CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Czech University of Life Sciences Prague
Faculty of Tropical AgriSciences

The Quest for the Holy Grail - which composite flour is the best?

Bachelor´s Thesis

Prague 2016

Supervisor:
Ing. Olga Leuner, Ph.D.

Author:
Anna Pavelková

Declaration

I declare that I have written my bachelor thesis on a topic "The Quest for the Holy Grail - which composite flour is the best?" all by myself with the help of literature listed in references.

In Prague, 2016

. . . .

Anna Pavelková

Acknowledgement

I would like to thank my supervisor Ing. Olga Leuner, Ph.D. for her supportive attitude and for her advice, especially for helping me to choose suitable and important flours and also helping me with choosing appropriate groups of people with special needs.

Also I would like to thank Mrs. Anna Chalašová for grammar corrections in my thesis.

Abstract

Composite flour is a very wide topic, and the interest about this topic has increased in recent years. Composite flours are created because of availability of raw materials and also because of dietary reasons. The bachelor´s thesis is an overview related to this issue, focusing on bakery products, especially bread.

The composition of flour was generally described at the beginning of this thesis and the other part of this literature review provides an overview of most of the ingredients which are added to baked goods, their properties, composition and their impact on the bakery products. Subsequently, the following plants, which are used to produce flours, were selected, they were: wheat, rye, barley, oats, maize, rice, buckwheat and quinoa. The overview of flours made from these plants, their main advantages and disadvantages were summarized in the table in Annex. This literature review shows that when the flours and other ingredients are combining properly, the final products have a really good nutritional value and taste. Not only flours but also other ingredients influence nutritive value, taste and structural properties of the dough and of the final products.

The last section was focused on specific groups of people and appropriate composition of bread. It also describes the problems of gluten-free bread. According to this literature review, great potential in composite flours have pseudocereals, such as amaranth, quinoa and buckwheat.

Keywords: bread, baking quality, composite flour, gluten, protein, starch

Abstrakt

Kompozitní mouka je velice rozsáhlé téma a v posledních letech o něj značně vzrůstá zájem. Kompozitní mouky vznikají jednak z důvodů dostupnosti surovin a jednak z důvodů dietetických. Bakalářská práce je přehledem týkající se této problematiky, se zaměřením na pečivo, zejména na chléb.

Na začátku této práce bylo popsáno složení mouky obecně a další část této literární rešerše obsahuje přehled většiny ingrediencí, které se do pečiva přidávají, jejich vlastnosti, složení a vliv na pečivo. Poté byly vybrány následující rostliny, které se využívají k výrobě mouky, byly to: pšenice, žito, ječmen, oves, kukuřice, rýže, pohanka, merlík. Přehled mouk z těchto rostlin, jejich hlavní výhody a nevýhody, byly shrnuty v tabulce v příloze. Z této literární rešerše vyplývá, že jestliže jsou mouky a ostatní ingredience vhodně zkombinovány, finální výrobky mají opravdu dobrou nutriční hodnotu a chuť. Nejen mouky, ale i další ingredience ovlivňují nutriční hodnotu, chuť a strukturální vlastnosti těsta i konečného výrobku.

Poslední část byla zaměřena na určité skupiny lidí a vhodné složení pečiva. Je zde také popsána problematika bezlepkového pečiva. Podle této rešerše, značný potenciál v oblasti kompozitních mouk mají pseudoobiloviny, jako je – amarant, merlík a pohanka.

Klíčová slova: chleba, kompozitní mouka, pekařská kvalita, protein, lepek, škrob

Content

List of figures

List of tables

List of abbreviations

FAO	Food and Agriculture Organization of the United Nations
NRI	Natural Resources Institute
TNO	Institute for Cereals, Flour and Bread
TPI	Tropical Products Institute
WIS	Water-insoluble pentosanes
WPI	Whey protein isolate
WS	Water-soluble pentosanes

1 Introduction

The composite flour firstly it can be a blend of wheat and non-wheat flours, determined for the production of leavened or no-leavened baked products. Secondly it can be blend of flours without wheat (100% non-wheat flour). These other flours (non-wheat) can be made from legumes, roots, tubers, cereals or from other materials. There are several reasons for adding available cereals and other crops to the wheat.

This addition ensures that wheat is less needed in areas where wheat is uneasily grown because of the local climate or because of other problems. Consequently, this substitution of wheat can encourage the local agricultural sector and the imports of wheat can be lower at the same time (Dendy, 1992).

The other important reason for the substitution of wheat flour is health problems that prevent people from consuming wheat products, there are people with allergies to wheat and people with coeliac disease (intestinal intolerance to gluten). There are also a lot of groups of people with special dietary needs and products made strictly only from wheat flour are not nutritiously sufficient for them. Other cereals and crops, especially the non-traditional ones have a much better nutritional value, often even better digestibility and they help prevent or fight various diseases (Christa, 2008).

Last but not least, the reason for adding of non-traditional crops is that thanks to their higher protein content, starch, vitamins and minerals, the use of composite flour can decrease malnutrition in some developing regions (Dendy, 1992).

Nowadays, a lot of products made from composite flour exist. For example the global market for gluten-free products develops rapidly and provides great opportunities for the industry. Sales of products such as non-wheat breads and other bakery products increased over the last three years by almost 120 % (Kohout and Pavlíčková, 2009).

The addition of other flours to the wheat flour or replacing wheat flour influences the properties of the dough and the technology of the baking process. Therefore, it is important to explore rheological properties in order to optimize the amount of added ingredients. If the suitable amount of non-traditional ingredients is added the negative influence in production technology is reduced (Matz, 1987).

Sometimes, especially when wheat flour is completely replaced by other flours, there are problems with quality properties of the bread. For example: unattractive appearance of these breads, such as compact crumb texture and low specific volume (Brites *et al*., 2010). One of the other problems with gluten-free breads is a lack of cohesiveness and resilience (Matos and Rosell, 2012). These factors are improved by many substances which can be added to the dough. It is important to be concerned about this topic of composite flours in bakery products in terms of finding suitable ratios among flours and improving the quality aspects of these products. It is also important to collect the results of many studies which were connected to this topic in terms of overview creation of the gained facts.

2 The aim of the thesis

The aim of this thesis was to provide comprehensive list of ingredients used during baking with a focus on their role in the dough and influence on the quality of the final products.

The aim of this thesis was not to suggest the best composite flour (because such a thing does not exist), but rather to summarize possible ingredients in composite flours - not only flour but in bakery products generally - so that each reader (scientists, operating experts or general public) can easily compile an appropriate recipe for desired diet/quality. Selected most common diets (gluten-free, protein and slimming) are discussed separately.

3 Methods

A search-compilation method was used for the Bachelor´s thesis. For the general characteristic – composition of flour and bread ingredients were used mostly printed resources and also electronic resources. For the characterization of composition of flours from certain crops and of bakery products from concrete composite flours were used mainly electronic resources, especially articles from scientific journals.

An important source of information was the website ResearchGate and Web of Science. From these databases/websites was the information used from scientific journals, articles including many studies and thesis. Also website of Czech National Library of Technology was an important source of scientific articles. The Bachelor's thesis is complemented with pictures and tables for better orientation in this issue.

This Bachelor´s thesis was written according to Methodical Manual for the Writing of Bachelor's Theses (2016). References were cited by Citation Rules of the Faculty of Tropical AgriSciences for writing theses in English (2014).

4 Literature review

4.1 History of composite flours

The first composite flours appeared in ancient times. The most used non-wheat product was barley, bread containing a large amount of barley was known as food for poor people.

Also rye, oats, and beans were added to wheat flour but it was too expensive for ordinary people. So bran was added to whole wheat flour for the poor to make sure that people buy the white flour bread.

By the end of the 19th century, the import of wheat in Britain was large. During the First World War and also during the Second World War, the imports were reduced so it was necessary to add non-wheat materials to bread (Dendy, 1992).

Until the 1960s, scientist did not have scientific interest in composite flours. The interest about composite flours came due to many reasons. Firstly, there were recent discoveries in starch chemistry and baking technology and it made it possible to use the composites. Secondly, people started to be interested in the food problems of the newly emerging nations of the tropics. The first interest of composite flour technology had Pierre Chatelanat and the FAO. Pierre Chatelanat noted that wheat flour was expensive in Papua New Guinea and after an agreement from FAO he provided a preliminary study at Wageningen, the Netherlands. This study was about using cassava in bread. There were three international organizations which were active at the beginning of composite flour research: the Tropical Products Institute (TPI), now the Natural Resources Institute (NRI), UK, Kansas State University (USA), and the Institute for Cereals, Flour and Bread (TNO), Wageningen. TNO had made a discovery which excited people´s interest in composite flours. It was found that the weaker wheats and certain surfactants could be used to form the dough structure. The structure and volume of bread stayed unchanged. This work was moved to Colombia and the pilot bread, which contained 30 % of cassava, was made.

It was easy to attract authorities that this topic about composite flours is really important. Many researches took place, students usually took a basic research using only kitchen equipment. However, the actual consumer trials were not that successful. They were successful for example in Colombia, Kenya, Nigeria, Sri Lanka, and Sudan because there were laboratories with excellent equipment. The quality of composite flour bread was much higher than bread from local bakers.

Then the Second Supplement to the Second Edition of the TPI Composite Flour Bibliography appeared in 1979, it contained 952 papers which had been published (Dendy, 1992).

4.2 Composition of flour

Flour is the powdery substance created when a dry grain is pulverized. This is referred to as the milling process. Flour consists of endosperm germ and brain. Endosperm is the center of starch, contains carbohydrates, proteins and a small amount of oil. Most simple white flours contain only this portion of the grain. The germ is a source of nutrients. Flour that retains the germ during the milling process will contain more vitamins, minerals and fiber. Brain is the outer husk of the grain, it is also known as bran. It adds mainly colour and fibre to flour. Bran gives whole grain flours the characteristic darker (brown) colour and rough texture (Moncel, 2015).

4.2.1 Proteins

According to Osborne´s classification from 1907 there are four groups of proteins. This classification is based on their solubility. These groups are: albumins (water-soluble), globulins (soluble in salt solutions), prolamins (soluble in 70% ethanol), glutelins (partially soluble in dilute acids and bases). These groups can be split into two main classes: non-gluten forming and gluten forming groups (Matz, 1987).

The non-gluten forming proteins are albumins and globulins. A dialysis step is used very often to separate the albumins and globulins. The globulins precipitate, the albumins stay in solution (Hudson, 2002).

The gluten forming proteins are prolamins and glutelins which are not soluble in water. These proteins are more important than the non-gluten forming ones because they are more useful during bakery. Prolamins and glutelins swell up in water and if we knead the dough at the same time, the energy from kneading and the atmospheric oxygen form a strong gel which we call gluten (Skoupil, 1994; Matějovský, 1995).

4.2.2 Lipids

Lipids are chemically esters of higher fatty acids and alcohol - glycerol. Lipids are soluble in alcohol but not in the water. There are mainly unsaturated fatty acids in flour (in it´ s chain have one or more double bonds) such as oleic acid, linoleic acid and smaller amount of saturated acids: palmitic acid and stearic acid. In contrast to wheat flour, the saturated lipids are the main part of lipids in the rye flour (Skoupil, 1994; Matějovský, 1995; Vodrážka, 1999; Mahdalová, 2012).

The negative property of fats is their tendency to go rancid. It is an oxidation process which depends on the presence of air, water, light, temperature and microorganisms. The catalysts of this reaction are specific enzymes – lypolitic enzymes which can split lipids.

Fats are split to glycerol and fatty acids and then split by other oxidative processes to aldehydes and ketones. They have an unpleasant taste and odour, flour lipids go rancid and destroy flour (Matějovský, 1995; Skoupil, 1994; Kadlec 2002; Mahdalová, 2012).

The presence of lipids in flour is necessary, especially phospholipid – lecithin, because when the dough is mixed with lecithin, it makes a complex with gluten which support gluten´s swelling capacity (Skoupil, 1994; Mahdalová, 2012)

4.2.3 Enzymes

The levels of enzymes depend on varieties and climatic conditions. A combination of various enzymes has a positive effect on volume, taste, aroma or colour and on many other properties, such as freshness. Albumins and globulins are contained in all cereal enzymes (Philips, 1989).

Alpha-amylase is one of the most important enzymes in wheat during making bakery products, especially bread. Alpha-amylase decomposes the starch into sugars which are fermented by the yeast. Changes in dough rheology caused by enzymes are the main reason for increasing bread volume. The alpha-amylase also slow down bread staling (it extends shelf life of products) (Hudson, 2002).

The negative process could happen if the starch grains in flour are too much destroyed during grinding grains. This fact together with the activity of amylase could cause too quick hydrolysis of starch during the fermentation in the dough. Consequently, a low molecular weight polymer chains are created too quickly which causes dough stickiness (Příhoda *et al.*, 2003).

On the other hand there are also enzymes which have negative effect on flour for example lypolitic enzymes which catalyse the reaction of flour to go rancid (they were mentioned earlier) (Skoupil, 1994; Matějovský, 1995).

4.2.4 Carbohydrates

The most important group of carbohydrates in flour is poly-carbohydrates. Poly-carbohydrates can be divided according to their function to the two groups, into storage carbohydrates and structural carbohydrates. The main representative of storage carbohydrates is starch. It creates the main part of flour (up to 80 % in wheat flour). The starch is located in the endosperm of grain. The important, previously overlooked components are non-starch poly-carbohydrates. The important functional part that is created by these carbohydrates is a fibre. Non-starch poly-carbohydrates are the main representatives of structural carbohydrates. The fibre is located in outer layers of the grain (Příhoda *et al*., 2003; Pečivová, 2006).

4.2.4.1 Starch

Starch - after swelling, gelatinization and saccharification – activates the yeast´s activities. Also it is the main part of crumb creation because it binds water after the denaturation of proteins (Matz, 1987). The starch is in grain and also in flour in the form of starch grains. Starch granules have a crystal structure. The starch contains two main parts - amylose and amylopectin. These two fractions are composed of molecules of glucose but they have a different glycosidic bound. Amylose has $1\rightarrow4$-α glycosidic bound and amylopectin has $1\rightarrow6$ glycosidic bound. Amylose and amylopectin have a different size of substitution in a wheat starch. The wheat contains about 25 % of amylose and 75 % of amylopectin. These two parts of starch have also a different structure so they have different chemical and physical properties. Amylose is water-soluble in a cool water. Amylopectin is not able to create solution with this water, it only swells up. Consequently, the starch is not soluble in water, in cool water it fill with water and swells up. With the increasing temperature the starch granules swell up more and more. As a result of increasing volume of starch grains, the viscosity of the suspension rises up. When the temperature of the water is higher, molecules of amylose release into the water. When the whole insoluble starch gelatinizes, the viscosity is getting lower. If this gel is cooled, the molecules of amylose and amylopectin start to re-associate and the viscosity increases (Matz, 1987; Matějovský 1995).

In fact, the starch grains in dough never become completely gelatinized during baking because there is not enough water in the dough for a complete gelatinization. So during baking the starch grains swell up and only their surface can be gelatinized. When the temperature of dough has increased, the amylose is partly dissolved in the gel, while amylopectin only changed it´ s structure. After cooling down the amylose is arranged to chains. A flexible starch gel is created which causes smoothness of the crumb. After some time the bakery products can go stale. It happens because of re-crystallization of the amylopectin. And also the water slowly disappears (especially during lower temperature), gel loses it´ s elasticity.

The starch included in the human organism (due to organism metabolism) is transformed to dextrins, maltose, glucose which is a quick source of energy (Matz, 1987; Příhoda *et al*., 2003; Mahdalová, 2012).

4.2.4.2 Fibre

Fibre is a part of the flour composed of indigestible or hard to digest polysaccharides. According to CODEX Alimentarius: Guidelines on nutrition labelling (Rev. 2011, Amendment 2013)*"Dietary fibre means carbohydrate polymers with ten or more monomeric units , which are not hydrolysed by the endogenous enzymes in the small intestine of humans and belong to the following categories: Edible carbohydrate polymers naturally occurring in the food as consumed; carbohydrate polymers, which have been obtained from food raw material by physical, enzymatic or chemical means and which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities; synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities*". The main representatives are cellulose and hemicellulose, as well as lignin, pectin´s substances, pentosanes, Β-glucans and fructans (Skoupil, 1994). Hemicellulose is insoluble in water (Příhoda *et al*., 2003). Cellulose is composed of chains of glucoses which have β-1, 4 glycosidic bound and is totally insoluble, even under normal conditions does not swell up (Kadlec, 2002; Mahdalová, 2012). Among physiologically important component of cereal fibre belong β-glucans, pentosans (arabinoxylans), and fructans.

