rpm. The feed to the rolls must be suffcient to provide an even layer of material to the nip of the roll. It is dufficult to maintain an even flow across the length of the roll with flow rates below a minimum quantity. Greater flow rates overload he roll drive and force the rolls to grind against the spring overload device, which cannot maintain an accurate gap. Most mills have enough capacity to use standard-size rolls of 1,000-1,250 mm (40-50 in.) in length. The 1,000-mm roll is preferred for reductions because rolls of greater length have problems maintaining an uniform gap between the rolls. A greater dustance between the roll bearings allow the roll to flex under pressure.

Surface

Rolls have been made of various materials to increase the life or work of their surfaces. Most rolls are made of cast iron and „chilled" (rapidly cooled) to harden the surface for longer life. For this reaseon, the rolls frequently are called „chills". The roll can be chilled or hardened from its surface to a depth of about 10 mm by the static casting method. The disadvantage is that the roll metal is hardest at the surface and becomes softer with increased depth. After the corrugations have been ground off the roll for recorrugating several times, the roll surface is soft and wears down rapidly; the roll then must be replaced.

Corrugation Profile

Corrugations (creason, 1975) sometimes called flutes, are grooves cut into the surface of the roll. The profile (cross-sectional shape) of the corrugation influences the work of the roll. The cutting action of the corrugation becomes more intense as the angle decreases, and the depth of the corrugation is matched to the particle size of the material being ground. If the corrugation is too deep, the cut up the bran without scraping off the endosperm. A corrugation that is too shallow does not penetrate sufficiently to scrape the endosperm off the bran or can result in more compression rather than shear on the particle.

The European method of corrugation uses a single-point tool to cut each corrugation at a prescribed angle measured from a ridus of the roll (Henry, 2000). The corrugation can be sharpened by recutting the groove. U.S. corrugators use multuple-point tool that can cut three to five corrugations on the roll surface in a single pass. This tool speeds up the cutting process and also makes it possible to cut profilest hat are curved as well as straightline angles. However, when the corrugation wears down, it cannot be resharpened but must be ground off to smooth surface and recorrugated.

Differential

Differential is the difference in rpm of the rolls working as a pair. The fast roll is driven by a motor or line shaft, which drives the slow roll with belts, chains, or gears. The slow roll exerts a holding action against the fast roll. A differential of 2:1 indicates that the fast roll is rotating at twice the revolutions of the slow roll, whereas a differential of 1:1 indicates equal rpm for both rolls. In flour mills, the common practice is to operatea t 2.5:1 in the break system for cealing the bran adn 1.25:1 to 1.5:1 in the smooth-roll reduction system to reduce the cutting of bran particles. At one time there was interest in a grand differential of 100:1 for reduction of endosperm; however, the capacity was restricted because of the movement of the slow roll int he grinding zone, and it is no longer used.

Direction or „Action”

Direction indicates the movement of the angle or side of the corrugation that does the work or exerts the force on the material to be ground (Fig. 5-18). *Dull to dull* direction means that the dull side (the larger angle from the radial) of the fast roll is passing by the dull angle of the slow roll. This is used in the break system of most flour mills to minimize cutting action on the bran; however, in semolina mills, *sharp to sharp* direction is used to uncrease the cutting action and minimize production of fines. The other direction combinations are *sharp to dull* and *dull to sharp*, which are used in some mills to conserve power or to ectend the life of a roll corrugation.

Hand

The corrugator needs to know the direction of rotation of the roll in order to cut the corrugations for the desired working angle. This is reffered to as the „hand” of the roll. Figure 5-19 shows the hand of rolls of different drive arrangements. The hand of the drive is determined by which end the drive is on, as you face the fast roll in the stand. European rolls have the fast roll on the outside of the stand and can be either hand, depending on the drive.

Spiral

The angle of inclination of the corrugation from the longitudinal line on the surface of the roll is known as the spiral. The spiral affects the cutting action by controlling the number of corrugations that cross the roll length in the grinding zone. The greater the spiral, the smaller the space between corrugations, which increases the grinding action.

Roll Cleaners

Keeping the roll surface clean is an important operating function. Cleaners can be brushes for corrugated rolls and scarpers for smooth rolls; both clean the roll surfaces by friction. They must be adjusted and monitored regularly to be effective. Improperly set cleaners can cause a *ring* on the roll surface, formed by the ground material sticking and building up on the roll, which forces the roll gap open and prevents proper grinding. The ring can also result in fire or damage in the roller mill. Newly designed rolls have a pneumatically activated, mechanism that causes the cleaning elements to be removed from the rotating rolls when they are disengaged.

3.2.1. *Grinding*

In the Break System

The objective of the break system is to open the wheat kernel and remove the endosperm and germ from the bran coat with the least amount of bran contamination and, at the same time, obtain a granulation distribution of maximum large middlings with a minimum of flour. The system can be considered in two parts, the primary or head break system, which releases relatively pure particles of endosperm along with more fine pieces of bran and germ.

The break roll corrugations and run in a dull-to-dull direction to minimize excessive cutting of the bran and produce cleaner middlings. The exception is in semolina mills, where fine middlings and flour must be kept to a minimum to produce a granular product. In that case, the roll corrugation direction is sharp to sharp. The roll corrugations must be in good condition and should be recorrugated on a regular schedule.

The work of the secondary break system is usually set by observation of the cleanliness of the bran. Examination will indicate how much of the bran is cut. The corrugation cuts should be visible on the bran but not to the point of completely cutting the bran on the last break operation. The objective is to scrape the endosperm from the bran without cutting up the bran.