The water-soluble, β-glucans and water-soluble pentosanes create in the stomach viscous, gel-like substance. Swelling of β-glucans and water-soluble pentosanes increases the viscosity of the chime in contact with water. The viscosity of the chyme causes a feeling of fullness and thus it is possible to prevent overeating and overweight. Β-glucans and water-soluble pentosanes do not change its structure in a small intestine. They are completely decomposed only in the colon by present microorganisms.

In contrast, the insoluble components of dietary fibre such as cellulose and water-insoluble pentosans are resistant to microbial degradation, these components are only partially fermented in colon (Sluková, 2011).

According to medical researches the fibre is healthful. It reduces the risk of vascular diseases and some kinds of cancer (Kadlec, 2002; Mahdalová, 2012). The fibre is still the object of investigation and many new studies show a new possible usage in the prevention of certain serious diseases of civilization (Sluková, 2011).

4.2.4.3 Beta-glucans

Beta-glucans are water soluble polycarbohydrates, they are mainly in rye and oats flour. Beta-glucans can create a high-viscosity gel. They have many positive effects on rye and oats bakery products. It can be seen in increasing of the products´ smoothness and the bakery product can be smooth longer. It has also a positive impact on physiological effect during digesting of rye products (Příhoda *et al*., 2003). Effect of β-glucans on cholesterol lowering is explained that β-glucans create a viscosity in a small intestine, it reduces the absorption of cholesterol and it causes its rapid excretion. B-glucans also reduce glucose levels in blood after meals by increasing peristalsis movements which helps to reduce the absorption of glucose (Sluková, 2011).

4.2.4.4 Water-soluble pentosanes (WS)

Water-soluble pentosanes are the second group of pentosanes (the first group, insoluble in water, are water-insoluble pentosanes (WIS)) (Kulp, 1992). The largest amount of water-soluble pentosanes is in rye flour (about 4-7 %); in wheat flour is 1-3 % of WS (Sluková, 2011). They influence the structure of dough because they create glycoproteins, compounds composed from proteins and carbohydrates (Příhoda *et al*., 2003).

4.2.4.5 Fructans

Fructans are digestible storage polysaccharide containing fructose with bound β- $(1 \rightarrow 2)$. Different types of fructans have a different structure and a molecular weight and can be divided into three groups: inulins, levans and branched structures.

The main source of fructans from cereals is wheat. Fructans can also be found in rye, where fructans´ content is about 4 % from the total fibre content (20 %). Fructans´ short chain isolated from plants have a sweet taste, it forms components of a natural low-calorie sweeteners. Fructans´ long chain are neutral in taste and produce an emulsion with a structure similar to fat (they can be used as ´fat mimetics´ - fat replacers).

The fructans, particularly fructooligosaccharides act in the colon as prebiotics and they are completely fermented into fatty acids with a short chain (acetic, propionic, butyric) (Sluková, 2011).

4.2.5 Ash

Ash in flour contains minerals which are left after burning the flour – it is residue on ignition (Skoupil, 1994). The main components of these minerals are: phosphorus, potassium, magnesium, calcium, sodium, sulphur, iron and manganese. Trace elements are copper, zinc, cobalt, silicon, chlorine, iodine and they are also biological active (Matějovský, 1995; Mahdalová, 2012).

4.3 Ingredients of bakery products

The ingredients which are added to the flour during making bakery products are really important. They affect the quality and nutritional value of products. Some of them are irreplaceable but most of them can be replaced. There are also many additives and improvers which can influence positively the quality of products.

4.3.1 Water

Water used for kneading bread dough has to meet requirements of potable water; it has to be sanitary water.

The structure of dough depends on the type of water. A soft water makes a freer and sticky dough which reduced water binding capacity. If the pH of the water is lower, the course of the maturation of dough is quicker. Volume of bread is larger but the colour of is not that bold (Příhoda *et al*., 2003; Kučerová, 2004; Müllerová, 2008).

Hard water slows the fermentation of the dough and highly strengthens the gluten. Alkaline water (pH above 8) slows the fermentation, and if the maturation of dough is not extended, it gives a lower bread volume. On the other hand bread has a good colour and a better texture of the crumb. Optimal pH for gluten and it´s development is about 5 - 6. If pH is 5-6 is above and below, gluten´s strength is reduced and it makes dough much more extensible (Dvořáková *et al*., 2011).

The natural water contains dissolved mineral salts, mainly calcium and magnesium, in the form of carbonates, sulphates and chlorides. The amount of mineral salts dissolved in the water cause physical and chemical changes in the dough because it strongly influences the activity of proteins. These changes of dough properties are positive – increasing the strength and elasticity of the dough (Matějovský, 1995).

Water has many positive effects on bread making process, there are some examples:

Water supports dissolution of substances composed of ions, e.g. sodium chloride produce the saturated solutions - the brine (Brine is a solution of salt (usually sodium chloride) in water). The concentration can be various, usually from 3.5 %) which is necessary to the manufacture of dough (Skoupil, 1994; Mahdalová, 2012).

4.3.2 Salt

Salt which is used in baking is chemically a sodium chloride. It´s quality must comply with the food regulations; it must be harmless to health. For the preparation of the dough is used - brine in concentration 26-29 % (Skoupil, 1994; Mahdalová, 2012). Salt in bakery production is not only flavouring but it is also a regulator of fermenting processes (Příhoda *et al*., 2003; Müllerová, 2008). Salt is never added to ferment because it could have the negative effect on the activity of yeast (Skoupil, 1994; Mahdalová, 2012).

The addition of salts has a positive effect on the rheological properties of the dough, it makes gluten protein more solid and it causes that the development of dough is longer because when we add a definite amount of salt, the activity of yeast is lower). The salt has an influence on colouring of crust of the bread during baking. The addition of too much amount of salt into dough causes that the rising of dough is worse and it creates small bakery products with a bad structure of crumb. Unsalted dough can easily rise too much and then they are destroyed (Kučerová, 2004).

4.3.3 Eggs

Eggs are one of the main part in bakery products. Using fresh eggs is not safe because it could be contaminated by diseases like salmonella. There are used deep frozen or dried eggs in bakery industry. Nowadays, the egg products are made with higher amount of sugar so the development of bacterial contamination is stopped. Dried and frozen egg products are imported pasteurized.

Eggs improve the properties of bakery products. They contain proteins and vitamins such as A, E, D, K and mineral substances so they increase the nutritious value of products. Yolks have an influence on the colour of crumb because they contain a large amount of carotene´s pigments. Yolks also contain an emulsifier lecithin (Kučerová, 2004).

The emulsifier lecithin has an important positive effect on dough during production and treating of bakery products. As a consequence of lecithin´s effect, water parts of the dough are fixed more effectively on the fat parts. Visually it is visible on the structure of the products. The porosity of bread and other products is more uniform and also the crumb of dough is drying out slowly. During baking, the proteins of eggs dilate and they help create the wall of the pores of bakery products. After they are dehydrated and coagulated (strengthened) (Skoupil, 1994; Kučerová, 2004; Müllerová, 2008)

4.3.4 Sweeteners

All of sweeteners which are used during baking are sugars. Sugars are added to the bakery products because of better taste and better colour of the crumb. A higher amount of sugars has an influence on the properties of the dough – the dough is thicker. Sugars are added to the dough in the dissolved form, they create a solution with water. The exception is sugar in the form of powder. The most common sugar in bakery products is a beet sugar. In tropical and subtropical areas, the most typical is sugar made from sugar cane. The glucose is not used very often because it is easily fermented by the yeast into carbon dioxide and alcohol.

Sugar is partly fermented by the yeast during fermentation of the dough. A sucrose which is disaccharide is breakdown into monosaccharides; these monosaccharides are fermented into carbon dioxide and alcohol. The rest of the beet sugar starts to caramelize during 160-220°C; it means water starts to break down. The sugar is transformed into caramel and it has a visual effect on the crumb of products (Matějovský, 1995).

4.3.5 Malt

Malt produced from barley is germinated and dried grains mainly of barley (rarely malt is made from wheat or rye). When malt is milled, malt barley flour is created. Also malt extracts can be made from malt, not from roasted but from green malt.

Adding malt flour or malt extract to wheat flour leads to increasing of formation of sugars during fermentation and therefore leavening dough is more intense. Sugars, which are formed under high heat during baking, caramelize, which causes colouring of the crust of bread. High-quality bread can be made from rye flour without addition of malt improvers (Hamer and Hoseney, 1998).

4.3.6 Milk

Milk and dairy products are one of the oldest food which people used. Also using milk and dairy ingredients during baking is well known as a positive thing for a long time. For the current production, cow's milk products are used the most often (Příhoda *et al.*, 2003).

Milk has an effect on the dough and also on the final version of products. The rising of the dough is slower because milk slows down the action of amylotic enzymes. The taste of final products is smoother and they have a higher nutritive value because milk contains many important substances. Especially, milk contains many vitamins and enzymes. From mineral substances there are calcium, potassium, phosphor and sodium.

The most used milk is a skimmed milk. The skimmed milk is produced if the fats from the full fat milk are removed. The problem is that many harmful bacteria can easily live and reproduce in skimmed milk. Because of that it is more suitable to use a milk powder (Matějovský, 1995).

4.3.7 Milk powder

Milk powder is a rich source of lactose and minerals, but is does not contain most of dairy proteins (except soluble proteins). Milk powder can affect the rheological properties and flavour of dough, depending on whether the acidic or sweet. The average of dry matter content is 95 % (of which proteins create 12.5 %, fats 1.5 %, lactose 69.5 %). Despite the high proportion of lactose, due to its low sweetness, it does not increase the sweetness of the products (Suková, 2011).

4.3.8 Fats

Fats are added into bakery products because they influence positively the taste and smoothness. The addition of 10-20 % causes that the products slowly dry out and it stays fresh longer. A higher number of percentage of fats does not have a positive effect anymore, because the dough loses its elasticity and the rising of the dough is more complicated and it is longer.

Fats must not be rancid or mouldy; it must comply with the quality standards. The most used fats during making bakery products are butter, lard, vegetable oil and margarine (Matějovský, 1995).

4.3.9 Yeast

Yeast gives products a greater volume and also affects the structure. The volume of bread is increased by CO_2, which is the final product of fermentation.

Yeasts are the main components during reaction which is called fermentation. It is an anaerobic reaction which means it can take place without the presence of oxygen. The main part of carbohydrates is transformed to alcohol. It is an important process that takes place during the preparation of the dough (Lessafre, 2011).

The metabolic fermentation is that the carbohydrates of flour are transformed to an alcohol which evaporates lately during baking to carbon dioxide (Šilhánková, 2002; Kubíková, 2010).

The formation of carbon dioxide has the influence on increasing of the volume of the dough. It is necessary to ensure an uniform loaf volume. The fermentation also influences the aroma and flavour of the bakery products (Miller and Smerak, 1971).

Many times people tried to shorten the time of fermentation but usually some of the benefits of the fermentation were lost. During the fermentation process the energy is also released but this is so small amount of energy so yeast can only survive they are not able to reproduce. The most known yeast is *Saccharomyces cerevisiae* and this yeast is used during baking (Reed and Peppler, 1973).

The yeast leavening process is more expensive than chemical aeration, it means that usage of chemical leaveners is better for producers (Matz, 1987).

4.3.10 Indirect method of baking

This method means that the ingredients are combined and the dough is prepared in more than a single phase. A part of flour, water and yeast are mixed and they are allowed to ferment before kneading the dough. The positive fact is that all flavours can fully developed, the fermentation in the dough increase the aroma. The most common in our country has been special starter which was composed from water, flour, yeast and malt. The ripening of this mixture takes about one hour after the barley malt is added. The ripening lasts about another 3 hours.

Nowadays, this type of fermentation is rarely used and almost not at all in the industrial production (Kučerová, 2004).

4.3.11 Direct method of baking

Most of the technological processes of today's manufacturing technology for the preparation of dough are without fermentation precursors. Usually during these processes some improvers are used. The reason is to reduce the time required for ripening of dough. The ripening of the dough takes about 10 minutes.

All ingredients are added at the same time and the kneading of the dough begins immediately. This method is more profitable but it cannot take place successfully without improvers (Matějovský, 1995; Kučerová, 2004).

4.3.12 Rye starter

Rye starter is fermented rye flour with water, it does not contain yeast. According to many studies the bread fermented by rye starter is not only much finer but also healthier and it has a longer shelf life (rye starter is a natural preservative). Rye starter consists of lactic acid bacteria and yeasts (Müllerová and Skalický, 1985). Lactic acid bacteria provide the necessary acidity to the rye starter and then to the dough. Bacteria of the genus *Lactobacillus* cause a lactic fermentation and composed sugars to lactic acid and acetic acid, aldehydes and alcohols, which are the main source of odour and taste of bread (Matějovský, 1958)

Rye starter is created so that water and rye flour is mixed and this mixture is allowed to ferment in a relatively high temperature (about 30 °C) (Müllerová and Skalický, 1985).

4.3.12.1 The traditional way of use

It consists of a three parts. Rye starter at the first degree is prepared by adding approximately the same amount of flour and water to the base (created by adding flour and water together) (Příhoda *et al.*, 2003). The maturing of this degree is about 4-5 hours under temperature 25 °C. After to the second degree another amount of flour and water is added. It is allowed to ferment about 4 hours under temperature 28 °C. The last degree of this preparation is the most important. The consistency and quality of the bread depend on the quality of this degree of rye starter. This part is ripened after three hours under temperature 27- 28 °C (Skoupil *et al.,* 1981; Příhoda *et al*., 2003; Kučerová, 2004).

4.3.12.2 Rye starter concentrate

These days, because of lack of the time and because people try to make everything easier, the using of traditional method to prepare rye starter are not often used. Nowadays, starter concentrates for leavened products are produced. They are made in form of powder or in form of paste. These concentrates are made by thickening of rye yeast (Hlinecký, 2009). If starter concentrates are added to the wheat-rye or rye-wheat dough which is leavened by yeast, the products have a similar taste as the products where traditional rye leaven is used (Příhoda *et al*., 2003). They contain acetic acid, lactic acid, citric acid and also colourings, usually hydrocolloids and emulsifiers are also added. The application of these concentrates is 2-5 % to the weight of flour (Hlinecký, 2009).

4.3.13 Additives substances, improvers

According to the definition the additives substances (regardless of their nutritional value) are not used separately or as a food itself. The additives are added to food during the production or packaging, transport or storage, so they (or their side products) become a food component (Kučerová, 2004).

„However, substances should not be considered as food additives when they are used for the purpose of imparting flavour and/or taste or for nutritional purposes, such as salt replacers, vitamins and minerals. Moreover, substances considered as foods which may be used for a technological function, such as sodium chloride or saffron for colouring and food enzymes should also not fall within the scope of this Regulation.“ (European Parliament and the Council, 2008)

The presence of additives must be stated on the packaging, a specific name and the corresponding European registration number known as an "E number" is required (Velíšek, 2002). Additives must be safe and there must be a technological need for their use (European Parliament and the Council, 2008). In case of possible adverse health effects, these effects must be stated too (Velíšek, 2002).

In Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives is stated *"The use and maximum levels of a food additive should take into account the intake of the food additive from other sources and the exposure to the food additive by special groups of consumers (e.g. allergic consumers)."* (European Parliament and the Council, 2008)

In the view of the fact that improvers improve many technological properties of the bakery products, they are indispensable. The first improver which was malt flour was used at the turn of the 19th and 20th century. At the turn of the 70^{th} and 80^{th} years using of enzymes shorten the time of ripening of starter to 20, even 15 minutes (Šedivý, 2009).

Improvers are not generally used in an amount of more than 10 % (Wasserman, 2009). Usually, the addition is about 1 %. It is calculated with respect to flour amount (Šedivý, 2009). It depends mainly on the purpose, these improvers contain an optimum amount of components .They are available as powder, in granular form, as liquid or as a paste

(Wasserman, 2009). The most used is a powder form, it is easily applicated manually and also by the technologies. Modern improvers enable to create the whole dough at the same time, without ripening the dough can be frozen, defrost and rise and these processes can be repeated (Šedivý, 2009).

Many facts are improved thanks to improvers. The quality of the products is better and it is the same every day. The application is easy and similar. Different properties among different types of dough are minimalized. The taste, nutritive value, aroma, colour and porosity are better. They make technologies easier, which means that the professional requirements on the employees are less strict (Šedivý, 2009).

4.3.13.1 Emulsifiers

The definition of emulsifiers is: *"Emulsifiers are substances which make it possible to form or maintain a homogenous mixture of two or more immiscible phases such as oil and water in a foodstuff."*

Basically, the main function of these additives is to prevent the separation of ingredients, it means they help some substances which do not normally mix to create a mixed blend. The foods additives also maintain a consistent texture (EUFIC, 2011).