In the Sizing System

The objective of grinding in the sizing system is to detach the bran pieces attached to the large middlings (endosperm particles with various degrees of attached bran) and produce clean middlings, while minimizing flour production. The rolls can be smooth or corrugated. Smooth rolls have less capacity than corrugated but do not cut the bran as much and more flour. Smooth rolls also tend to flake the large chunks of endosperm, which are then separated with the bran in the sifter and lost to the tailings recovery system. Corrugated rolls do a better job of detaching the bran chips ad can be used for dirty sizings and for fine sizings because of the increased amount of attached bran in these stocks.

In the Reduction System

The objective of the reduction system is to reduce the middlings to flour in the most economical way, while retaining the most desirable baking characteristics. This is achieved by a gradual reduction system to control starch damage and minimize the amount of bran particles passing through the sifter into the flour. The grinding action of the smooth rolls reduces the more friable endosperm and at the same time leaves the bran pieces intact so that they can be separated in the sifter.

Grinding on the smooth rolls should reduce the particles of endosperm with a minimum amount of flakes. Flakes are compressed pieces of endosperm formed by the pressure of the rolls. A few flakes will be present; these can be broken up in an impactor following the roll. The amount of fiber in the stock to the roll determines the amount of roll pressure to use in grinding. High-fiber stock should be ground with less roll pressure to keep it from passing through the sifter sieves into the flour. The grinding should be adjusted to the sifter separations, where the larger branny particles are scalped off into the tailing section for recovery of endosperm back into the reduction system. The miller can determine the optimum roll setting by examination of the sifter particle size separations is necessary to obtain the optimum roll setting.

In the Tailings System

The objective of grinding in the tailings system is to recover small pieces of endosperm by reducing their size in relation on the bran and germ particles, so that a relatively pure middlings separation can be made in the sifter. The grinding pressure is usually light to avoid flaking the middlings.

High-extraction flow diagrams sometimes use corrugated rolls in some of the tailings steps. The grinding is usually done with low roll pressure to avoid introducing too much fiber into the middlings system. Impaction machines are also used to reduce the endosperm and break up the flakes. These machines usually follow the rolls ahead of the sifter to improve the sifting efficiency.

3.2.2. Sieving

The term sieving commonly refers to the separation of a ground mass of material into various particle-size classification. In the flour mill, sieving after each grinding, operation classifies the material for the sub sequent step (further grinding, purification, etc.) and removes the flour produced in the grinding operation. Sieving machines separate particles by size. The most common sieving machines in the flour mill are 1) a gyrating box sifter containing as many as 30 stacked sieves and capable of making a maximum of eight separations, 2) a reciprocating sieves capable of making two to four separations, and 3) a reel-type machine consisting of screen cylinder that rotates or moves the material along the surface of the screen and usually makes two to three separations.

Separation by a sieve is normally accomplished by the movement of the material on the sieve screen, which causes the particles smaller than the mesh opening to pass through by the force of gravity. Passage through the apertures, or openings, also can be forced by rotating beaters on the material or by air currents.

Sieve Material and Weave

Most of the screen media used in flour milling is smooth, to minimize friction drag on the particles (to avoid attrition) and to increase the flow capacity of the sieve. Thus, smooth wire (tinned mill or stainless steel mill) is used in the break scalps (first separation of coarse material) to support heavy loads, and light wire (stainless steel *bolting cloth* or durloy, a light wire) is used in the sieves for aperture sizes of 1,200 µm and smaller. These wires have a smaller diameter so that, for the same aperture, they have more open area than sieves made with heavier wire, such as tinned mill screens.

The screens for grading middlings and sifting flour once were made of silk, but most sifting media now are made from synthetic nylon filaments. The filaments are monofilament (one fiber makes a thread). The threads are woven to make a fabric (screen) that is attached to the sieve frame. The weaver's term "warp" denotes the thread running the fabric's length, and the "weft" is the thread running the width of the fabric.

Screens that are used on abrasive stocks, or heavy loads at high tensions, are woven with the square weave. These are the milling Forte and XXX screens. These screens provide maximum strength but, because of the larger thread diameter, the percent open area and sifting efficiency are reduced. Nylon *grits gauze (GG)* screens are used on coarse middlings, moisture and provides more shear action on the surface.

Sieve Cleaners

Sieve cleaners are necessary to keep the apertures open and prevent blocking, or blinding. Blocking occurs when near-size particles (those slightly larger than the aperture) lodge in the aperture, very fine sticky particles adhere to the underside of the mesh and block the opening, or static electricity acts between certain sticks and the screen. The static electricity problem can be minimized by grounding the screen with a conducting wire.

The sieve cleaner rests under the screen on a wire mesh called a *backwire*, having about 2.5 meshes per inch, so that the sifted product can pass easily and also impart agitation to the cleaner. The backwire mesh can be intercrimped to impart more movement to the cleaner.

3.2.3. Purification

In a general sense, purification is a term applicable to almost every process in the milling system. Purification is any process that separates bran particles and germ from endosperm. In particular, it is the gradual reduction of middlings to reduce endosperm and flatten the germ and bran particles so that they can be removed in the sifter. The residual tailing system also separate bran particles from endosperm by reduction of the endosperm and sieving to remove the flattened bran. This chapter explains the process to remove bran from middlings that are produced in the break system.

Although the objective of the break system is to remove the endosperm from the bran without breaking the bran into small particles, some shattering of the bran occurs and results in a mixture of endosperm and bran in the released middlings. The purpose of the purifier is to separate the middlings into three fractions: pure endosperm, a mixture of endosperm with attached bran, and bran particles. The purifier also grades the endosperm into particle size ranges, which can be more efficiently ground separately in the reduction system. The clean separations from the purifier are sent to the head end of the reduction system and branny materials to the tailings recovery system.

Purifiers can remove bran fiber and classify middlings by size and purity for the reduction system. This is not possible with sifters alone. Purifiers are versatile and, because they make the mill flow diagram more flexible, are excellent tools for maintaining mill balance. The miller can change the flaps on the collection trays below the sieves to direct the middlings to reduction rolls. Purifiers aid greatly in the production of patent flour with low ash and good color. They are essential in producing granular products, like farina and semolina.

However, in recent years, the role of purifiers in the mill flow diagram has diminished as millers have evaluated their cost effectiveness. The trend has been toward higher ash in bakers' flour grades and less demand for low-ash patent flour, which decreases the need for extensive purification. Purifiers require considerable air to operate. When purifiers are used in the reduction and tailing systems, the air dries the material, which increases bran breakage, thus increasing the ash content of the flour. Although in mills that control the relative humidity such drying is minimized, modern flow diagrams have eliminated the use of purifiers in the reduction and tailings systems. However, the moisture content is high in the break system middlings, and purifiers can be used to clean the middlings with little loss of moisture. Purifiers are used to clean the middlings from the break system in the flow diagram today. The skill of the operator plays an important part in the successful operation of purifiers, and with fewer personnel in the mills, monitoring and proper adjustment of the purifiers is difficult. Poor milling results often are caused by purifiers that are out of adjustment.

The Purifier Surface

The purifier surface can be expressed as the width of the sieve and the total area of the sieves. The width of the sieve determines the depth of material on the screen at the entry. This is the critical factor in determining the capacity of the machine.

The amount of purifier surface used in the mill flow diagram depends on the type of wheat milled and the finished products produced. Durum semolina mills require the most purifier surface and soft wheat mills the least. The finished product from a durum mill, semolina, is granular, and the bran can be removed only by purifiers, not by grinding and sieving as in soft and bread wheat flours. Many soft wheat mills use purifiers only on the coarse middlings, to remove the germ and bran particles, or not at all.

Hard wheat mills usually use purifiers on the primary middlings from the beak and sizings system. Additional purifiers are required for repurification of middlings to produce farinas.

3.2.4. Mill Flow Sheet Design

The mill flow sheet or mill diagram is the actual "road map" of the equipment and the flow of intermediate and final materials within the process. Designing the flow sheet and determining machine location in the mill is based on accumulated data, specifications calculated from the data, and subjective decisions by the designer. Types of wheat, types of flours to be produced, experience, and collected data from previous operations are the basis for the flow sheet design.

Steps in Mill Flow Sheet Design

To a large extent, the flow sheet design is a road map for all the numerous intermediate materials generated in the milling process. Decisions concerning where to direct these intermediate materials are based on the individual characteristics of the material. The decisions are affected by factors such as differences in particle size, the amount of pure endosperm or other constituents of the wheat kernel, and the amount of particles that are still made up of different constituents, such as endosperm that is still attached to bran.

The terms "long" and "short" mill flow sheet refer respectively to the incorporation of more or less machine surface. The length of the flow sheet determines the specific load level to the different machines in the mill. The level of similarity of the materials flowing to each stage and their respective physical characteristics, size, and shape also are determined. Longer flows, with greater quantities of grinding and shifting area, can classify the intermediate materials more specifically. This allows the miller to handle each classification separately to maximize the separation of bran and germ from the endosperm and to produce the greatest amount of flour. Such a long flow gives greater flexibility and produces higher extractions, usually with lower quantities of bran and germ particles in the flours. Shorter flows utilize less equipment in the milling system, which reduces the miller's ability to handle large variations in wheat quality while still producing optimum results.

The mill designer estimates the loads to different machines within the mill based on data for different wheats and different mill capacities. Knowing the specific loads to the machines allows the designer to allocate roll surface and sifter area for each classification in the mill.

3.3. Flour Handling and Blending

The flour-handling system can be a very simple on-stream packing operation; a simple load-or facility into bulk trucks and rail cars, with only a surge storage bin to hold the flour stream from the mill between switches; or an extensive storage and flour-blending system to ensure uniform quality of the flour shipments and to treat the flour for special products. The flour-blending department often has facilities for such treatments of the flour as infestation control, enrichment and additives, flour stabilization, flour drying, fine grinding, and air classifications. The system can employ a process computer for fully automatic operation of the flour blending, final packing, invoicing, and loading for shipment to the customer.

The on-stream system require that all the *flour treatment* and final rebolt sifting be done in the mill. Special feeders are used to feed very small amounts of ingredients and enrichments to the flour stream, which is agitated at high speed in a nonmetal agitator. there is no room for mistakes, and coordination with transportation is critical. Uniform wheat mixes and online quality control also are important. Variations in flour quality that max occur from the wheat mix or the milling process are passed on to the customer or are unloaded and rehandled at extra expense. The advantages of the system are low capital costs and low operational expenses.