Emulsifying agents positively influence the technological properties of dough and sensory properties of products and can be considered as improving agents. Due to emulsifiers the dispersion of the fat in the dough is better, as a result the digestibility of the products, workability and the structure of the dough are improved. They are able to form complexes with amylose and also create complexes with wheat protein (Skoupil, 1994). Emulsifiers can improve softness and porosity of the crumb, they can increase the volume of bread and slow down bread staling (Kučerová, 2004).

Emulsifiers are added in an amount of about 0.3 to 0.8 %, according to the weight of processed flour. In some case emulsifiers can replace the fat in the recipe (Müllerová and Chroust, 1993).

Creation of fat emulsion in water is one of the processes which takes place during mixing the dough and is important.

The emulsion which is created due to emulsifiers is finer and more stable; the evaporation of the water is slower. Slow evaporation of water from the dough during baking means that the porosity of the dough is more uniform and products have a greater volume. The slow evaporation of water from the crumb during storage influence the shelf life of the products, it means that the products stay longer smooth, the staling is slowed down (Müllerová and Skoupil, 1988). Influence of emulsifiers is shown in Figure 1.

Another important property of emulsifiers is their stability. This property can be explained on the example of an oil-water mixture. After the emulsion is created, it is kept in rest. The oil in the emulsion will rise to the surface and after some time, these two substances (water and oil) are separated again. The rate of this separation depends on the size of the oil droplets. The smaller droplets create the effect of emulsifier, the stable emulsion is formed. The stability of emulsions also affects the possibility of mutual contact of the individual droplets. If two drops of the oil are connected and they create a fusion, thereby the stability of the emulsion is reduced (Příhoda *et al*., 2003).

Figure 1. Influence of the emulsifier on the bread (Šedivý, 2009)

4.3.13.2 Oxidizing agents

Oxidants make gluten tougher; they increase its ability to retain leavening gases (Müllerová and Skoupil, 1988). Oxidants can be used to whiten flour (in the Czech Republic is the use of chemicals for bleaching flour legislatively prohibited), to speed up the ripening of the flour (in the Czech Republic it is prohibited), to improve positive properties of the dough, e.g. increasing flexibility and workability, increasing the volume of final product (Kučerová, 2004).

Using too small or too large amount of oxidants has a negative effect on the dough. In case those oxidants are not used in sufficient amounts, the dough is weak and bakery products have a small volume. If large amount of oxidants is added, the stickiness and toughness of the dough is increased (Skoupil, 1994).

There are some examples of oxidants used but in the Czech Republic they are forbidden and not allowed to use: acetone peroxide (it is used as a bleaching agent and accelerate ripening of the flour), azodicarbonamide (it makes the structure of the dough tougher), Calcium peroxide (it strengthens the gluten and reduces the acidity of the dough), bromate and potassium iodate (they influence the rheological properties of dough).

The ascorbic acid is the most common oxidizing agent used in bakery technology and in the Czech Republic it is the only one allowed oxidant. The ascorbic acid in presence of the air acid acts as an oxidizing agent (Příhoda *et al*., 2003). An oxidizing agent in dough is actually dehydroascorbic acid, to which ascorbic acid is, almost immediately after the application, oxidized due to present of enzyme ascorbate oxidase (Sluková, 2011). It stabilizes gluten, it increases gluten´s ability to retain gas, and also the ascorbic acid improves the volume and texture of bread. In the absence of the air this acid acts as a reducing agent (Příhoda *et al*., 2003). The influence of the ascorbic acid is shown in Figure 2.

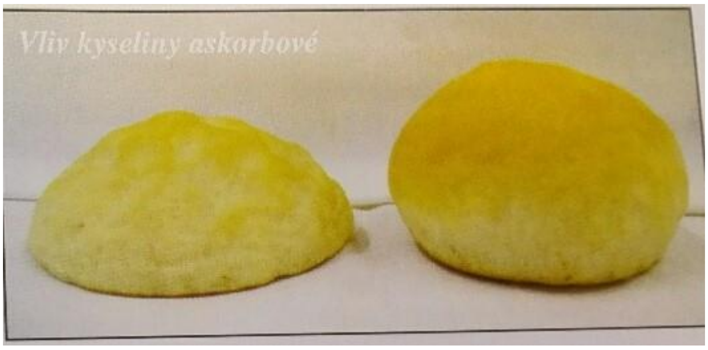

Figure 2. Influence of ascorbic acid on the bread (Šedivý, 2009)

4.3.13.3 Reducing agents

Reducing agents used in bakery technology are: L-cysteine, L tripeptide glutathione and various types of hydrogen sulphates. Reducing agents shorten the kneading and they make the dough weaker (they increase the ductility and reduce the elasticity of gluten) and as a consequence the kneading process shortens (Kučerová, 2004). Reducing agents are used only in case that the flour is thick. When reducing agents are added to the weak flour it has a negative effect

L-cysteine is an amino acid that is contained in the proteins but for commercial using it is created synthetically.

Glutathione is contained in low concentrations in the flour. And also it is released from the yeast cell, when they die and crack, it explains why the dough is weak when old yeast is added (Příhoda *et al*., 2003).

4.3.13.4 Hydrocolloids

The characteristic property of the hydrocolloids is that they are able to bind a really large number of water corresponding to ten times, hundred times or (in extreme conditions) five hundred times their own weight (Příhoda *et al*., 2003; Šedivý, 2009).

Hydrocolloids can be divided according to their origin:

- Animal origin: gelatine, egg albumin, casein and milk protein.

- Vegetable origin: vital gluten, acacia, guar gum, modified starches

- Marine origin: agar-agar, carrageenan and alginates

- Microbial origin: dextran and xanthan

- Synthetic origin (Kučerová, 2004).

Hydrocolloids improve many properties. They increase volume of bakery products, improve smoothness, prolong shelf life of products, and increase the stability of the defrost dough (Šedivý, 2009).

Xanthan gum (E415) is used as an additive substance. Xanthan gum is a polysaccharide with a high molecular weight which is produced by fermentation of carbohydrates by culture bacteria *Xanthomonas campestris.* The product is purified by alcohol, dried, and then change to powder form. Xanthan gum does not contain gluten, so it is also used in gluten-free baked goods. It gives a needed stickiness to the dough if there is no gluten. Xanthan gum strengthens the structure of the dough, improves its elasticity, binds water and retains the gas. Final products stay longer fresh.

Generally, xanthan gum is considered as a safe addition without the side effects. There are known rare cases of allergy to xanthan accompanied by digestive problems, diarrhoea and headaches. In the Czech Republic the usage of this substance is allowed in the necessary quantity also in child nutrition (Simon, 2000; García-Ochoa, 2000).

Guar gum (E412) is a fibre and is used as a thickener and stabilizer. It is able to bind a lot of water, even cold. It is obtained from the seeds of *Cyamopsis tetragonolobus*.

Guar gum has not undesirable effects in adequate amount, even it can lower a blood cholesterol. However, it can cause urticarial to some sensitive people (Kawamura, 2008).

4.3.13.5 Enzyme preparations

Enzyme preparation can be used only with the consent of the Ministry of Health. Enzyme preparations contain the enzymes as main component (Kučerová, 2004). Enzymes are specific proteins to catalyse the chemical reactions in organism. Enzymes are preferable then artificial catalysts in many ways. Enzymes have certain specificity, they catalyse only some type of the reaction and influence only a substrate with a specific structure. Enzymes usually work under mild conditions (temperature 20-40 °C, pressure 0.1 MPa, pH 7).

Enzymes used in cereal technology are: amylases, proteases, peptidases, hemicelluloses peroxidase, glucose oxidase, lipoxygenase, lipase (Zehnálek, 2003).

Enzymes - transglutaminase and cyclodextrinase have become popular in making a gluten free bread and they are considered as very useful.

Enzymes are added to achieve these changes in the dough and in the final product: Partial hydrolysis of gluten to improve the workability of the dough; partial hydrolysis of starch to create monosaccharides and disaccharides needed for fermentation; partial oxidation of lipids to strengthen the dough (Příhoda *et al*., 2003).

Enzymes preparations are contained in flour, especially yeast contain enzyme preparation. Yeasts are able to ferment some monosaccharides and disaccharides. Therefore starch must be initially degraded to fermentable sugar. Starch is degraded thanks to amylase in flour. Wheat flour usually does not have sufficient amount of amylase, so enzyme preparations are added to wheat dough (Kučerová, 2004).

The bakery technology, amylases are used mainly for increasing the volume of the product, improving the colour of the crumb, improve texture of the bread and slow down a staling of the product (Kučerová, 2004). Influence of amylase is shown in Figure 3.

A very common is the use of enzyme active malt flour of barley or wheat malt, which is the oldest bakery product, which has been used to improve properties of flour (Sluková, 2001). Malt flour provides especially amylotic activity. Malt and fungal amylase improve the texture of the crumb of the product; they reduce the consistency of the dough and improve its workability.

The process is as follows. During milling starch granules are damaged, the starch thereby becomes a substrate for amylase. A-amylase splits starch into dextrins which are split by β-amylase into maltose. Maltose is a substrate for yeasts which split maltose. Another product of this dissociation is a fermentation gas, necessary for proper leavening of the dough and for achieving a good volume of the finished product.

The colour of the crumb is improved thanks to dextrins which are formed during amylase activity. Dextrins slow down the staling of products because they prevent the interaction between gluten protein and starch (Hoseney, 1991).

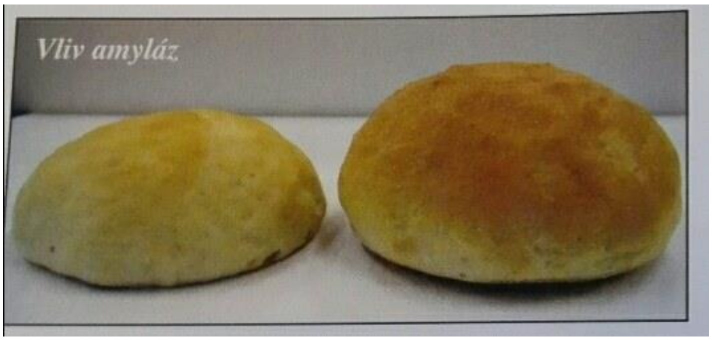

Figure 3. Influence of amylase on the bread (Šedivý, 2009)

Peptidases and proteases are used in the wheat dough. They can split peptide bonds in proteins and peptides. Their effect is to weaken the gluten. They have a similar effect as reducing agents. Proteases and peptidases are used for strong flour with too much fixed gluten. After the application the dough becomes more ductile and weaker (Příhoda *et al*., 2003).

4.3.13.6 Preservatives

Preservatives are substances which prolong the shelf life of bakery products and they protect them against deterioration caused by microbial activity (Kučerová, 2004). The method of their use depends on the type of food, the required minimum of shelf life, type of the packaging (normal packaging, vacuum packaging etc.).

Permitted preservatives in bakery products are: sorbic acid, sulphur dioxide and its compounds, propionic acid and its salts (Příhoda *et al*., 2003).

Table 1. Preservatives permitted in bakery products (Příhoda *et al*., 2003)

Preservative	Possibility of using
Sorbic acid	• Sliced bread with a shelf life longer than 5 days • Pastry and confectionery with a shelf life longer than 5 days
Sulphur dioxide and its compounds	• Crisps, crackers
Propionic acid and its salts	• Sliced bread with a shelf life longer than 5 days • Bread with a reduced energy content with shelf life more than 5 days • Pre-baked and packaged bread with a longer shelf life than 5 days • Packaged pastry and confectionery from flour

4.3.13.7 Chemical leaving agents

There are two ways to provide the production of carbon dioxide. Firstly it can be by the biological way, there is carbon dioxide as a result of activity of microorganisms (yeasts). Secondly, carbon dioxide can be provided chemically. Then it is a result from the reaction of added chemical agents (acid, and sodium or potassium bicarbonate).

Chemical leaving agents are substances or mixtures of substances which release leavening gases during their decomposition and thereby increase the volume of the dough. Mainly released gases are carbon dioxide, ammonia and water vapour, used for loosening dough. To ensure the required volume of products it is necessary to ensure a sufficient creation of carbon dioxide (Kučerová, 2004).

Chemical raising agents generally include acid (citric acid, tartaric acid, lactic acid) and soluble bicarbonate (usually sodium or potassium). Some of raising agents, e.g. ammonium bicarbonate is decomposed after heating and it produces gases which cause loosening of the dough (Příhoda *et al*., 2003).

4.3.13.8 Bakery mix

There exist various types of bakery mixtures. It depends on the requirements of the bakery. The bakery mix includes all dry ingredients (flour, dry milk, shortening, salt, and baking powder).

The complete mixture - contains all dry ingredients. These mixtures are suitable for smaller bakeries which do not have their own sources of flour.

The complete concentrated mixtures - contain all the dry ingredients with a minimum content of flour. They are suitable for larger bakeries, having their own flour sources.

The pre-mixes - have a different proportion of the ingredients. During preparation of a particular product, the mixture is added in various concentrations (Příhoda *et al*., 2003).

4.3.14 Oilseeds

The addition of oil seeds or nuts improves dough properties and affects the taste, improve and increase a nutritional value of products. They are able to bind water and they can increase their weight in several times. Oilseeds are used in the preparation of sweet and salty bakery products. They are useful for our health because they content important nutrients like fatty acids, fibre and essential minerals (Příhoda, 1991).

4.3.14.1 Sesame seed

Sesame seed contains mainly calcium. Proteins in the seed contain all essential amino acids in the ideal ratio. Sesame seed has a nutty flavour. The seed colour is brown, cream or black; they have different sizes and flavours (creamy sesame has a nutty flavour, black is bitter). They are described as a supportive agent in the treatment of diseases of the heart and blood vessels; reportedly they increase the immunity and improve the digestion (George Mateljan Foundation, 2003).

4.3.14.2 Linseed

Linseed is used for its beneficial nutritional properties and attractive, nut flavour. Its advantage is that it does not contain gluten, it contains large amounts of fibre, omega-3 fatty acids (linolenic) and it has a high antioxidant activity (lignins, phenolic acids, anthocyanins and flavonols). When whole linseed is used, its health benefits cannot be fully expressed, it passes through the digestive system in basically intact form. Linseed should be used in crushed form in order to use all of nutritional benefits but crushed linseed has a relatively short shelf-life. There are brown and gold seeds available on the market. Both types have the same effects (Suková, 2011).

4.3.14.3 Sunflower seeds

Sunflower seeds have a high energy value. Sunflowers are known primarily for its high protein content (15 %). Cores of seeds are also used roasted. Sunflower seeds can help treat people with heart disease, also diseases of metabolism, liver and gall bladder (George Mateljan Foundation, 2004).

4.3.15 Spices

Usually, spices are fried products of plant origin which are used mostly for flavouring food. Many parts of the plant can be spices – e.g. leaves, fruits, seeds. Their flavour is dependent on the content of volatile oils. Some of spices can be used also as colouring agents (Matz, 1987).

4.3.15.1 Caraway

It is the dried fruit of Caraway (*Carum carvi*). Caraway has a pleasantly sweet but slightly biting flavour and it has a spicy aroma. It contains 1-2 % of volatile oil. The most important quality factors are taste and door another factor is its colour which should be from light brown to dark brown. The main use of caraway is in rye bread (many people rarely recognize rye bread without caraway) (Matz, 1987).

4.3.15.2 Coriander

It is the dried fruit of Coriander *(Coriandrum sativum).* These seeds have a typical brown colour they have a round and a ridged form. Its aroma and taste are sweet. The flavour can remind a lemon. Seeds of coriander contain a lower amount of volatile oil than Caraway, about 0.3 % (Matz, 1987).

4.3.15.3 Anise seed

It is a dried seed of Anise seed (*Pimpinella anisum).* It is a small annual plant. Seeds sometimes resemble to caraway in its appearance. Anise seed is imported from Spain, Turkey, Egypt and China. Anise seed from Spain is considered as the best because it has a smooth flavour and better appearance and also higher volatile oil content. It has a flavour similar to liquorice. Undertones of the taste are mint, pine and fruit (Matz, 1987).

4.3.15.4 Fennel

It is a dried fruit of Fennel (*Foeniculum vulgare).* Fennel seeds have brown and yellow colour. It has menthol taste with musty and green flavours. It contains about 1 % of volatile oil (Matz, 1987).

4.3.15.5 Garlic

Allium sativum, known as garlic, is a plant of the family Alliaceae (Rahman, 2003). It has a form of a bulb which develops underground and it is composed of many segments covered by tough white skin. Other varieties are available, such as pink and yellow and they have a little bit different flavour (Matz, 1987). It has a characteristic flavour and door because of unique organosulfur compounds (Rahman, 2003). When segments are bruised, it damages the cells and it causes releasing of enzymes which react and form allyl disulphide and this compound is responsible for specific door (Matz, 1987).