Most modern mills have more extensive storage and flour-blending systems. They provide facilities for storing and blending flour to ensure uniform flour quality. Flour quality is analyzed as the flour goes into the storage bins, and blending produces a flour of known quality characteristics before shipment. Some mills manufacture basic flour grades for storafe and blend from these bins in the proper percentages to meet the flour specifications of the customer. his provides the maximum flexibility for producing flour grades without mill adjustment, where length of run and other factors could make it impossible to change the milling system for a short run of a given grade of flour. It also improves milling effeciency by optimizing the mill adjustment over a longer period.

Many mills also provide sufficient flour storage capacity to pack or loaf on the day shift only in order to save labor costs and better control the operation while the laboratory and management staff is present. This operation can be expanded to include special treatment of the flour for certain customers, such as flour drying, air classification, stabilization of enzymatic action, and addition of ingredients. An expensive flour-handling system adds to the cost of the operation, but it gives millers more control of the final flour quality and, thus, provides better service to the mill customers.

Flour Storage and Blending

Pneumatic lines conveying the flour from the mill can be directed through electronically activated valves to the appropriate bins according to quality. Mills chill the positive pneumatic conveying air to reduce the flour temperature after milling and before storage; cooling reduces condensation on the exposed inside surface of the bin.

Flour storage capacity in the mill is related to operational issues, regulations, and economic feasibility. The number and capacity of flour bins depends on the mill size, the number of flour types produced, and the expected storage time after production. However, from the operational viewpoint, more and larger flour storage bins, more flour conveyors and accurate feeders under each bin, and the ability to blend flour from any bin with any other bin all add to the operators' flexibility. The ability to send flours or blends to different destinations at the same time that the mill production is binned allows the mill operators flexibility in running the mill and in producing different flour types. However, budget and space usually require some compromises in flexibility. In countries where oxidizing and bleaching chemicals are allowed in flour, these are blended in just before direct shipment to customers. In countries where additives are not permitted, flour is stored for up to 14 days so that natural *aging* can occur. The natural aging of flour takes longer for "strong" flours, i.e., those with high protein content and high-quality gluten. Accordingly, a mill should have flour storage bins or space in a warehouse of sufficient capacity to hold enough bagged flour to satisfy customer requirements.

The storage bins can be metal of concrete. The type of material depends on cost, maintenance, length of useful life, and size of each bin. Special attention must be given to a smooth surface on the inside of the bin walls and properly shaped hoppers to provide good discharge of the product from the bin. Flour bin outlets must be large enough to prevent arching. The hoppers should have a minimum slope angle of 75° on the side and sufficiently low friction to allow the material to flow along them. The inside wall surfaces of concrete bins usually are coated with epoxy to give them a smooth finish. Air-exhaust systems are necessary on top of the flour bins to prevent flour dust from escaping (causing housekeeping problems) and condensation from forming on the interior walls. The exhaust system is engineered so that flour bins that are not being filled are sealed to conserve the amount of air required for the system.

The flour-blending system can be continuous blending or batch blending. The continuous-blending system provides facilities to meter the flow of flour from each bon to any other bin or to the blending system, where different flours are blended onto a final homogeneous mix. This requires appropriate bin dischargers and feeders that guarantee a uniform flow of flour from the bins. The bin dischargers are usually screw conveyors modified to draw material evenly from across the full diameter or cross-section of the bin with either variable-diameter flights (tapered) or a variable-pitch screw.

Milling of Durum Wheat

Durum wheat is milled to flour or to a granular endosperm product called semolina, which is used for the production of pasta products. Semolina differs from farina in that the latter can be produced from any wheat but semolina is made only from durum.

Semolina is defined similarly except that it is made only of durum wheat, and its maximum dry ash content is 0.92%.

Durum wheat, which originated in the Mediterranean Basin, is also used in many of the surrounding countries for other local foods.

The durum kernel is usually vitreous and much harder than that of common hard wheat. When reduced to flour, the percentage of damaged starch from the endosperm is higher than for kernels of other wheats. This can be a very important factor in quality control, especially where durum flours are blended with other wheat flours.

It is more critical to achieve balance of the load to the different machines, especially the purifiers, when milling durum than when milling other varieties of wheat. Therefore, the miller must have a thorough understanding of the following basic factors: the paste manufacturer's specific requirement; good wheat selection and handling procedures; efficiency in the cleaning house, conditioning and blending; grinding techniques; efficient stock classifications, sifting, and purification; and control of the environmental conditions in the milling facility. While these factors are important in processing all wheat flour, they are especially so in milling durum.

Durum Wheat Quality

Therefore, durum wheat protein levels for semolina milling should be between 13 an 16%, taking into account an estimated loss of about 1% in protein between wheat and semolina. The above difference between wheat and semolina protein content should be determined for each mill. Other wheat characteristics such as test weight and 1,000-kernel weight, sprout damage, gluten strength, kernel color, and kernel vitreousness or discoloration are important factors in the determination of durum quality. White spots in the pasta are the result of using yellow berry kernels; the endosperm particles of such kernels cause inadequate hydration and mixing of semolina. The percentage of vitreous kernels in the wheat is negatively related to fine flour (through 100 U.S. mesh) produced during milling and is positively related to the protein level.

3.4. Food Safety and Hygiene in the Flour Mill

Government agencies, worldwide inspect flour mills and enforce a variety of regulations concerning the flour milling industry. Such regulations apply to the grain producer, the miller, and the end-users of the flour. Accordingly, it is in the miller's interest to be aware of the regulations, which affect the technology, reputation, and safety of the products. Food safety and compliance with manufacturing standards are also demanded by mill customers because end-users of flour are required to use raw ingredients that comply with standards and good manufacturing practices (GMPs). Numerous publications deal with the issues of food safety, surveillance, risk prevention, and control systems such as *hazard analysis critical control points (HACCP).* In addition, various organizations have developed programs for third-party audit in operating plants.

Hygiene in the mill is part of a complete mill sanitation program. The program needs the support of management and all employees to guarantee that safe products are delivered to customers. Management leadership, education, enforcement, and audits are needed in all stages of the plant. Mills and Pedersen (1990) published a flour mill sanitation manual, which includes factors responsible for product contamination, information about an integrated pest control management program, and a sanitation guide for application in a flour mill.

Infestation and Pest Control

Control of pests that infest the mill is a major issue in all flour mills around the world. Accordingly, it is the mill manager's direct responsibility to make sure that the appropriate steps are taken by persons certified to deal with the issue. Problems with infestation and its control have a direct relationship to mill operation time, shutdown, customer complaints, and long-range investment and planning. Pests in flour mills include insects, rodents, birds, and microbes.

Insects that infest flour mills are susceptible to very low temperatures and are quickly killed. (Although this method is used in the mill, it is not practical in flour storage areas because of the insulating properties of flour.) In winter, during subzero temperatures, the practice of opening the mill building and allowing it to cool down can be used where climatic conditions allow. This treatment, if scheduled properly, is an inexpensive method of eliminating or reducing insect infestation. Cotton et al (1945) described precautions to be taken before opening windows and doors. It is necessary to drain all steam lines and radiators and empty all receptacles containing liquids that freeze. Accumulation of milling stock or sweepings from the floors of the mill should be removed and elevator boots cleaned out as they can protect live insects during subzero temperatures.

The flour beetles of the genus Tribolium, which constitute the greater part of the insect population of a flour mill, are susceptible to cold and can be killed readily in 24 hr by exposure to subzero temperatures. Whenever there is a prospect of two or three days of subzero weather, it would seem well worthwhile for mill managers to take advantage of the situation by arranging for a "freeze-out" of their mills.

ISO in the Flour Milling Industry

ISO 9000

In 1987, the International Organization for Standardization (ISO) issued the ISO 9000 series of international standards, which are generic standards for quality management and quality assurance (Hedman,1994). Numerous publications were published on the ISO issue and its application in different industries and services. Lamprecht (1993) described the process of implementing an ISO 9000 quality assurance system in small and large companies in a work-book format. The ISO standard contributes to global homogeneity by creating a similar approach to evaluation, quality control, and services worldwide. It is unique in that it is a market-driven standard that does not rely on regulations but exists solely for the competitive advantage of companies that apply it. The impact of the ISO standard on any industry is that if one segment or plant adopts the standard, all its suppliers also need to be certified. The ISO standards are becoming a prerequisite for company certification. The ISO series consist of the following:

ISO 9000. Quality Management and Quality Assurance Standards: Guidelines for Selection and Use.

ISO 9001. Quality Systems: Model for Quality Assurance in Design/Development, Production, Installation, and Servicing.

ISO 9002. Quality Systems: Model for Quality Assurance in Production and Installation.

ISO 9003. Quality System: Model for Quality Assurance in Final Inspection and Test.

ISO 9004. Quality Management and Quality System Elements Guidelines.

The ISO standards do not specify or require adoption of a particular or regulated quality system. ISO registration certifies only that the organization has its unique quality system. Registration requires that companies document the quality system they have already set up and are able to prove that they adhere to that system while manufacturing their products or providing a service.

The unique characteristics of the flour milling system require adoption of quality control methods and procedures that, in the long run, improve mill performance. Documentation of break releases, typical ash curves, and typical granulation curves for different kinds of wheat are some of the records that help to improve mill performance. Documentation of stock size distribution and the ash of different fractions can indicate corrugation wear and the need to refurbish rolls. Because the mill's final products depend heavily on the ever-changing characteristics of the raw material, wheat receiving and evaluation are significant parts of the ISO program. Procedures that guarantee representative sampling of incoming wheat and other materials, sending that information to data collection, and recording the information throughout the operation form the basis for the ISO system.

ISO 14000

While the ISO 9000 provides companies with a standard system for practicing quality, the ISO 14000 is a set of standards that addresses environmental concerns. The ISO 14000 standards seek to promote a common approach to environmental protection programs. They cover the following topics (Giese, 1996): environmental management systems; environmental auditing; environmental performance systems; environmental labeling, terms, and definitions; life cycle assessment; and environmental aspect in product standards. The flour milling industry also deals with issues related to ISO 14000 such as packaging materials, air filtration, and wastewater. The ISO 14001 creates a system of guidelines to follow in relation to the efficient use of natural resources, waste reduction and recycle of refuse, reduced pollution as a result of transportation, as well as energy savings per unit of productions. The following are some of the ISO 14000 series Standards:

14000. Guide to Environmental Management Systems: General Guidelines.
14001. Environmental Management Systems: Specifications.
14010. Guidelines for Environmental Auditing: General Principles.
14011. Guidelines for Environmental Auditing: Audit Procedures.
14012. Guidelines for Environmental Auditing: Qualification Criteria for Auditors.
14020/24. Environmental Labeling.
14031/32. Guidelines on Environmental Performance Evaluation.
14040/43. Life Cycle Assessment: General Principles and Practices.