Garlic is mainly used as a flavouring agent. Also it can be used in traditional medicine and as a functional food to improve physical and mental health (Rahman, 2003). For bakery industry it is the most used in dried form but other forms are also available in food manufacture, such as granulated, powdered, diced and sliced (Matz, 1987).

4.3.15.6 Paprika

It is a powder from sweet red pepper – *Capsicum annum*. Paprika is produced in Spain, Europe and in USA. It has a typical red colour. Paprika is used as flavouring agent and also as pigment agent. The taste is sweet and mild, hot taste is rare. The intensity of colour influences quality of paprika (Matz, 1987).

4.4 Methods for determining the baking quality

The quality of the bakery products is mainly influenced by quality of the flour. This is determined by the quality of the processed grain. This quality is less influenced by the effect of milling, e.g. amount of damaged starch or granulation of the flour.

The complex determination of flour in terms of its behaviour during technological process, it means during baking, and its impact on the quality of the final product, can be provided only by baking experiment. Special methods and devices provide information about concrete substances and properties (Kovaříková and Netolická, 2011).

Apart from protein and starch content and properties other facts are also important and influence the quality of the flour, such as moisture content, ash content and colour of the flour.

The moisture content is determined when the flour is heated in an air oven and the weight of the sample before and after heating is compared.

When a sample is in an ash oven, the very high temperature basically burns away the organic materials, only the ash stays. The ash from flour contains minerals.

Flour´s colour is determined by measuring the whiteness of a flour sample. For this method Minolta Chroma Meter is used (Wheat Marketing Centre, Inc, 2004).

4.4.1 Proteins

These methods are used to determine the amount of protein: Kjeldahl method, NIR technology, determination of wet gluten.

These devices methods are used to determine the quality of proteins, tests of: gluten ductility swells of gluten, GI (gluten index), sedimentation value (Zeleny test, SDS test), devices: rheological devices - farinograph, extensograph, alveograph.

NIR technology is the use of wavelengths near to the infrared waves. It works on the principle of measuring absorption and reflection of functional groups of organic compounds, in the wavelength range 800-2600 nm.

Among the methods that determine the total amount of nitrogen substances (then the proteins are specified by index) belong the Kjeldahl method and Dumas method. Kjeldahl method is based on mineralization by sulfuric acid in the presence of a catalyst (Kovaříková and Netolická, 2011).

Determination of wet gluten is performed by reference method, which is simple and less chemicals are used. The determination may be performed by mechanical washing out of the gluten.

GI (gluten index) is defined as the ratio of the amount of gluten that is retained on a standard metal network under strictly defined conditions and the total amount of gluten.

The gluten quality is measured by Zeleny test. The sedimentation index detects swelling of gluten in an alcohol or lactic acid. After the fibrillation gluten creates stable sediment in this liquid. The point is that about 85 wheat proteins are able to create wet gluten which is the base of the dough. The high value of sedimentation index correlates with a high retention capacity of gases in the network (values are between 8 and 78) (Burešová, Palík, Sedláčková, 2003).

Farinograph records the resistance of dough (change of consistency) while the dough is kneaded under defined conditions. Extensograph is used to measure the resistance of the dough and the dough ductility (Kovaříková and Netolická, 2011).

4.4.2 Starch

Quality of flour depends on digestibility of the starch by alpha-amylase. These devices and methods are used to determine properties and amount of starch: amylographs, viscographs, promylograph, viscometers, falling number test (Kovaříková and Netolická, 2011).

Quality of flour depends on digestibility of the starch by alpha-amylase. Determination of alpha-amylase is measured by a fall number test. The falling number test determines the amylase activity. A concrete amount of water and flour is heated in a special test tube. The tube is placed in a boiling water bath for 55 seconds; it allows the sample to gelatinise. Then the plunger is released on the surface of the sample. The time that it takes the plunger to sink through the gelatinised starch is recorded. Flours with normal fall number (230-280) form during the baking test a well-porous elastic crumb. Low values under 220 mean inelastic, moist crumb, on the contrary a high number (above 300) causes that the crumb is dry, and products have a small volume (New Zealand flour millers association, 2010)

Amylograph is used to determine properties of starch and amylotic and other enzymes.

The flour is mixed with water and gets warmed. After some time the starch starts to gelatinize. The resistance which the instrument has to overcome is showed in the form of amylograph (Wheat Marketing Centre, Inc, 2004).

4.5 Cereals

Cereals are the oldest cultivated plants. During 10-9 thousand years BC people intentionally started to grow crops mainly wheat and barley in the Fertile Crescent

(today - Palestine, Syria, Turkey, Iran and Iraq).

Botanically cereals belong to the family Poaceae. The cereals´ edible seeds are important for people. Cereals are divided by morphological and physiological properties into two groups. The first group consists of wheat, barley, rye, triticale and oats, these cereals require less heat but more water, they exist in spring and winter forms. Cereals which prefer more intensive heat and less water are maize, millet, sorghum, rice.

4.5.1 Wheat

Wheat (*Triticum* spp.) is one of the oldest cultivated crops; the beginnings of cultivation are associated with the development of agriculture. Wheat is one of the most widespread crops in the world and in our country (Prugar, 2003).

The most known and also the most grown is common wheat (*Triticum aestivum* L.) (Liyana-Pathirana and Shahidi, 2006; Holasová *et al.*, 2007). Durum wheat *(Triticum durum Desf.)* has grains with typical strong, rigid gluten, which is not suitable for baking bread and other bakery products because it creates a small volume of these products. Spelt (*Triticum spelta* L.) also known as hulled wheat was cultivated in the Middle East. Its nutty flavour has been popular for centuries in Europe, particularly in Italy and southern Germany (Jarmílková, 2007). Differences between grain of *Triticum spelta* and *Triticum aestivum* can be seen in Figure 4. and Figure 5.

Figure 4. *Triticum spelta* grain (Rasbak, 2013)

Figure 5. Seeds of *Triticum aestivum* (Roberta, 2012)

4.5.1.1 Chemical composition of common wheat

The protein content in the grain is 10-15 %. Wheat is a source of energy due to the high starch content (50-70 %), which is easily digestible. The crude fibre content is low (1.6-2.0 %).

The fat content is also low (1.5-3 %) with a large amount of unsaturated fatty acids, oleic acid and linoleic acid.

From vitamins, which are contained in wheat grain there are especially B vitamins, vitamin E, and in smaller amount also β-carotene. The main minerals are phosphorus and potassium.

Wheat contains large amounts of phenolic acids, which belong to the derivatives of cinnamic acid and benzoic acid. These derivatives include ferulic acid, caffeic acid, parahydroxybenzoic acid, protocatechuic acid, and syringic acid. Natural antioxidants, including ferulic acid, are important to neurodegenerative diseases such as Alzheimer's disease. Ferulic acid is 57-77 % of the total content of phenolic compounds of wheat (Zhou *et al*., 2004). The total content of phenolic compounds and total antioxidant activity was higher in the varieties of soft wheat than for durum wheat varieties (Liyana-Pathirana and Shahidi, 2006; Holasová *et al*., 2007).

4.5.1.2 Chemical composition of spelt wheat

Due to a greater proportion of aleurone layer, spelt contains more proteins (16-17 %) in comparison with common wheat. The content of essential amino acids is slightly higher (especially a content of methionine, phenylalanine) but similar to the common wheat is limiting the content of lysine, from other amino acids it has higher content of leucine than common wheat.

Spelt is an excellent source of some B vitamins, especially thiamine, riboflavin and niacin. It has a higher the content of potassium, sulphur and magnesium than common wheat (Michalová and Hutař, 1998).

4.5.1.3 Chemical composition of wheat flour

Wheat flour contains about 15 % wheat protein. The non-gluten proteins create about 10-20 % of the total flour proteins. So gluten forming proteins create 80-90 % of the proteins in flour.

Fermented bakery products which are bread and buns require more than 10 % of protein. These products need it for gas retention and dough rise during fermentation. Products such as biscuits, cookies and cakes require lower content of protein, 8-9 %. These products need lower amount of proteins because it ensures dough extensibility and spread ability which is necessary for texture and quality of these products.

The rheological properties of wheat flours and bread making process depend on the quality and quantity of their proteins (Hudson, 2002; Příhoda *et al*., 2003). Bread with the addition of spelled flour has a distinctive smell, a large volume, cracked crust which tastes great and it is long-lasting and fresh for longer time (Michalová, Hutař, 1998).

4.5.1.4 Gluten

The gluten forms the main structure of the wheat dough (Příhoda *et al*., 2003). Actually, gluten does not exist in the grain of wheat; it is created during kneading the dough when the network of wheat proteins is created. Gluten consists of water-insoluble proteins and it is formed when we mix water with wheat flour. Gluten is created by prolamins and glutelins which are in a ratio of 2:3 (Šalplachta *et al*., 2005). Prolamins of wheat are called gliadins. The main type of glutelins is glutenin; it makes up 47 % of the total protein content. It is not typical for these proteins to consist of pure form of proteins because there are many overlaps among them. These overlaps depend on extraction conditions - on time, type and concentration of alcohol which we use and also on temperature (Sluková, 2009). Gliadins and glutelins give completely different physical properties to the gluten network in wheat flour dough. Gliadins behave as a viscous liquid when they are hydrated and they provide extensibility. Gliadins allow dough to rise during fermentation. Glutelins give the dough elasticity and strength, it prevent the dough from being over-extended and from collapse during fermentation or in baking (Matz, 1987; Philips, 1989; Příhoda *et al*., 2003).

4.5.2 Rye

This grain became cultivated crop later than wheat and other grain. It was common in Northern Europe because soils were poor and climate cold and rye was a crop which was suitable for these conditions. Rye can be plant under wide range of conditions (Matz, 1987). Rye is closely related to wheat, but its grain is thinner, as you can in Figure 6. (Matějovský, 1995).

Figure 6. Rye grain (Ratmaner, 2011)

4.5.2.1 Chemical composition of rye

The rye grain contains in suitable conditions 9-12 % proteins. Prolamins and glutelins (which form technologically important gluten) represented a smaller part than in wheat. Rye gluten is not washable under normal conditions. Gluten forms together with water-soluble pentosanes create viscous solution (Lekeš, 1990). Rye proteins are not able (partly due to the action of rye pentosanes) to create an individual structural network which supports wheat bread and it is its main structure. Rye contains the highest proportion of the amino acid lysine of all cereals (Matějovský, 1995).

Rye contains about 70 % of technologically important carbohydrates, mainly starch. The starch is characterized by faster gelatinization under lower temperature than is the gelatinization of wheat starch (Sluková, 2011). The important part of saccharides in rye flour creates rye pentosanes; they have really high water retention. Process of starch gelatinization together with swelling of other substances such as pentosanes has influence on appearance, volume, and organoleptic properties of the bread (Lekeš, 1990). Although rye is more nutritious than wheat, it is harder to digest (Pamplona-Roger, 2009). Nevertheless rye has more positive effect to the digestive system than wheat, mainly because it has higher fibre content and its structure is more suitable for humans (Matějovský, 1995). The total fibre content is 15-17 % and a soluble fibre creates 3-4 % (Sluková, 2011).

Rye is a source of vitamin B complex, vitamin E, iron, and many minerals (Matějovský, 1995). The main representatives of minerals are phosphorus, magnesium and iron as well as zinc. Rye has a lack of calcium which is the reason why rye is combined with other food which contains a lot of it. Rye has a higher content of selenium and vitamin E than other cereals. Selenium and vitamin E are antioxidants which help to better circulation of the blood and make arteries more flexible. Because rye has a positive effect on arteries and it is sodium-free it can help to reduce high blood pressure (Pamplona-Roger, 2009).

4.5.2.2 Rye flour

Rye flour is easily combinable with other flours and gives bread specific and greasy taste.

Rye flour is white with a grey undertone (Matz, 1987).

Although rye contains more proteins than wheat, there is only small amount of glutelins and prolamins proteins which form gluten (Pamplona-Roger, 2009). Due to the fact that this flour has less gluten, adding wheat flour to the dough can help dough to rise better (Matz, 1987). Usually 10-30 % of wheat flour is added to rye flour. Gluten of wheat flour gives elasticity and toughness to the rye dough. The crumb of the bread is tougher and the volume of the bread is larger (Matějovský, 1995). If the wheat is not added the rye, bread is heavier than wheat bread and the dough raise harder (Pamplona-Roger, 2009).

Rye starch is well coated with the cellulose, which makes the releasing of glucose molecules slower. Therefore rye causes a slow increase of glucose in blood, so it is suitable for diabetics (Pamplona-Roger, 2009). The rye starch helps create a structure of crumb of the bread. Starch plays a more important role in dough making and also during creating the crumb than in wheat products (Příhoda *et al*., 2003).

The composition of amylase-starch complex has the main impact on quality of bakery products from rye flour. If there is an excessive activity of amylotic enzymes or starch granules were previously damaged, rye flour is able to create many products of starch hydrolysis very quickly (e.g. maltose, dextrins). The workability and quality of rye flour is decreased. The milling of rye is rougher than milling of wheat. Consequently, a large part of starch is usually damaged and it causes the activity of amylases. This process is slowed down and stopped if the traditional way of baking is used. There is used rye leaven which has a higher acidity so the activity of amylases is optimized.

The ther problem during baking can be the huge and untimely fermentation after kneading the dough, because the fermenting capacity of yeast is exhausted. As a result bakery products lose volume or they are deformed. Furthermore the dough could be stickier due to large amount of dextrins, then there is a problem with processing the dough (Příhoda *et al*., 2003).

Bread made from rye flour stays longer fresh and soft. Some Scandinavian flat breads require very little leavening effect so to these bread are added flaked rye kernels. Bread made from rye flour keeps its freshness and softness for a longer time (Matz, 1987).

4.5.3 Barley

In Central Europe is the beginning of growing barley (*Hordeum* ssp.) dated to the 5th-4th century BC. Currently, barley is the fourth most common cereal in the world after rice, wheat and corn. Typical barley grain can be seen in Figure 7. Cultural barley is an annual crop, grown as spring or winter form. There are many types of barley, according to botanical and agronomic designations. For example there are hull-les, naked, covered barley. Covered barley dominates (Matz, 1987).

Figure 7. Barley grain (Ifong, 2012*)*

4.5.3.1 Chemical composition of barley

Proteins create 14-16 %. Carbohydrates are a major source of energy and constitute up to 84 % of barley grain. The starch content is about 65 %. The grain of commonly grown barley contains 25 % of amylose and 75 % amylopectin. Barley starch has viscoelastic properties similar to starch from potatoes. Non-starch polysaccharides are also important; they are an important part of the total dietary fibre. The total content of fibre is 15-24.1 % and non-starch polysaccharides creates about 86 % of dietary fibre, β-glucans creates 56 % and pentosanes create 23 % of non- starch polysaccharides (Hrušková *et al*., 2012).

Fat content in the grain depends on variety and conditions; it is from 1.9 to 7 %. It is reported that composition of fatty acids is barley is similar to the composition in olive oil. There are significant proportions of palmitic acid in barley and particularly also unsaturated fatty acids - oleic acid, linoleic acid and linolenic acid.

An important group of vitamins in barley grain are the tocopherols and tocotrienols, especially alpha-tocotrienol, which helps to reduce the cholesterol synthesis. Barley is also a source of vitamin B1, B6, pantothenic acid, folic biotin. Grain contains minerals such as phosphorus, calcium, potassium, magnesium and iron and selenium. There are also some inhibitors in barley (inhibitors of the enzyme protease, trypsin, chymotrypsin, and serine (Vaculová, 1999).

4.5.3.2 Barley flour

The nutritional composition is evaluated as the average and the main part in barley flour are starch (60-65 %), protein (12-16 %) and fibre (12-15 %). These days the most preferable is the relatively high content of beta-glucans, which, as a part of soluble fibre, have a positive impact on human health (Hrušková *et al*., 2012). Barley is a really rich source of β-glucans, the content is 2-6 %, in some cultivars of barley there was found even 14-16 % β-glucans.

A small amount of barley flour in our conditions is produces from abraded grain. More useful is to use the hull- less varieties of barley. These varieties lose the outer layer of the grain at the time of harvest, so it is not necessary to peel them and reduce the content of beneficial substances for cooking. Wholegrain barley flour is a suitable part in the production of bread or biscuits (Vaculová, 1999).

Barely is usually used as a minor ingredient in bakery products. Its positive influence on colour, texture and nutrition is inconsiderable. On the other hand it does not affect the colour or the taste negatively (Matz, 1987).

4.5.4 Oats

Hulls oats (*Avena nuda*) is the most grown species of oats nowadays. Hulls oats is characterized by a pleasant taste, dietary character and ability to stimulate the defensive functions of metabolism. *Avena nuda* has a better chemical composition than *Avena sativa* and it is recommended for children, elderly persons and for special diet (Hrušková *et al*., 2012). Oats grain can be seen in Figure 8.

Figure 8. Oats grain (Imagman, 2011)

4.5.4.1 Chemical composition of oats

Oats has a lower amount of carbohydrates than other cereals but it has higher protein and fat content. The protein content of milling oats is about 13 % (Perlín, 2007). Proteins in oats have the highest biological value from cereals. Essential amino acid lysine content in oats is by 30 % more than in wheat (Moudrý, 1999). Oats may not be strictly excluded from the celiac diet because it has a lower content of prolamins (which are called avenins) and has a lower content of glutamine and proline. It is a similar composition to the gluten-free cereals, e.g. maize, millet and rice. According to experts, only 5 % of celiac patients are sensitive to oats (Perlín, 2007). Lipids are contained in an amount of 4-10 % (Matz, 1987). Oats content 11-13 % dietary fibre, soluble fibre creates from this amount 3-5% (Sluková, 2011). The content of fibre is influenced by presence of glumes, so oats with glumes has a higher amount of fibre, oats without glumes (naked oats) contains 0.8-2.6 % of fibre. Oats contains 3.1- 5.8 % β-glucans which are in endosperm's cell wall (Bušinová, 2009).

Oats is an important source of minerals. It contains magnesium, potassium, iron, zinc and manganese. Oats contains a significant amount of vitamin B1 and vitamin E and other antioxidants. Content of vitamins A, C, D is low (Moudrý, 1999; Butt *et al.*, 2008).

4.5.4.2 Oats flour

Oat flour is added to the bread and other bakery products in amount about 30 % (Butt *et al.*, 2008). It is added as a part to modify texture, flavour and appearance and also provide a positive nutritive value (Matz, 1987).

4.5.5 Maize

Maize (*Zea mays* L.) originates from Central and South America, where it was cultivated by Aztecs, Mayas and Incas. Currently, it is cultivated throughout the Earth in areas with warm climate (FAO, 2003). Maize is commonly known as corn.

There exist three fundamental market classes of corn. Corn is classified into these tree classes according to its colour. The yellow corn includes all variety of yellow colour and does not include more than 5 % of kernels of other colours. The white corn contains at least 98 % of white kernels, very lights colours and light pink are classified as white corn. The mixed corn includes many colours of corn and cannot be classified as white or yellow corn because of high percentage of other colours. Also there are two types of corn which do not depend on colour – flint and dent. Flit corn contains 95 % or more of the kernels of the flint varieties. Flint and dent Corn contains 5-95 % of flint varieties. Dent corn does not contain any other variety of corn

Corn does not content extensible gluten; it is not able to create leavened bread. All corn recipes require an amount of wheat flour to perform the gas retaining function (Matz, 1987). Traditionally, the maize bread is made by mixing 30-50 % maize flour with wheat flour. Rie *et al.* (2012) reviewed that the ideal substitution of maize flour into wheat flour is 25 % without affecting bread. .According to the study of Paucean and Man (2013) also the deffated maize flour can be used; it has higher content of proteins, dietary fibre and minerals than commercial maize flour. The result of this study is that the addition of the maize flour to the level up to 40 % and the addition of defatted maize germ flour up to 15 %, produces bread without any negative effect in quality of the bread and it can be nutritious and a healthy alternative product to consumers. The difference between yellow corn grain and white corn grain you can see in Figure 9 and Figure 10. The difference between flint and dent corn is shown in Figure 11.

Figure 9. Yellow corn grain (Unal Ozmen,M, 2010)

Figure 10. White corn grain (Urban Farmer, 2016)

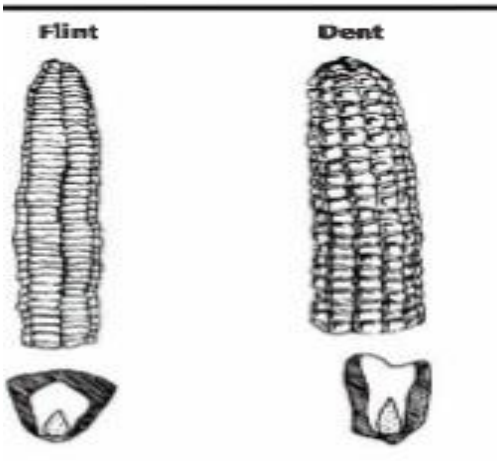

Figure 11. Flint and dent corn (Eames-Sheavly, 2012)

4.5.5.1 Chemical Composition of maize

Corn has relatively low protein content (about 10-12 %). Dominant are storage proteins zein (prolamine) and glutenin, which have a low biological value, contain a low amount of lysine and tryptophan. Corn grain has the highest energy value from all cereals. It has high starch content (73 %). The crude fibre content is low (about 2 %). Corn contains up to 5 % of fat. The fat is composed mainly of unsaturated fatty acids (linoleic and oleic), in small quantity also palmitic acid and stearic acid. The mineral content is, compared to other cereals. Very low is calcium content. Varieties with yellow grains have a higher content of b-carotene and also contain other yellow pigments - xanthophyll and zeaxanthin. Relatively high is content of thiamine, riboflavin, pyridoxine (FAO, 2003).

4.5.5.2 Maize flour

Ingredients milled from corn are used all over the world relatively frequently. The most used meals from milled corn are probably home-baked products. Corn flour can be a suitable substitute for wheat flour for people with celiac disease (FAO, 2003). Corn bread is a well-known Mexican food, especially non – leavened tortillas. Still, more than milled products from corn non-bakery, foods from corn are consumed (Matz, 1987).

4.5.6 Rice

Rice has many useful properties for people - it is hypoallergenic, it can carry a bland flavour. So it makes rice a perfect addition to the flour. The examples of these products are: rice bread or tortillas. It is an easily digestible food that causes feeling of saturation. Seeds of the rice can be seen in Figure 12.

Rice causes different glycemic responses in healthy individuals. This happens because of many reasons; it depends on rice´s cultivar, amylose content, cooking time and processing time. These factors influence increasing or decreasing of the accessibility of the starch to digestive enzymes (Bryant *et al.*, 2001).

Figure 12. Rice seeds (MLA Trading Company, 2015)

4.5.6.1 Chemical composition of rice

Rice contains 8-12 % of proteins. The main part of rice proteins consists of glutelin which are easily digested. There is a relative high content of lysine (Biagi, 2004). Rice contains 68-72 % of carbohydrates. The main part is starch. The important is a content of crude fibre, for unpeeled rice is about 10 %. Another advantage of rice is that it contains a very small amount of fat, usually it is about 3.5 % (Xia *et al.,* 2012).

Peeling of rice removes complex B vitamins, most of the fat and minerals contained in these layers. Rice and its products contain a very small amount of vitamin C or D. In contrast, it contains a high content of thiamine and riboflavin. Another important vitamin in rice is vitamin E. It is considered for one of the most powerful antioxidants (Bienvenido, 2009).

4.5.6.2 Rice flour

The cost of rice is higher per pound than corn or wheat, but the application in value-added products give the industry many varieties of using the rice flour and so the demand can be increased. Rice is often more preferable than wheat or maize because of its good flavour. Milled rice contains about 7.6 % of protein.

The application of rice flour into wheat flour is suitable. The amount of addition is about 30 %. The problem with using rice to make bread is due to lack of gluten. Some investigators tried to make pure rice flour bread by using some gums to improve the structure of the bread. It was acceptable for average consumers (Matz, 1987). Rie *et al*. (2012) confirmed that the ideal substitution of rice flour for wheat flour is 25 % without affecting bread making quality adversely.

4.6 Pseudocereals

Pseudocereals have a similar composition and utilization as cereals but botanically they do not belong to cereals (it means they do not belong to family Poaceae). These crops are naturally gluten-free, so they are suitable for people with celiac disease. Those species of pseudocereals have a high nutritional value and positive health effects. Compared to grains they contain a higher amount of proteins, unsaturated fatty acids and fibre. Pseudocereals are also considered as a good source of vitamins and minerals (Christa, 2008).

4.6.1 Buckwheat

Buckwheat (*Fagopyrum esculentum* Moench.) by its appearance of grain and similar chemical composition to cereals resembles cereals but botanically it is dicotyledonous plant, belongs to the family Polygonaceae and the genus *Fagopyrum* (Petr *et al*., 200; Kopášová, 2007). Buckwheat originates from Southeast Asia. Currently, the largest producers are China and Russia. Buckwheat is a crop suitable for ecological farming and because of its nutritional properties it is considered as a crop of high quality (Janovská *et al*., 2009). Typical buckwheat grain can be seen in Figure 13.

Apart from buckwheat (*Fagopyrum esculentum* Moench.) tartary buckwheat (*Fagopyrum tataricum*) is also partly grown (Kopášová, 2007).

Figure 13. Buckwheat grain (Popova, O, 2011)

4.6.1.1 Chemical composition of buckwheat

Proteins' content is characterized by a high proportion of albumin and globulin and a very low content of prolamin and glutelin which makes buckwheat gluten-free, suitable for gluten free diet. Buckwheat proteins have a high biological value but are digestible with difficulties (Bonafaccia *et al*., 2003; Kopášová, 2007).

In terms of the nutritional value the buckwheat is known for its balanced mix of amino acids. The total contain is 18 different amino acids, buckwheat has a high content of lysine (Bonafaccia *et al*., 2003).

Buckwheat starch content is from 55-70 % of weight of dry seed and is quantitatively the most important carbohydrate. Buckwheat contains 3.4-5.2 % of fibre, thereof about 20-30 % is a soluble fibre (Šmajstrla *et al*., 1999).

Buckwheat has a relatively high content of unsaturated fatty acids. The main is linoleic acid (37-48 %) , which together with linolenic acid contributes to lower blood cholesterol in blood Lipids from buckwheat contain 0.2 % of sterols that decrease the absorption of dietary cholesterol (Šmajstrla *et al*., 1999; Bonafaccia *et al*., 2003).

Buck wheat contains many minerals - potassium, phosphorus, calcium, iron, copper, manganese, zinc, selenium. From vitamins, there are the higher representations having vitamins from group B, vitamin E and choline (Týř *et al*., 2009). Choline regenerates liver´s cells after diseases (Šmajstrla *et al*., 1999). The most important is rutin. It has a positive effect on vascular system and protects against vascular diseases (such as varicose veins). Using the amount of 15 % of buckwheat into wheat-rye flour, the quality of the dough is not decrease, the bakery products have the same volume (Týř *et al*., 2009).

Buckwheat´s negative property is that it can cause allergic reactions that are caused by allergenic proteins of buckwheat. The main reasons of allergies are low molecular weight proteins. The allergic symptoms are observed in humans who consume products containing buckwheat frequently and in a high amount. The allergy frequently occurs in individuals who suffer from celiac disease in combination with other food allergies (Kreft *et al*., 2006; Christa *et al*., 2008).

4.6.1.2 Buckwheat flour

Food made from buckwheat has a good nutrition value. Flour is produced by milling buckwheat seeds. Buckwheat flour has a strong nutty flavour; therefore it has to be combined with other ingredients, to make this flavour less distinct. The outer layers of the seeds can be milled and added to the flour (whole wheat flour) (Šmajstrla *et al*., 1999; Rysová *et al*., 2008; Janovská *et al*., 2009).

Another requirement to the quality, except a high nutritional value, is the quality and taste of buckwheat grains. Tartary buckwheat *(Fagopyrum tataricum)* contains a high amount of routine, but it is not suitable for the production of flour. Tartary buckwheat has a disadvantage, which is tannin that causes a bitter taste (Kreft *et al*., 2006; Kopášová, 2007; Rysová *et al*., 2008).

In a study of Elgeti *et al*. (2014) it was found that the addition of up to 40 % of buckwheat flour to the commercial gluten-free bread mixtures can improve leavening properties of the dough and increase the viscosity - thanks to its high dietary fibre content and also thanks to positive properties of the buckwheat starch. This study shows that high amount of buckwheat flours incorporated into gluten-free breads improve textural and nutritional properties.

4.6.2 Quinoa

Quinoa (*Chenopodium quinoa)* is an annual, dicotyledonous plant from family Amaranthaceae. Quinoa´s seeds resemble to millet´s seeds. They are small and have a light colour. Quinoa is one of the oldest plants of the American continent. It is a food of 21st century (Jancurová *et al*., 2009). With the European colonization, the cultivation of quinoa was replaced by cereals, quinoa was grown only in some areas of South America. The main producers today are Bolivia, Ecuador and Peru. In the Czech Republic quinoa has been grown experimentally on fields (Koubová, 2005). Quinoa is a very variable species, especially the colour is very variable, it can be white, yellow, pink, orange, red, brown or black (Benda *et al*., 2000). Seeds of quinoa are shown in Figure 14.

Figure 14. Quinoa seeds (Madlen, 2011)

4.6.2.1 Chemical composition of quinoa

Carbohydrates in quinoa represent 54.1-64.2 %. Quinoa contains about 60 % of starch. The amylose content is relatively low (11-12 %). Starch is characterized by greater viscosity in comparison with cereals but is not much suitable for baking bread (Moudrý and Kalinová, 2004).

Quinoa contains 10-18 % protein. Quinoa proteins can be one of the best ingredients which can be added together with cereal or legume proteins. Quinoa´ s grain has higher protein content and a very favourable amino acid composition. The main part of protein creates albumins and globulins (44-47 %). Prolamins content is low (0.5-7 %). Compared to cereals quinoa has higher content of lysine, methionine and cysteine (Moudrý and Kalinová, 2004; Abugoch *et al.*, 2009; Jancurová *et al.*, 2009). Content of lysine in comparison with cereals is more than twice the amount.

Content of fats is 4.5-8.75 %. The composition of fatty acids in quinoa is similar to other cereals; main acids are linoleic acid, oleic acid and palmitic acid.

Quinoa also contains a relatively high amount of vitamins and minerals. It contains more riboflavin (B2) than rice, barley or wheat. Compared with cereals, it has a lower content of niacin. Minerals in quinoa are mainly calcium, magnesium and zinc and iron. The mineral content is reduced by abrasion and by washing the seeds in water (potassium and chlorine) (Moudrý and Kalinová, 2004; Jancurová *et al.*, 2009).

Quinoa contains the substance with anti-nutritional effect. It contains saponin which coats every grain of quinoa. Saponin has a really unpleasant, bitter flavour. The content of saponin can be 0-4 %. Traditional methods used to remove saponin from quinoa´s grain are: perfectly wash them in cold water or remove them mechanically, seed coats are removed (Kopášová, 2007; Jancurová *et al.*, 2009).

4.6.2.2 Quinoa flour

Quinoa flour has low gluten content due to low content of prolamin and glutamine. It is usually used to improve baking flour. It is used for bread but also for biscuits or pasta, bread. Quinoa flour provided enough moisture and a pleasant aroma. It is highly digestible, has a really good taste and therefore it is used in child nutrition. (Kopášová, 2007; Jancurová *et al.*, 2009).

Quinoa provides nutritious, economical and tasty food source, which is important also for people with gluten intolerance (Jancurová *et al*., 2009). Nowadays, Czech Republic is still an importer of products from quinoa (Dřímalková, 2003).

4.6.3 Amaranth

Amaranth (*Amaranthus* ssp.) belongs to the family Amaranthaceae. It is the crop with a high agronomic and food potential. It can be grown in soils with a lower quality than other cereals. Amaranth is mainly grown in Latin America, Africa and Asia (Kopášová, 2007; Yawadio Nsimba *et al*., 2008). Seeds of amaranth are shown in Figure 15.

Figure 15. Amaranth seeds (Maraze, 2012)

4.6.3.1 Chemical composition of amaranth

Proteins in amaranth grain are of very high quality and its amino acid composition (lysine, tryptophan) is close to proteins of animal origin. Content of lysine, methionine and cysteine in the seeds of amaranth is more balanced if it is compared with cereals such as wheat, rice or corn. Amaranth seeds have a positively high content of lysine and tryptophan in amaranth, but it have low content of leucine so corn can be added because it contains a high amount of leucine (Herzig *et al*., 2007).

Amaranth flour does not contain a large number of monosaccharides; oligosaccharides are in amount of 2-3 %. Amaranth has a low glycaemic index; therefore, it is also suitable for diabetics. In Amaranth´s starch the amylopectin is dominant. Starch in amaranth has a structure of relatively small starch grains and it has a low amylose content which affects its chemical and also physical properties. If starch of amaranth is compared to starch of corn it a has lower solubility, greater ability to retain water and it swells up better. Amaranth is easily digested (Koubová, 2005; Herzig *et al*., 2007).