Good Manufacturing Practices

Methods for GMPs vary among mill location and countries. Guidelines for food plants and flour mills developed by the Food Protection Committee (1995) of the Association of Operative Millers (AOM, now the International AOM) include the following topics: legal aspects of regulatory compliance, insects pests of the foods industry, insect controls by chemicals, rodents and rodent control, birds and bird control, employee practices, laboratory detection of contaminants, and programming sanitation. Internal rules and regulations are implemented and enforced regarding wheat receiving, storage, cleaning, and milling; end-product storage, blending, and packing; and truck and rail car cleaning and loading. Testing, cleanliness, and organization are the fundamentals of a good system.

HACCP in the Flour Milling Industry

HACCP is a program applied in food processing and other operations within the food industry, from production to consumption. Point critical to safety of food are identified and are systematically monitored and controlled to prevent the creation of hazardous product. In many cases, the HACCP system is incorporated into the mill's ISO standard 9000 regarding quality parameters of mill products. The flour milling industry could be considered to have low risk of producing hazardous products because of the low water activity in mill products. The hazard is decreased further in the final products since wheat flour is, in many cases, the raw material for baking, which is a heat-intensive process. Nevertheless, it is good practice to implement a HACCP program. In the first place, a HACCP program is needed to accommodate flour customers who mandate HACCP for their own operations and from the suppliers of their raw materials, including the mill. Secondly, the HACCP program is a preventive approach to food safety.

When HACCP is properly developed and applied, there is a reasonable expectation that the flour mill using the strategy should receive economic benefits. Such benefits are gained through better process control, which result in the reduction and elimination of defects from the milling process. Accordingly, the HACCP system is described in Chapter 16, on mill management, because the essential first step for the success of the program is management commitment. It is the responsibility of mill management to motivate, implement, and control the application of the program. Identification of CCP as well as implementation of control procedures should be worked out by a team. The HACCP team should have, in addition to a coordinator, one representative from each operating department or discipline (Vail, 1994). The team should keep producers and documentation as simple as possible without sacrificing protection. A plant tram is familiar with the plant and business and can make sure that none of the critical points are overlooked. Employee training is key to successful implementation. Employees must learn which control point are critical in an operation and what the critical limits are at these points, for each preparation step they perform. (FDA,1999).

Similar programs and regulations have also been published in the European Community. The "white book" of the European Commission (Directive 93/94/ECC on Hygiene of Foodstuff Manufacturing, Altering, Packaging, and Transportation) is similar to the HACCP program and is now part of national legislation in all EC member states. The directive promotes the protection of human health and consumer trust in foreign and local foods.

4. CORN MILLING

Milling of Grains Other than Wheat

4.1. DRY CORN MILLING

The corn kernel presents a number of problems for the miller. It is large, hard, flat, and, in addition, contains a larger germ than other cereals (~12% of the kernel). The germ is high in fat (34%) and must be removed if the product is to be stored without becoming rancic.. In the traditional stone-grinding of cornmeal, the germ is not removed however, even though the product is generally not shipped very far, it is often rancid. In corn milling, the desired products are low-fat grits rather than corn flour. Thus, the miller wants to remove the hull (that is, the pericarp, seed coat, and aleurone layers) and germ without reducing the endosperm to small particle size. The most effective way to accomplish this is with a degerminator, a specialized attrition mill. It is basically two cone-shaped surfaces, one rotating inside the other. They rub the corn to remove the hull and break the germ free. Generally, the corn is tempered to a high moisture content (~21%) before it is degermed. This allows easier separation of the germ from the endosperm.

Entoleters have also been used for degerming. The entoleter is an impact device rather than an attrition mill. The corn enters the machine by falling on a rapidly rotating disk containing pins. It is forcefully thrown against the wall and degermed by the impact.

After the germ and hull are removed, the endosperm is reduced to grits of the desired size by roller milling much in the fashion of wheat milling. It is usually dried to obtain a desired moisture content. The dry corn mill is basically a break system, as flour is not the desired product. The hulls are sold as animal feed, and the germ is processed to recover the valuable oil.

4.2. Wet Milling: Production of Starch, Oil and Protein

Dry milling is primarily concerned with separation of the anatomical parts of the grain. Wet milling strives for the same separations but also goes a set further and separates some of those parts into their chemical constituents. Thus, the primary products are starch, protein, oil and fiber instead of bran, germ and endosperm.

After a cleaning similar to that used in dry milling, the corn is steeped. Steeping involves submerging the corn in water containing 0,1-0.2% sulfur dioxide. The temperature is elevated and controlled at 48-52°C, and the steep time varies from 30 to 50 hr. As a result of steeping, the corn contains about 45% moisture and is softened sufficiently so that the softness can be detected by squeezing. About 6% of the corn kernels become soluble during the steeping process. Commercially, corn is steeped in tanks that may hold 3,000 bu of grain. The steeping system normally uses about 10 tanks, with the corn moving from tank 1 to tank 10 and the steep water moving from tank 10 to tank 1.

Sulfur dioxide, often generated by burning sulfur, is used for two reasons. First, it aids in stopping the growth of putrefactive organisms. Second, the bisulfite ion reacts with disulfide bonds in the matrix protein of corn and reduces the molecular weight of the proteins, making them more hydrophilic and more soluble. As a result, the release of starch from the protein matrix is much easier and the yield of starch is higher. During steeping, the level of sulfur dioxide in the steep water decreases as more of the bisulfite ion reacts with the protein. Corn that has been dried at excessively high temperatures gives lower amount of soluble protein when steeped with bisulfite.