The fibre in amaranth seeds is similar to the fibre in wheat and corn. Amaranth´s fibre is gluten-free and it is of high quality (Herzig *et al*., 2007).

Important lipids in seeds of amaranth are linoleic acid, oleic, palmitic acid and stearic acid. These four fatty acids represent over 95 % fatty acids in amaranth (Herzig *et al*., 2011). Amaranth´s fats also contain an important component-squalene (7-8 % of all fats), which prevents from an excessive synthesis of cholesterol in the human body. Also it is a powerful antioxidant (Kopášová, 2007).

Amaranth seeds are good sources of vitamins B_2, and E and many minerals, particularly magnesium and potassium. Other important minerals are calcium, iron and sodium, in comparison with grains of other cereals (Kopášová, 2007; Kaur *et al*., 2010).

Same as quinoa, amaranth contains saponin. Traditional methods used to remove saponin from quinoa´s grain are: perfectly wash them in cold water or remove them mechanically, seed coats are removed (Kopášová, 2007; Jancurová *et al*., 2009).

4.6.3.2 Amaranth flour

Species of amaranth used for consumption in form of amaranth flour are *A. cruentus*, *A. caudatus* and *A. hypochondriacus* (they are also grown in Czech Republic). Amaranth flour is perfect flour for gluten–free bread but also for many other products such as pastas or biscuits (Písaříková *et al*., 2005).

It has a characteristic spicy flavour, therefore, it is not recommended to use only amaranth flour during baking, but preferable is a combination with other flour. Another reason why it is not probable that products containing of 100 % amaranth flour will be used is because the price of amaranth seed is really high. There are enough traditional grains, amaranth flour will be combined with other flours. This can ensure an excellent taste and quality of the final product. Amaranth Flour can be used to replace about 25 % of the flour in recipes (Herzig *et al*., 2007; Kaur *et al*., 2010).

4.7 Non-grain crops

The study shows that non-traditional grains are good ingredients which can be added to wheat flour (Hrušková *et al*., 2014). Composite flours which contain wheat and non-grain seeds are popular nowadays in the baking technology because more and more customers are interested in healthier food. Furthermore, these flours are suitable for people who suffer from celiac disease (Perlín, 2002; Hrušková, 2008).

Non-traditional flours can change positively the chemical composition of wheat cereal products. They contain protein, fibre, fat and other positive components which are good for human health, such as vitamins and minerals (Sanz-Penella *et al*., 2013). For example wheat-chia blends contained a higher amount of dietary fibre (Hrušková *et al*., 2014). Furthermore, the combination of wheat and non-grain flour can provide a better balance of essential amino acid, particularly higher lysine portion. This combination can also influence technological properties of dough because of dilution of gluten (gluten is responsible for the structure and volume of the products) (Dervas *et al*., 199; Kohajdová *et al*., 2011).

Generally, non-grain flours contain higher amount of protein than wheat flour. Proteins are important due to their nutritional significance and they influence a bread texture. The protein content depends on the type and percentage of non-grain component which is used (Saturni *et al*., 2010). The study shows that the best sources of protein are Amaranth and lupine flours (Hrušková *et al*., 2014).

4.7.1 Hemp

It belongs to the genus *Cannabis* and family Cannabaceae (Deferne and Pate, 1996). Hemp (*Cannabis sativa*) is planted as two subspecies - ssp. *culta* and ssp. *indica*. The second one is forbidden because it contains intoxicated substances and intoxicating products can be made from it (Perlín, 2002). Hemp seeds are shown in Figure 16.

Figure 16. Hemp seeds (McCallum, 2012)

4.7.1.1 Chemical composition of hemp

Hempseed´s content of proteins is 20-25 %. From the total amount of proteins, 65 % is in the form of edestin which is important in health care and it belongs to a low molecular weight globulins. Hemp seed contains carbohydrates mainly in the form of fibre. Carbohydrates in hemp seed create about 52.67 %; the simple sugars create only around 2.47 %. The total content of insoluble fibre is 10–15 % (Deferne and Pate, 1996). Hemp seed contains 25–35 % of oil, Hemp seed is the source of one of the finest natural oils. This oil is rich in unsaturated fatty acids – the most contained are linoleic acid and gamma-linolenic acid. Hemp contains a high amount of beta-carotene and vitamins B1 and E, the main representatives of minerals are iron and zinc (Peč and Dušek, 2008; Hrušková *et al*., 2012). Hemp was traditionally used mainly for fibre and oil. Hemp oil has a positive influence on human nutrition because of high amount of unsaturated fatty acids (Callaway, 2004; Hrušková *et al*., 2014).

4.7.1.2 Hemp flour

Hemp is known as non-traditional ingredient in bakery industry but it becomes interesting because of positive effect on dough rheological properties, bread quality and nutritional value. Composition of hemp flour is - 30-33 % of proteins, 7 % -13 % fats and 40 % starch. Thanks to the way the proteins are structured, hemp a bit easier to digest than soy. Main part of hemp proteins represents edestin, which belongs to low molecular weight globulins (Hrušková, 2008; Hrušková *et al*., 2012). The highest quantity of minerals in non-grain flours was found in hemp composited flour (Hrušková *et al*., 2014). There is no evidence of allergies caused by hemp or hemp products.

4.7.2 Soybean

Soybean has been an important foodstuff from twentieth century; it is irreplaceable food with a huge amount of proteins and fats. Especially it is important in many countries in Asia and other higher populated areas (Momčilová and Martínková, 1996). It originated from China but nowadays the most producers are in Brasilia, Argentina and in the USA. It is grown mainly in tropical and subtropical areas (Nováková, 2009). Seeds of soybean are shown in Figure 17.

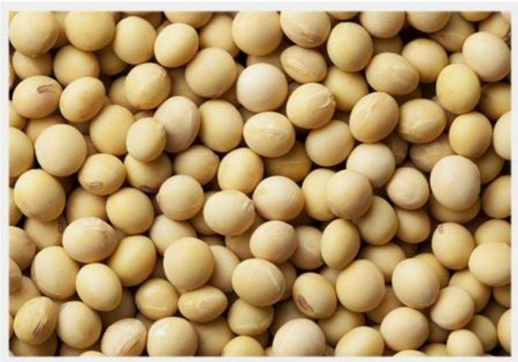

Figure 17. Soybean seeds (Somkaew, 2011)

4.7.2.1 Chemical composition of soybean

Soybean contains the largest number of proteins from all crops (about 30 %). These proteins contain a huge amount of essential amino acids (Nováková, 2009). The main protein is lysine; this protein makes soybean the perfect supplement of wheat in bakery industry (Matz, 1987). The content of sugars is relatively low: 5-6 %, so soybean is suitable also for diabetics. It does not contain cholesterol so it can be an important part of diet. Soybean's phytoestrogens play an important role because they help prevent from cancer and other diseases. Content of bier is about 5 %.

Soybean contains except for large number of proteins and fats many vitamins especially thiamine (B_1). Important minerals are phosphor and iron, calcium and magnesium. The concentration of minerals is really high about 4.5-5 %. It has a positive effect on nervous system (Nováková, 2009). Soybean is also full of various types of enzymes, e.g. urease, B-amylose, lipases. Unfortunately, these enzymes are destroyed because of heat during the process of removing the bitter taste from soybean. For the best utilization of enzymes from soybean, sometimes soybean is added to the flour without removing the bitter**.** It does not have bad influence on the taste, because the complete removing of the bitter taste from soybean occurs during baking by the impact of water vapours inside the bakery products (Matějovský, 1995).

Soybean´s negative property is that it is a relatively strong allergen and many people suffer from allergy to soybean. Especially it occurs in Europe and America because historically soybean was not available as a crop in the past (Nováková, 2009).

4.7.2.2 Soybean flour

There exist two types of soybean flour. There is full fat and defatted soybean flour. The full fat flour is extracted from the beans after peeling and roasting (with the intention of neutralizing toxic natural substances). Low fat flour is a secondary product while the oil is obtained from soybean. In terms of nutrition specific defatted flour is preferable. Using soybean flour can replace the addition of oil or fat (about 10 % lower using of fat or oil). Soy flour is used as an additive to other flours, usually in amount about 20-25 %.The properties of flour are better after the supplement has been added. The crumb is softer and it can easily keep moisture, the porosity of the crumb is better and also volume of the bread can be larger. If more percentage is used, the influence of soybean flour is not so useful (Matějovský, 1995). Even when a small amount of soybean flour is added (1 part soy flour to 10 parts of wheat flour) it improves nutritional values and it can replace yolks and fats (Momčilová and Martínková, 1996).

4.8 Commonly used composite flours

The most known and also the most sold nowadays is still wheat and rye flour combination, usually 10-30 % of wheat flour is added to rye flour (Matějovský, 1995). Of course 100% rye flour bread can be made but usually some improvers are added (Pamplona-Roger, 2009). Oat flour is added to bakery products in amount about 30 % (Matz, 1987). Maize flour can be used with rice flour in ratio 1:5. Rice flour itself is usually used in addition about 30 %, 100% rice bread can be made but with addition of some substances, for example gums (hydrocolloids) (Maghaydah, 2013). Addition of up to 40 % of buckwheat flour considerably influences the properties of the dough (Elgeti *et al*., 2014). Amaranth can be used to replace about 25 % in flour, it is not suitable to make 100% amaranth flour because it has characteristic spicy flavour and the prize of amaranth seeds is really high (Herzig *et al*., 2007; Kaur *et al*., 2010). The suitable combination is amaranth with maize flour (higher leucine content). Using soybean flour can replace the addition of oil or fat, even a small amount of soybean flour addition improves nutritional value. Usually it is added in amount about 25 % (Matějovský, 1995).

According to literature, the very suitable combination is: rice and maize flours at a ratio of 5:1 and usage of substitutes 1 % of xanthan and 1 % of carrageenan or 1 % of xanthan and 1 % of pectin; the best combination is 30 g kg^{-1} of guar gum and 1 ug^{-1} of transglutaminase enzyme added to the dough (Mohammadi *et al.,* 2015); buckwheat and maize can be used in almost all ratios, it is suitable combination of flours; combination of addition of proteins with polysaccharide hydrocolloids could retard bread staling (Ziobro *et al*., 2015); from maize, rice, potato and cassava starches, sorghum bread containing 50 % cassava starch had the best overall crumb properties (Waterschoot, *et al.,* 2014).

4.9 Bakery products for people with special needs

There are many groups of people with special needs for bakery products. This chapter is focused on people with celiac disease and allergies to common cereals, such as wheat, who cannot consume all kinds of *Triticum*, sometimes also rye and barley or oats. This part is also focused on people on slimming diet and on protein diet.

4.9.1 People with celiac disease and allergies to certain cereals

Celiac disease is defined as a permanent (fixed) intestinal intolerance to gluten contained in some kinds of cereal or as an inflammatory disease of the small intense with hypersensitivity to the protein gliadin (Petr *et al*., 2003; Kohout and Pavlíčková, 2009).

Wheat (All kinds of *Triticum* such as durum wheat, spelt, kamut), rye and barley have been identified as grains which, according to scientific reports, contain gluten. These cereals and all products prepared from them must be excluded from the gluten-free diet, if not, they have to be marked as gluten-free (Kohout and Pavlíčková, 2009; Evropská unie, 2009).

Except celiac disease, other more or less serious allergies to proteins of wheat, rye, barley and other cereals has occurred in recent years. So these cereals and all products prepared from them must be excluded from diet of these people (Skřivan, 2015).

The number of patients suffering from celiac disease and allergies has increased in recent years and unfortunately this number still continues to grow. Therefore, the global market for gluten-free products develops rapidly and provides great opportunities for the industry. Sales of products such as non-wheat breads and other bakery products increased over the last three years by almost 120 % (Kohout and Pavlíčková, 2009).

4.9.2 Gluten-free bread

The main sources for the production of gluten-free bakery products are rice, maize, buckwheat, quinoa, amaranth, hemp, soybean and many other alternatives.

The absence of gluten in dough production has a high influence. The production process and the quality of the products are influenced. The gluten-free doughs are much less cohesive and elastic, difficult to handle and stickier (Cauvain, 1998). The compact crumb texture and a low specific volume have been typical for gluten-free breads; it is confirmed by Brites (2010). This unattractive appearance of gluten-free bread is a challenge in bread making. New technologies are developing and using of starches, hydrocolloids, enzymes, proteins, sourdough and other possible substances make it possible to find appropriate alternatives (Schober, 2009).

Hydrocolloids are often used for creating the viscoelastic and cohesive behaviour of gluten and to increase the gas binding capacity by raising the viscosity (Toufeili *et al*., 1994). Chemically or biochemically synthesized hydrocolloid hydroxypropylmethylcellulose increases the gas retention and water absorption of dough, which reduces bread staling. Carboxymethylcellulose increases dough elasticity and bread volume, it does not affect the crumb firmness (Ngemakwe, 2015).

Enzymes are used to influence positively the water-binding capacity, to stabilize the dough structure, the shelf life, the retrogradation and the crumb softness. Transglutaminase enzyme can create a high protein-content network, which stability depends on the protein origin; it can be skim milk powder, egg protein powder, soya proteins or many others (Han, 1996). Transglutaminase improves the dough viscosity and elasticity and decreases hardness of the crumb (Ziobro *et al*., 2015). In study of Houben (2012), it was worked out that special buckwheat and brown rice flour pretend to be good transglutaminase substrates. Another enzyme - cyclodextrinase also improves dough viscoelasticity and crumb hardness (Ziobro *et al*., 2015). Laccase creates cross-linking of proteins and proteins with water-soluble pentosanes. Glucose oxidase creates cross-linking of the water-insoluble pentosanes. Laccase and glucose oxidase stabilize the dough structure.

One of the other problems with gluten-free breads is their lack of cohesiveness and resilience (Matos and Rosell, 2012). These aspects can be improved by the addition of starches According to study of Mancebo *et al*. (2015) the maize starch is very suitable.

Proteins can also be added during dough preparation, they form a network similar to gluten network. The proteins which are used can be of animal origin like milk proteins and egg albumins or plant origin, like proteins of soya. Milk proteins have a high nutritional value and their chemical structure is quite similar to the gluten proteins (Marco and Rosell, 2008).

The difference between gluten-free bread and gluten containing bread is also its aroma. This difference is mainly related to the volatile compounds contained in the crust of the bread. The lack of pyrazines in the aroma of the gluten-free bread represents the main disadvantage. If the aroma precursors of Maillard reaction are added in the dough, as a pair of proline and glucose, it gives to the bread an acceptable aroma to be produced (Pacyński *et al*., 2015).

Many combination and interaction among ingredients and also among flour are possible; lots of studies try to find out the best combination.

The positive effect of an addition of full egg powder can be increased by the additional use of the enzyme transglutaminase; the structure similar to gluten is received (Houben *et al*., 2012).

The addition of guar gum and microbial transglutaminase enzyme can positively influence the composition of gluten free bread. The formed network is the same as gluten structure, and the dough texture is improved. Transglutaminase has a negative effect on the specific volume at the same time it has a positive effect on the structure of bread. In contrast guar gum has mainly positive effect on specific volume. Only guar gum addition does not have any effect on the bread texture but together with the addition of transglutaminase at the same time it has positive effect on the dough. The best combination is $30\ g\ kg^{-1}$ of guar gum and $1\ u\ g^{-1}$ of transglutaminase enzyme added to the dough (Mohammadi *et al.*, 2015).

The results from study of Dvořáková (2012) shows that maize flour can be used together with buckwheat flour. Maize flour is used there as an improver, it has a positive effect on texture parameters as chewiness. On the other hand, an increasing amount of maize dough caused that the bread became crumby and incoherent. Nevertheless, these mixtures of buckwheat and maize can be used in making gluten-free bread in almost all ratios.

4.9.3 Slimming diet

When people are on slimming diet it is necessary to supply the organism with biologically valuable substances so that the body does not suffer from reduced energy intake. Common mistake is that bakery products should be excluded from this diet (Šimek, 2010).

Suitable are products from whole grain flours, such as amaranth flour, rice flour, buckwheat flour, corn flour, oat flour, quinoa flour, also whole grain spelt flour and rye flour. Bakery products from whole grain flours cause feeling of fullness and so it is possible to prevent overeating and overweight. At the same time the whole grain products are consumed the intake of fats is reduced (Jirkovská and Havlová, 2003).

The main part of bakery products in this diet it should be the fibre. Higher amount of fibre is suitable for digestive system. The suitable flours are - soybean, the content of sugars is low, and flours from pseudocereals, such as amaranth, quinoa and buckwheat, they are important sources of energy due to their starch content, provide a good quality protein, they have a lot of dietary fibre and large amount of unsaturated fats. Rye and oats flours contain large amount of Beta-glucans. Beta-glucans reduce glucose levels in blood after meals by increasing peristalsis movements which leads to reduce the absorption of glucose (Sluková, 2011).