The starch still contains too much protein (~1%) at this point and must be purified by recentrifuging or with hydroclones. The hydroclones used here work on the same principle as those used to separate germ; however, they are much smaller in size, and larger numbers of them are used in sequences. Starch coming from them contains less than 0.3% protein and is ready for chemical modification, conversion to syrup, or drying to be sold as starch. Most drying is accomplished with flash dryers. The dewatered starch is injected into a rapidly moving stream of heated air. The granules are dried rapidly and collected with dust cyclones.

Notice that all the water enters at the final washing step and works its way back to the steep tanks. The concept of countercurrent flow of water and corn is sometimes difficult to grasp. It is not water flowing one direction in a pipe and corn flowing another. As the starch is washed, the wash water removed from the starch is used in a preceding step of the flow. This process is then repeated until the water is in the steep tanks. There are no effluent streams; the system is bottled up, and water leaves the plant only as water vapor.

5. Rice Processing

The three grains discussed in this chapter are similar in that all are harvested with the hulls attached. The other cereals lose their hulls during the threshing step and are handled as naked grains. As might be expected, the first step in processing cereals is to remove the hulls. Barley's hull tightly adheres (in fact, is „cemented") to the outer layers of the pericarp. The hull of rice or oats is, instead, a separate intact structure that essentially surrounds the grain with no bonding between the grain and hull.

Rice with the hull on called paddy or rough rice. About 20% of paddy rice is hull. The kernel remaining after the hull is removed is brown rice.

The most common huller used today is the rubber-roll sheller made in Japan. The rough rice is passed between two rubber-coated rolls that turn in opposite directions and are run at a differential (different speeds). The pressure and shear remove the hulls as much rubbing peanuts between your hands removes the shells. The pressure exerted by the rolls can be varied, as different cultivars may require different pressures for adequate shelling. Excessive pressure may discolor the grain and cut down the life of the rolls, which is already limited. The rolls must be replaces every 100-150 hr.

Rubber-rolled shellers are preferred because of their efficiency in removing hull (>90%) and because they cause less breakage than the older types of shellers. One older type is the disk sheller, which has a horizontal abrasive-surfaced wheel that rotates on a vertical axis just below a stationary abrasive-surfaced wheel. Rough rice enters through an opening in the center of the stationary top wheel and, because of the spinning bottom wheel, brown rice flows out between the two wheels. The abrasive action of the wheels on the rice hull essentially sands off part of the hull and frees the brown rice. This type is less efficient and results in more breakage.

After separation, the hull is removed by aspiration, and the remaining rough rice is separated

from the brown rice. The separation, which is based on bulk density, can be made on a gravity separator (sometimes called a paddy machine). The paddy is returned for another pass through the sheller. Products at this point are hulls, brown rice and broken brown rice.
It is common knowledge that brown rice is more nutritious than white (milled) rice, but hardly anyone eats brown rice. The last sentence is undoubtedly true. The reason behind this situation could be debated, but, in general, we eat not for nutrition but for other, complex reasons. For one thing the cooking time of brown rice is much longer than that for white rice. Undoubtedly a strong relationship exists between the preferences of eating white or brown rice and those for eating white or brown bread.
The milling of brown rice is essentially the removal of the bran by pearling. Dry calcium carbonate (about 3.3 g/kg) is added to the brown rice. The calcium carbonate is an abrasive that helps in removing the bran. In some cultivars of rice, the bran adheres to the grain more tightly than in others, and a small amount of water may be added to soften bran layers.
????…of silica is unknown; however, silica has been related to disease resistance in rice. Whatever the reason, the silica must be deposited somewhere in the plant, and the hull is the depository for much of it.
Numerous uses for rice hulls have been suggested in the literature. However, the disposal or utilization of them still remains a major problem. Estimates indicate that, of the hulls produced, as much as one third is not utilized. Early workers felt that hulls were dangerous in feed, but this has been disproved. The most common use of hulls is to mix them with rice bran and sell them as rice millfeed. Such products generally contain about 61% hull, 35% bran, and 4% polish.
Hulls can also be used as bedding or litter, as a fertilizer or mulch, and in number of industrial uses, including burning for fuel. They are essentially sulfur free. The heat produced may be two-thirds that of wood. Small amounts of hulls are used to produce carbon also furfural. The rice hull yield of furfural, an important organic intermediate, is low compared to the yield from such sources as oat hulls, cottonseed hulls, or corn cobs and is generally related to the pentosan level. Small amounts of hulls are also used as a filter aids or abrasives.

RICE BRAN AND POLISH

Rice bran and polish are by-products from rice-milling. The bran is the outer layer of the pericap from brown rice; the polish is the inner layers, containing aleurone cells and small amounts of starchy endosperm. As might be expected, the amounts of bran and polish vary widely, depending on the milling procedure employed. As stated earlier, bran normally is about 8% of brown rice and polish about 2%. The general composition of the two fractions is shown in Table I. In addition to the values shown, rice bran ash is high in magnesium, potassium, and phosphorus. Rice bran has also been shown to reduce cholesterol. Bran is also an excellent source of B-vitamins (typical values are thiamin, 10.6; riboflavin, 5.7; niacin, 309; and pyridoxine, 19,2 µg/g) and vitamin E but contains a little or no vitamins A, C, or D.