Preferred are bakery products from flour which has low glycaemic index. The consumption of these products causes slow release of glucose into the blood, and that causes the natural and also slow release of insulin, which converts glucose into cells in organism. Glucose level is balanced, people after consummation feel good and feel fullness for a longer time. Whole grain flours has relatively low glycaemic index, mainly flours from pseudocereals (such as amaranth flour) (Jirkovská and Havlová, 2003).

Seeds are important in bakery products. They have great energy value. They contain a high amount of fats, from which most of them are unsaturated fatty acids and they do not contain cholesterol. They also contain large amount of proteins and minerals. Moreover their consumption is great for the prevention of cardiovascular diseases. Examples of these suitable seeds are linseeds, sunflower seeds, sesame seeds and many others (Příhoda, 1991).

4.9.4 Protein diet

The diet is based on high intake of protein and a large reduction in the consumption of fats and sugars. At the moment when the human body has limiting intake of sugars, the level of ketones in the blood is increased, it is call ketosis. In the absence of carbohydrates the body begins to take the energy from fats, which is exactly what is needed to lose the weight. Whole-wheat bakery products should predominate in the diet (Forsythe, 2006).

Nowadays, special protein breads are made. They are usually made from whey protein isolate (WPI) that has been stripped of lactose, fat, and carbohydrates. WPI is the one of the fastest absorbing protein. It consists many amino acids, they are quickly used up by skeletal muscles, for example during physical activity.

The one bread can contain 28 grams of protein per two slices. This bread is 100 % whole wheat. The bread is cholesterol-free and it is a rich source of fibre.

The best addition to this bread is seeds, especially oats, linseeds, sunflower seeds (P28 Foods, Inc, 2014). They are useful for our health because they content important nutrients like fatty acids, fibre and essential minerals (Příhoda, 1991).

Other proteins, which are very suitable as an addition to the bread, are hemp or soy protein. Hemp protein is a protein with very high nutritional value. It contains all the amino acids, it is not usual composition of protein of crops. Furthermore it contains the unsaturated fatty acids which have great influence on health (Deferne and Pate, 1996). The Soy protein is also a useful supplement. As it was mentioned in this review, soybean contains the largest number of proteins from all crops (about 30 %). These proteins contain huge amount of essential amino acids (Nováková, 2009).

5 Conclusion

Bakery products from composite flour are relatively popular nowadays. It has become well known during recent years for many reasons, composite flour represent many benefits.

The one of the aim of this thesis was to summarize the possible ingredients used during baking and their role in the dough and the influence on the quality of the final products. It is almost impossible to suggest the best composite flour, it can be mentioned that such a thing does not exist. There are several possibilities how to combine the flour and other ingredients. The ingredients which are added to the flour during making bakery products are really important. They affect the quality and nutritional value of products. Some of them are irreplaceable but most of them can be replaced or taken out, but the final bakery product does not have such nutritive value, taste and structural properties. There are also many additives and improvers which can influence the quality of products positively. Common diets - gluten-free, protein and slimming, were discussed separately.

According to this review the gluten-free breads are hardly made without any additives or improvers; they do not have sufficient properties because they have a lack of gluten. When the flour and other ingredients are combined properly, the final products have a really good nutritional value and taste.

Products from whole grain flour, such as amaranth flour, rice flour, buckwheat flour, corn flour, oat flour, quinoa flour, also whole grain spelt flour and rye flour are suitable for people on slimming diet. The main part of bakery products should be the fibre. Bakery products from flour which has low glycemic index are preferred.

Whole-wheat bakery products should predominate in the protein diet. Nowadays, special protein breads are made. They are usually made from whey protein isolate. Other proteins, which are very suitable as an addition to the bread, are hemp or soy protein.

A great potential in composite flour have pseudocereals, such as amaranth, quinoa and buckwheat, they are important sources of energy, good quality protein and they have a lot of dietary fibre and a large amount of unsaturated fats. They can be combined with wheat flour but also with other gluten-free flour and in this case these pseudocereals are suitable for all three groups, which were described in this thesis.

The topic of composite flour should be further researched and developed by the right selection and combination of the suitable ingredients in order to obtain high quality breads.

6 References

Abugoch L *et al.* 2008. Study of Some Physicochemical and Functional. Journal of agricultural and food chemistry 56: 4745-4750.

Alvarez-Jubeteab L, Arendtb EK, Gallaghera E. 2009. Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. International Journal of Food Sciences and Nutrition 60: 240 – 257.

Benda V, Baburek I, Ždárský J. 2000. Biologie II : Nauka o potravinářských surovinách. Prague: VŠCHT. 195p.

Biagi F *et al.* 2004. Miligram of Gluten a Day Keeps the Mucosal Recovery Away: A Case Report. Nutrition Reviews 62: 360-363.

Bienvenido, OJ. 2009. Rice in human nutrition. Available at http://www.fao.org/inpho/content/documents//vlibrary/t0567e/T0567E00.htm#Contents: Accessed 2016-03-12.

Bonafaccia G, Marocchini M, Kreft I. 2003. Composition and technological properties of the flour. Food chemistry 80: 9-11.

Bryant RJ, Kadan RS, Champagne ET, Vinyard BT, Boykin D. 2001. Functional and Digestive Characteristics of Extruded Rice Flour. Cereal Chemistry 78: 131- 137.

Burešová I, Palík S, Sedláčková I. 2003. Hodnocení kvality pšenice a žita 2001, 2002, odhad 2003. Available at www.vukrom.cz: Accesed 2016-03-20.

Bušinová I. 2009. Bezlepková kuchařka 2. Prague: Grada. 217p.

Butt MS *et al.* 2008. Oat: unique among the cereals. European Journal of Nutrition 47: 68-79.

Callaway JC. 2004. Hempseed as a nutritional resource: An overview. Euphytica 140: 65–72.

Cauvain SP. 1998. Other cereals in breadmaking. Cauvain SP, Young LS, editors.Technology of breadmaking. London: Blackie Academic & Professional, p330–346.

Crosby G. 2014. Explaining gluten. Avaiable at http://www.cookingscienceguy.com/pages/wp-content/uploads/2012/07/Explaining-Gluten.pdf: Accessed 2016-02-10.

Deferne JL, Pate DW. 1996. Hemp seed oil: A source of valuable essential fatty acids. Journal of the International Hemp Association 3: 4–7.

Dendy DAV, James AW, Clarke PA. 1972. Composite flour technology bibliography. London: Tropical Products Institut. 11p.

Dendy DAV. 1992. Composite flour - Past, present and the future: A review with special emphasis on the place of composite flour in the semi-arid zones. Gomez, M I, House, L R, Rooney, LW, and Dendy, DAV, editors. Utilization of Sorghum and Millets. India: International Crops Research Institute for the Semi-Arid Tropics, p67-73.

Dendy DAV. 1992. Perspectives in composite and alternative flour products. Feillet P, editor. Cereals chemistry and technology: a long past and a bright future. Monpellier: INRA, p151-158.

Dervas G, Doxastakis G, Hadjisavva-Zinoviadi S, Triantafillakos N. 1999. Lupine flour addition to wheat flour doughs and effect on rheological properties. Food Chemistry 66: 67–73.

Dřímalková M. 2003. Mycoflora of Chenopodium quinoa Wild. seeds. Plant Protection Science 39: 146-150.

Dvořáková P, Burešová I, Kráčmar S. 2012. Buckwheat as a gluten-free cereal in combination with maize flour. Journal of Microbiology Biotechnology and Food Sciences 1 (February Special issue): 897 -907.

Dvořáková P, Kučerová J, Kráčmar S. 2011. Effect of sweet yeast bread formula on evaluating rapid mix test. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 59: 39-46.

Eames-Sheavly M. 2012. The Three Sisters, Exploring an Iroquois Garden. Available at http://www.slideshare.net/Fayina19z/the-three-sisters-exploring-an-iroquois-garden: Accessed 2016-03-01.

EUFIC. 2011. What are stabilizers and emulsifiers? Available at http://www.eufic.org/page/en/page/faq/faqid/stabilizers-emulsifiers/: Accessed 2016-02-14.

European Parliament and the Council. 2008. Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives (Text with EEA relevance) Available at http://eurlex.europa.eu/legalcontent/EN/TXT/?uri=celex%3A32008R1333: Accessed 2016-02-12.

Evropská unie. 2009. Nařízení komise (ES) č. 41/2009 o složení a označování potravin vhodných pro osoby s nesnášenlivostí lepku. Úřední věstník Evropské unie: 1-3.

FAO. 2003. Maize in Human Nutrition. Available at http://www.fao.org/docrep/T0395E/T0395E00.htm#Contents: Accessed 2016-02-20.

Forsythe CMS. 2006. Where do you find a diet that's low in sugar and calories, but loaded with protein, fibre, and flavour? Right here, that's where. Available at http://www.menshealth.com/nutrition/high-protein-diet: Accessed 2016-03-15.

García-Ochoa *et al.* 2000. Xanthan gum: production, recovery, and properties. Biotechnology Advances 18: 549-579.

Gembalová A. 2003. Ječný slad je základ mnoha zdravých dobrot. Available at http://www.jimehlavou.cz/cz/obilniny-a-pecivo/Emag/DetailClanku/ic-220/jecny-slad-je-zaklad-mnoha-zdravych-dobrot.html: Accessed 2016-02-01.

George Mateljan Foundation. 2003. Sesame seeds. Available at http://www.whfoods.com/genpage.php?tname=foodspice&dbid=84: Accessed 2016-02-27.

George Mateljan Foundation. 2004. Sunflower seeds. Available at http://www.whfoods.com/genpage.php?tname=foodspice&dbid=57: Accessed 2016-02-27.

Hamer J and Hoseney RC. 1998. Interactions: The Key to Cereal Quality. St.Paul: American Association of Cereal Chemists. 173p.

Han XQD .1996. Thermodynamic compatibility of substrate proteins affects their cross-linking by Transglutaminase. Food Chem 44: 1211–1217.

Herzig I, Písaříková B, Suchý P, Straková E. 2007. Nutriční a dietetická hodnota tuzemských proteinových krmiv jako alternativa sóji a sójových produktů : Část III - Amarant jako alternativní proteinové krmivo. Available at http://www.vuzv.cz/sites/Herzig%20Amarant(2).pdf: Accessed 2016-03-15.

Hlinecký I. 2009. Kvasové koncentráty. Pekař Cukrář Odborný časopis pro pekaře a cukráře 5: 11-15.

Holasová M *et al*. 2007. Změny obsahu vybraných vitamínů a hygienické a senzorické jakosti naklíčených zrn pšenice ošetřených vysokým tlakem. Available at http://www.vupp.cz/czvupp/publik/07poster/07posterSKDmh3.pdf: Accessed 2016-02-09.

Hoseney RC. 1991. Wheat gluten: rheological and gas retaining properties. Levine H., Slade J, editors. Water relationships in Foods. New York: Plenum Press, p657-666.

Houben A, Höchstötter A, Becker T. 2012. Possibilities to increase the quality in gluten-free bread production: an overview. Eur Food Res Technol 235: 195–208.

Hrušková M, Švec I, Jurinová I. 2012. Composite Flours - Characteristics of Wheat/Hemp and Wheat/Teff Models. Food and Nutrition Sciences 3: 1484-1490.

Hrušková M, Švec I, Hofmanová T. 2012. Reologické hodnocení směsí mlýnských výrobků. Mlynářské noviny XXIII(3): 10-12.

Hrušková M, Švec I, Hofmanová T. 2014. Department of Carbohydrates and Cereals. Agriculture Journals 32: 288–295.

Hrušková M. 2008. Wheat. J. Prugar, editors. Plant Products Quality on Beginning of the Third Millennium. Brno: VÚPS, p75-103.

Hudson. 2002. Biochemistry of Food Proteins. London: Elsevier Applied Science. 284p.

Christa K, Soral-Smietana M. 2008. Buckwheat Grains and Buckwheat Products-Nutritional. Czech Journal of Food Science 26: 153-162.

Ifong C. 2012. Barley grain. Available at http://www.shutterstock.com/: Accessed 2016-03-14.

Imagman L. 2011. Pile of Whole Oats Isolated on White Background. Available at http://www.shutterstock.com/: Accessed 2016-03-15.

Jancurová M, Minarovišová L, Dandár A. 2009. Quinoa Review. Czech Journal of Food Sciences 27: 71-78.

Janovská D, Kalinová J, Michalová A. 2009. Metodika pěstování pohanky obecné v ekologickém a konvenčním zemědělství. Prague : Výzkumný ústav rostlinné výroby, v.v.i. 13p.

Jarmílková S. 2007. Jak připravovat obiloviny, luštěniny, semena a ořechy, Prague: nakl. Motto. 170p.

Jirkovská A, Havlová V. 2003. Dieta pro diabetiky tradičně i netradičně. Available at http://www.zdrav.cz/modules.php?op=modload&name=News&file=article&sid=2075: Accessed 2016-03-20.

Juliano BO. 1985. Polysaccharides, proteins, and lipids. In: Juliano BO, editor. Rice chemistry and technology. St. Paul: AACC, p98–142.

Kadlec P. 2002. Technologie potravin. Prague: Vydavatelství VŠCHT. 300p.

Kaur S, Singh N, Chand Rana J. 2010. *Amaranthus hypochondriacus* and *Amaranthus caudatus* germplasm. Food chemistry 123: 1227-1234.

Kawamura Y. 2008. Guar gum Chemical and Technical Assessment. Available at http://www.fao.org/fileadmin/templates/agns/pdf/jecfa/cta/69/Guar_gum.pdf: Accessed 2016-03-01.

Kohajdová Z , Karovičová J, Schmidt Š. 2011. Lupine composition and possible use in bakery – a review. Czech Journal of Food Sciences 29: 203–211.

Kohout P, Pavlíčková J. 2006. Celiakie a bezlepková dieta : Dieta a rady lékaře. Praha: Maxdorf s.r.o. 129p.

Kopášová O. 2007. Trendy ve zpracování cereálií s přihlédnutím zejména k celozrnným výrobkům. Available at http://www.bezpecnostpotravin.cz/UserFiles/File/Kopov_Cerelie%20web.pdf: Accessed 2016-03-15.

Koubová D. 2005. Pseudocereálie z Jižní Ameriky. Available at http://www.agronavigator.cz/default.asp?ch=1&typ=1&val=33468&ids=414: Accessed 2016-02-25.

Kovaříková D, Netolická V. 2011. Vzdělávací materiál pro předmět Technologická příprava. Prague: Investice do rozvoje vzdělání. 56p.

Kreft I, Fabjan N, Yasumoto K. 2006. Rutin content in buckwheat (Fagopyrum esculentum Moench). Food chemistry 98: 508-512.

Kubíková V. 2010. Kvasnice v pekárenském a pivovarnickém průmyslu [Bc.]. Zlín: Univerzita Tomáše Bati ve Zlíně. 120p.

Kučerová J. 2004. Technologie cereálií. Brno: Vydavatelství MZLU. 141p.

Kulp K, Ponte JG. 1992. Handbook of cereal science and technology. New York: Marcel Dekker, Inc. 796p.

Lekeš J *et al.* 1990. Žito. Prague: SZN. 247p.

Lesaffre. 2011. Informace o droždí. Available at http://www.vseodrozdi.cz/cs/index.php: Accessed 2016-02-09.

Liyana-Pathirana CHM, Shahidi F. 2006. Antioxidant properties of commercial soft and hard winter wheats (Tritium aestivum L.) and their milling fractions. Journal of the Science of Food and Agriculture 86: 477-485.

Lunn J *et al*. 2007. Carbohydrates and dietary fibre, Nutrition Bulletin, 32: 21-64.

Madlen I. 2011. Quinoa seeds. Available at http://www.shutterstock.com/: Accessed 2016-03-10.

Maghaydah S, Abdul-Hussain S, Ajo R, Tawalbeh J, Alsaydali O. 2013.Utilization of Different Hydrocolloid Combinations in Gluten-Free Bread Making. Food and Nutrition Sciences 45: 496-502.

Mahdalová M. 2012. Hodnocení senzorické jakosti chleba [Bc.]. Brno: Vysoké učení technické v Brně. 49p.

Mancebo CM, Merino C, Martínez MM, Gómez M. 2015. Mixture design of rice flour, maize starch and wheat starch for optimization of gluten free bread quality. Journal of Food Science and Technology 52: 6323-6333.

Maraze C. 2012. Amaranth seeds. Available at http://www.shutterstock.com/: Accessed 2016-03-09.

Marco C, Rosell CM. 2008. Functional and rheological properties of protein enriched gluten free composite flours. Journal of Food Engineering: 94–103.

Mariotti M, Pagani MA, Lucisano M. 2013. The role of buckwheat and HPMC on the breadmaking properties of some commercial gluten-free bread mixtures. Food hydrocolloids 30: 393-400.

Matějovský K. 1958. Přehled pekařství: Díl druhý – Technologie kvasů a těst. Prague: Vydavatelství a nakladatelství ROH. 147p.

Matějovský K. 1995. Přehled pekařství: Díl první – Suroviny. Prague: Vydavatelství a nakladatelství ROH. 148p.

Matos ME, Rosell CM. 2012. Relationship between instrumental parameters and sensory characteristics in gluten free bread. Eur Food Res Technol 235: 107–117.

Matz SA. 1987. Ingredients for bakers. Chichester: Ellis Horwood. 284p.

McCallum E. 2012. Hemp seeds. Available at http://www.goodfood.com.au/good-food/food-news/hemp-seeds-should-this-superfood-be-illegal-20140707-zszaf.html: Accessed 2016-03-12.

Michalová A, Hutař M. 1998. Pšenice špalda, Výživa a potraviny 53: 186-188.

Miller JA, Smerak LJ. 1971. Yeast leavened bread dough composition and process of manufacture. USA: The United States Patent office certificate of correction. US 3578462 A.

MLA Trading Company. 2015. Rice seeds. Available at http://www.indiamart.com/mla-trading-company/: Accessed 2016-03-12.

Mohammadi M, Azizi MH, Nevestani TR, Hosseini H, Mortazavian AM. 2015. Development of gluten-free bread using guar gum and transglutaminase. Journal of Industrial and Engineering Chemistry 21: 1398–1402.

Momčilová P, Martínková V. 1996. Sója – mouka, boby, vločky. Prague: Nakladatelství Pavla Momčilová. 64p.

Moncel B. 2015. A Guide to Flour, Flour Components. Available at http://foodreference.about.com/od/Ingredients/a/A-Guide-To-Flour.htm: Accessed 2016-01-15.

Moudrý J, Kalinová J. 2004. Pěstování speciálních plodin : Alternativní pseudoobiloviny. Available at h.zf.jcu.cz/~moudry/skripta//index.html"ttp://www2.zf.jcu.cz/~moudry/skripta/2/index.html: Accessed 2016-03-09.

Moudrý J. 1999. Oves nahý. Výživa a potraviny 54: 77-78.

Müllerová M, Chroust F. 1993. Pečeme moderně v malých i větších pekárnách: Příručka pro pekaře začátečníky i mírně pokročilé. Pardubice: KORA. 205p.

Müllerová M, Skalický J. 1985. Zpracování mouky II. Prague: SNTL Nakladatelství technické literatury. 168p.

Müllerová M, Skoupil J. 1988. Technologie pro 4. ročník SPŠ. Prague: SNTL. 240p.

Müllerová P. 2008. Přídatné suroviny v běžném pečivu [Bc.]. Brno: Mendelova zemědělská a lesnická univerzita v Brně. 48p.

New Zealand flour millers association. 2010. Flour quality parameters. Available at http://www.flourinfo.co.nz/index.php?option=com_content&view=article&id=16:flour-quality-parameters&catid=5:flour-&Itemid=58: Accessed 2016-03-20.

Ngemakwe PN. 2015. Advances in gluten-free bread technology. Food science and technology international 21: 256-276.

Nováková E. 2009. Sója. Pekař Cukrář Odborný časopis pro pekaře a cukráře 11: 30-33.

P28 Foods, Inc. 2014. High protein bread. Available at http://www.shutterstock.com/: Accessed 2016-03-14.

Pacyński M, Wojtasiak RZ, Mildner-Szkudlarz S. 2015. Improving the aroma of gluten-free bread. LWT - Food Science and Technology: 706–713.

Pamplona-Roger GD. 2009. Encyklopedie léčivých potravin. Prague: Advent Orion. 391p.

Păucean A, Man S. 2013. Influence of defatted maize germ flour addition in wheat: maize bread formulations. Journal of Agroalimentary Processes and Technologies 19: 298-304.

Peč J, Dušek J. 2008. Composition and Utilization of Hemp Oil with Respect to Therapeutic Effect of Essential Fat Acids. Praktické Lékárenství 4: 86-89.

Pečivová P. 2006. Vliv definovaných přídatných látek na pekárenské vlastnosti pšeničného chleba [Ing.]. Zlín: Univerzita Tomáše Bati ve Zlíně. 120p.

Pelikán M. 2001. Zpracování obilovin a olejnin. Brno: MZLU. 148p.

Perlín C. 2002. Hemp as a Food. Výživa a potraviny 57: 121-122.

Perlín C. 2007. Mohou celiaci konzumovat oves– stále nevyřešená a řešená otázka. Available at http://www.agronavigator.cz/default.asp?ch=13&typ=1&val=66005&ids=163: Accessed 2016-02-08.

Petr J, Michalík I, Tlaskalová H, Capouchová I, Faměra O, Urminská D, Tučková L, Knoblochová H. 2003. Extension of the Spectra of Plant Products for the Diet in Coeliac Disease. Czech Journal of Food Sciences 21: 59-61.

Phillips RD, Finley JW. 1989. Protein Quality and the effects of processing. New York: Marcel Dekker. 416p.

Písaříková B, Zralý Z, Kráčmar S, Trčková M, Herzig I. 2005. Nutritional value of amaranth (genus Amaranthus L.) grain in diets for broiler chickens. Czech Journal of Animal Science 50: 568-573.

Popova O. 2011. Buckwheat grain. Available at http://www.shutterstock.com/: Accessed 2016-03-10.

Prugar J. 2003. Obiloviny v naší výživě (4). Výživa a potraviny 58: 34-35.

Příhoda J, Humpolíková P, Novotná D. 2003. Základy pekárenské technologie. Prague: Pekař a cukrář, s.r.o. 363p.

Příhoda J, Skřivan P, Hrušková M. 2003. Cereální chemie a technologie I: cereální chemie, mlýnská technologie, technologie výroby těstovin. Prague: Vydavatelství VŠCHT. 202p.

Příhoda J. 1991. Cereální chemie a technologie III: Technologie trvanlivého pečiva a snack výrobků. Praha: Vysoká škola chemicko-technologická. 58p.

Rahman K. 2003. Garlic and aging: New insights into an old remedy. Ageing Research Reviews 2: 39–56.

Rai S, Kaur A, Singh B, Minha KS. 2012. Quality characteristics of bread produced from wheat, rice and maize flours. Food Sci Technol 49: 786-789.

Rasbak J. 2013. Triticum spelta grain. Available at http://www.shutterstock.com/: Accessed 2016-02-28.

Ratmaner I. 2011. Rye grain. Available at http://www.shutterstock.com/: Accessed 2016-02-28.

Reed G, Peppler HJ. 1973. Yeast Technology. Connecticut: The Avi Publishing Company. 378p.

Roberta M. 2012. Seeds of Triticum aestivum. Available at http://www.shutterstock.com/: Accessed 2016-02-28.

Rysová J *et al.* 2008. Pohanka tatarská a její využití v potravinách. Available at http://www.vupp.cz/czvupp/publik/08poster/08rysovaSD3.pdf: Accessed 2016-03-11.

Sanz-Penella JM, Wronkowska M, Soral-Smietana M, Haros M. 2013. Effect of whole amaranth flour on bread properties and nutritive value. Food Science and Technology 50: 679–68.

Saturni L, Ferretti G, Bacchetti T. 2010. The gluten-free diet: Safety and nutritional quality. Nutrients 2: 16–34.

Schober TJ. 2009. Manufacture of gluten-free speciality breads and confectionery products. Gallagher E, editor. Gluten-free food science and technology. Oxford: Wiley-Blackwell, p130–180.

Simon, JL. 2000. Gomme xanthane. Available at http://www.techniques-ingenieur.fr/base-documentaire/procedes-chimie-bio-agro-th2/fabrication-des-grands-produits-industriels-en-chimie-et-petrochimie-42319210/gomme-xanthane-j6670/: Accessed 2016-03-03.

Skoupil J, Müllerová M, Štrobach J. 1981. Zpracování mouky. Prague: Nakladatelství technické literatury. 135p.

Skoupil J. 1994. Suroviny na výrobu pečiva. Pardubice: Kora. 211p.

Skřivan P. 2015. O lepku a paleo dietě bez předsudků. Available at: http://www.zitnecentrum.cz/2015/02/05/o-lepku-a-paleo-diete-bez-predsudku: Accessed 2016-03-15.

Sluková M. 2009. Kvalitativní ukazatele pšenice a pšenišných mouk. Available at http://www.vscht.cz/main/soucasti/fakulty/fpbt/grant_TRP/dokumenty/06.pdf: Accessed 2016-02-08.

Sluková M. 2011. Sacharidy obilovin a obilná vláknina. Available at http://www.zitnecentrum.cz/2016/01/05/sacharidy-obilovin-a-obilna-vlaknina/: Accesed 2016-02-09.

Somkaew Ch. 2011. Soybean seeds. Available at http://cherpatsomkaewcoltd.com/: Accessed 2016-03-11.

Suková I. 2011 Lněné semínko–nutriční benefity. Available at http://www.agronavigator.cz/default.asp?ids=147&ch=13&typ=1&val=111351: Accessed 2016-02-25.

Suková I. 2011. Výživový potenciál syrovátky. Available at http://www.agronavigator.cz/default.asp?ids=147&ch=13&typ=1&val=109394: Accessed 2016-03-01.

Šalplachta J, Allamier G, Chmelík J. 2005. Proteomická identifikace glutenových bílkovin. Available at http://www.chemicke-listy.cz/docs/full/2005_12_967-971.pdf: Accessed 2016-02-08.

Šediv P. 2009. Přídatné látky v pečivu. Pekař Cukrář Odborný časopis pro pekaře a cukráře 3: 13-17.

Šilhánková L. 2002. Mikrobiologie pro potravináře a biotechnologie. Prague: Nakladatelství Academia. 363p.

Šimek J. 2010. Úloha výživy při vzniku a nápravy nealkoholické jaterní steatózy. Výživa a potraviny 1: 3-6.

Šmajstrla Z, Adámek P, Gajdušek J. 1999. Pohanka ve mlýně a v kuchyni. Rožnov pod Radhoštem: Vydavatelství TNM. 110p.

Toufeili I, Dagher S, Shadarevian S, Noureddine A, Sarakbi M, Farran M. 1994. Formulation of gluten-free pocket-type flat breads: optimization of methylcellulose, gum Arabic, and egg albumen levels by response surface methodology. Cereal Chem 71: 594–60.

Týř O, Štanglica B, Dřízal J, Mihulka S, Musil S. 2009. Pohanka. Pekař Cukrář Odborný časopis pro pekaře a cukráře 10: 20-25.

Unal Ozmen M. 2010.Yellow corn grain. Available at http://www.shutterstock.com/: Accessed 2016-03-14.

Urban Farmer. 2016. Hickory King White Corn Seed. Available at http://www.ufseeds.com/Hickory-King-White-Corn-Seed.item: Accessed 2016-03-15.

Vaculová K. 1999. Ječmen (Hordeum L.) bezpluchý. Výživa a potraviny 54: 108-110.

Velíšek J. 2002. Chemie potravin. Tábor: OSSIS. 344p.

Vodrážka Z. 1999. Biochemie. Prague: Academia. 506p.

Wasserman L. 2009. Bread improvers – action and application. Available at http://www.wissensforum-backwaren.de/files/wfb_broschuere01_e.pdf: Accessed 2016-02-15.

Waterschoot J, Gomand SV, Fierens E, Delcour JA. 2014. Production, structure, physicochemical and functional properties of maize, cassava, wheat, potato and rice starches. Starch 67: 14-29.

Wheat Marketing Center, inc. 2004. Wheat and Flour Testing Methods: A Guide to Understanding Wheat and Flour Quality. Portland Oregon: Wheat Marketing Center. 71p.

Xia N, Wang JM, Gong Q, Yang XQ, Yin SW, Qi JR. 2012. Characterization and In Vitro digestibility of rice protein prepared by enzyme-assisted microfluidization: Comparison to alkaline extraction. Journal of Cereal Science 56: 482 - 489.

Yawadio Nsimba R, Kikuzaki H, Konishi Y. 2008. Antioxidant activity of various extracts and fractions of Chenopodium quinoa and Amaranthus spp. seeds. Food chemistry 106: 760-766.

Zehnálek J. 2003. Biochemie 2. Brno: MZLU. 186p.

Ziobro R, Juszczak L, Witczak M, Korus J. 2015. Non-gluten proteins as structure forming agents in gluten free bread. J Food Sci Technol 53: 571-580.

Annex

Table 2. Main advantages and disadvantages of flours

Flours	**Main advantages**	**Disadvantages**
Common wheat	-Able to create individual structural network thanks to gluten -Large amount of Phenolic acids, Ferulic acid prevent of neurodegenerative diseases	- Lots of allergies to wheat -Coeliac disease (inflammatory disease of the small intense with hypersensitivity to the protein gliadin)
Spelt	-High amount of B vitamins and Beta-carotene -Able to create individual structural network thanks to	-Lots of allergies to wheat -Celiac disease
Rye	-Relatively high amount of proteins (9-12 %) and dietary fibre (15-17 %). -Sodium-free, so it can help to reduce high blood pressure.	-Not able to create individual structural network (lower volume, less soft consistence) -Lack of calcium
Barley	-Relatively high amount of proteins (12-16 %) and dietary fibre (12-15 %). -Content of vitamins: tocopherols and tocotrienols, especially alpha-tocotrienol, which helps to reduce cholesterol synthesis -High content of β-glucans (reduce cholesterol in blood)	-Celiac disease (inflammatory disease of the small intense with hypersensitivity to the protein gliadin)
Oats	-The highest biological value from cereals (essential amino acid lysine content in oats is 30 % higher than in wheat). -Do not have to be excluded from the celiac diet	-Content of vitamins A, C, D is low
Maize	-Maize grain has the highest energy value from all cereals, it has high starch content	-Very low calcium content
Rice	-Vitamin E. It is considered as one of the most powerful antioxidants -Great taste	-The cost of rice is higher per pound than corn or wheat
Buckwheat	-Vitamin Choline - regenerates liver´s cells after diseases -Vitamin Rutin - protects against vascular diseases -High amount of proteins, balanced mix of amino acids	-Can cause allergic reactions (frequently occurs in individuals who suffer from celiac disease) -Strong nutty flavour, it has to be combined with other ingredients
Quinoa	-Highly digestible, has a really good taste -Relatively high amount of Riboflavin -Higher protein content and a favourable amino acid	-Contain Saponin (bitter flavour) – it has to be removed

Amaranth	-Proteins in amaranth grain are very high quality (similar to proteins of animal origin) -Low glycaemic index (suitable for diabetics) -From fats is important squalene (prevents excessive synthesis of cholesterol)	-Low content of leucine -Contain Saponin (bitter flavour) – it has to be removed
Hemp	-High content of proteins is 20–25 %, main is edestin (important in health care) -Highest quantity of minerals -High amount of beta-carotene and vitamins B1	
Soybean	-Really high amount of proteins (30 %), main protein is lysine -Concentration of minerals is really high	-Relatively strong allergen, many people suffer from allergy to soybean

Table 3. Substances which improve gluten-free bread

Substances		Examples of substances	Effect of substances
Hydrocolloids	Chemically or biochemically synthesized	Carboxymethylcellulose	- Viscoelastic and cohesive behaviour like gluten, increase the gas binding capacity - Used as a thickening agents, helping in swelling, with gelatinization
		Hydroxypropylmethylcellulose	
		Methylcellulose	
		Xanthan gum	
	Microbial biosynthetic	Casein	
		Soy protein	
		Egg albumin	
	Plant origin	Guar gum	
		Agar–agar	
		Carrageenan	
		Pectin	
		β-glucan	
		Gum Arabic	
		Bean gum	
Enzymes		Transglutaminase	- improve the water-binding capacity and dough viscosity and elasticity, decrease hardness of the crumb, prolong the shelf life (retrogradation of the starch)
		Cyclodextrinase	
		Protease	
		Cyclodextrin glycosyltransferases	
		Laccase	- mainly stabilize the dough structure
		Glucose oxidase	
Starches		Maize starch	- cause that the gelatinization occurs quickly and completely - facilitate development of a cohesive crumb network
		Potato starch	
		Rice starch	
Fats		Vegetable oil	- decrease the starch gelatinization and the starch solubility in gluten-free bread - increase the gas-binding capacity
		Margarine	
Proteins		Plant origin (soybean, pea, lupine…)	- form a network similar to gluten network - increase the nutritional level
		Animal origin (milk proteins, egg albumins…)	
Emulsifiers			- slow down evaporation of water from the dough, porosity of the dough is more uniform, products have greater volume, prolong shelf life