The utilization of rice bran and polish is nota s great as one might expect from their composition. Both bran and polish are excellent sources of nutrients in animal feeds. However, when rice bran is stored without inactivation of lipase, the fat in the bran rapidly becomes hydrolyzed and oxidized, causing the bran to become rancid and unpalatable. The bran, particularly if it is damp, is an excellent growth media for microflora, the microflora can produce mycotoxins and bacterial toxins. When either of those conditions prevails, the bran cannot be used as a feed and therefore is used as a fuel or fertilizer.

Rice bran is a source of oil. Generally, the bran is solvent-extracted. It contains appreciable amounts of wax that must be separated from the oil. After refining, rice oil is comparable to other edible oils.

RICE QUALITY

As with most food products, the quality of rice is determined by its ability to produce the desired end product. Because most rice is consumed as whole kernels, the milling yield of head rice is an important quality factor. Consumer acceptance varies from country to county and even between regions within a specific country. Most U.S. consumers prefer rice that cooks to produce dry and fluffy kernels. Each kernel should retain its shape and separate identity after cooking. Other consumers, particularly in Asia, prefer rice that cooks to be moist and chewy, with the kernels sticking together.

Rice cultivars grown in the United States are divided by grain size and shape into three types: short-, medium-, and long-grained. Typical long-grain types are dry and fluffy after cooking and are preferred for quick-cooking rice, canned rice, canned soups, and convenience foods containing rice. Typical short- and medium-grain types cook moist and sticky and are suitable for breakfast cereals, baby foods, and brewing.

In the United States, all rice is bland in taste and translucent in appearance. A small amount of waxy rice (with all-amylopectin starch) is grown; it generally has an opaque endosperm. In other parts of the world, many rice cultivars are scented (aromatic). These usually yield poorly, but in many countries small areas are grown by farmers for their personal use.

Rice varies rather widely in a number of physicochemical properties. This is in contrast to other grains. For example, the amylase content of rice starch varies widely, depending upon the cultivar and type. U.S. long-grain cultivars are characterized by higher amylase content (23-27%) than are short- and medium-grain types (15-21%). These differences in amylase content greatly change many other properties of the rice. However, recent data suggest that the amylase content may not actually vary. The apparent amylase content does vary, but this may actually be because of differences in the amylopectin structure.

Rice endosperm varies in its composition more than do the endosperms of other cereals. Flour abraded from the outer layer of miller rice may contain 20% protein, whereas the total milled kernel may contain only 8%. Similar results have been reported for lipids (6% compared to 0.3%), vitamins (four to eight times higher in the outer layers), and certain minerals. The starch content, of course, changes in the opposite direction from the protein content: that is, starch content is higher in the center of the endosperm and lower at the outer edges. This type of data must be examined carefully, as a small amount of aleurone left on the outside of the milled kernel could after the data significantly.

QUICK-COOKING RICE

Milled rice requires 20-35 min to cook. This relatively long time is caused by the slow rate at which water diffuses into the kernel. Most rice is translucent and thus tightly packed, with no air space or other channel for water to penetrate the kernel. For cooking to occur, water must penetrate to the center of the kernel with sufficient heat capacity to gelatinize the starch. Thus, to produce a quick-cooking rice, we need to provide channels for water to penetrate the kernel during cooking.

Several techniques are used to produce quick-cooking rice. One is precooking to about 60% moisture (fully cooked rice contains about 80% moisture), followed by slow frying to 8% moisture; this process allows the rice at about 10% moisture, which causes internal fissuring. Pregelatinization, as described above, and rolling or bumping the grains followed by drying produces a relatively flatter grain (which means that water has less distance to diffuse during cooking). Precooking followed by freezing, thawing, and drying or puffing by rapid changes in pressure have also been used to produce quick-cooking rice. In general, anything that opens the kernel and allows the water to penetrate readily decreases cooking time. As a result of most of the methods used to produce quick-cooking rice, the uncooked kernels become opaque and larger in volume.

PARBOILED RICE

Parboiling, the process of heating paddy rice in water and then drying it, has been practiced since ancient times. It was probably started to aid in dehusking (dehulling). Today we know that its major advantage is nutritional. As mentioned earlier, much of the vitamin and mineral content if rice is concentrated in the outer layers. Parboiling helps to move these nutrients into the kernel.

It is estimated that as much as 25% of world rice is parboiled. Its major consumption is in India, Sri Lanka, and parts of Africa. Very little parboiled rice is consumed in Asia.

Parboiling consists of three steps; steeping, steaming, and drying. Steeping is generally done at about 60°C. Lower temperatures require longer times, and thus the chances of fermentation, sprouting, and other side effects are greater. After the steeping, the excess water is removed, and the paddy is heated with steam of gelatinize the starch and sterilize the paddy. The gelatinization of the starch traps the vitamins in the endosperm. The rice can be rapidly dried to about 18-20% moisture and then dried more slowly (this avoids cracking and frissuring).

Parboiled rice is not quick cooking. In fact, it requires slightly longer cooking times. Parboiled rice has advantages and disadvantages relative to its regularly milled counterpart. The major advantages are: a higher yield of head rice from milling because the kernel is more resistant to breakage, more resistant to insects, more nutritiousness (particularly more vitamin B1), and less tendency to become sticky or mushy during cooking. This, of course, explains why the process is not popular in Asia, where consumers do want a sticky rice. The major disadvantages are a darker color, a slightly different flavor, and increased susceptibility to rancidity.

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