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Chemical composition of various rice types

BACHELOR THESIS

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DECLARATION

I declare in lieu of oath that I wrote this thesis myself. All information derived from the work of others has been acknowledged in the text and a list of references is given.

In Prague, April 2016 ………………………………

Inesa Musić

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ABSTRACT

On the market are commonly found different types of rice - polished, long, basmati, jasmine etc. Bachelor thesis aims to compile data on the chemical composition of each type of rice and critically evaluate, whether sufficient data are available so that both customers and government agencies are able to distinguish them from each other. The theme was proposed to process by Czech Agriculture and Food Inspection Authority.

Keywords: rice, varieties, forms, grain, chemical composition

Na trhu se běžně vyskytují různé typy rýže - leštěná, dlouhozrnná, basmati, jasmínová atd. Bakalářská práce má za cíl zpracovat údaje o chemickém složení jednotlivých typů a kriticky zhodnotit, zda jsou dostupné dostatečné údaje k tomu, aby je jak zákazníci, tak státní úřady dokázaly tyto typy rýže od sebe odlišit. Toto téma navrhla zpracovat Státní zemědělská a potravinářská inspekce.

Klíčová slova: rýže, odrůdy, formy, zrno, chemické složení

Contents

1. PREFACE

China. India. Indonesia. Vietnam. Thailand. Do you know what all these countries have in common except the fact they are located in Asia? They are top 5 producing countries (FAOSTAT data, 2012) of the most important crop in the world - rice (*Oryza sativa*). Since ancient time, mankind is dependent on cereals which were among first crops grown by human. In different parts of the world grains gained significant status throughout history. Rice is the predominant staple food for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa (Kennedy, 2002).

The journey from young bright green plant to the nutritious meal on our plate is thousand miles but it begins with a single step - planting which is followed by harvesting, drying, storing, milling, packing, and selling. Rice is native to Asia and Africa, but due to trade and exportation it can be find across the globe.

Have you ever wondered why you eat fish, meat or beans with rice? Main reason is to make your diet balanced. Rice is great source of energy, lipids and vitamins B, but it lacks in amino acids and micronutrients. Adding fish increases level of proteins and micronutrients. In Southeast Asia, where agriculture is a major source of livelihood, the average annual consumption of rice per capita was about 197 kg and provided 49 % of the calories and 39 % of the protein in the diet in 2007 (Redfern at al., 2012). It is known that rice has been feeding the region’s population for well over 4 000 years and is the staple food of about 557 million people (Redfern et al., 2012).

Rice is rich in diversity. Thanks to genotype, processing and science, nowadays we can differ many varieties of rice which do not have equal nutritional value. Due to the importance of this cereal in the diet, its composition and nutritional characteristics are connected with human's health. The biggest problem rice-consuming countries are confronting is malnutrition which is not only caused by rice consumption.

For people living in developing areas of the world, rice is more than just food. It is main source of nutrition, employment and income. Rice is life.

2. AIMS OF THESIS

International and national markets offer large amounts of rice types varying in colour, shape, scent, taste consistency prior and after cooking. Both general public and experts face difficulties to recognize and verify particular types of rice, because definite markers are missing. The objective of this study was to collect data on the chemical composition and appearance of various types of rice and assess specific differences in composition, colour, shape so that they can be unmistakably distinguished from each other.

3. METODOLOGY OF THE THESIS

This thesis was written in the form of literature review. Information essential for understanding the topic was obtained mostly from reviewed scientific literature.

As a pillars of thesis were used:

1. Rice in human nutrition written by Juliano OB, published with the collaboration of International Rice Research Institute (IRRI) and Food and Agricultural Organization of the United Nations (FAO), Rome, 1993

2. Ricepedia, a product of CGIAR and GriSP (Consultative Group on International Agricultural Research; Global Rice Science Partnership)

Furthermore, scientific databases such as ScienceDirect and Web of Knowledge were used. All sources were listed in references.

The layout and style of the references were done according to the "Methodical Manual for the Writing of BSc Theses" published by Faculty of Tropical AgriSciences (FTA) 2014 (edited 2016).

In following sections information about four major groups of *Oryza sativa* can be found: indica, japonica, aromatic rice and glutinous rice. Firstly, classification of rice is introduced according to degree of postharvest processing and its impact on nutritional value. Next chapters are about aromatic rice - Basmati, Jasmine and Patna rice, pigmented rice - Red and Black rice and genetically engineered - Gold rice. Additionaly, information about Arborio and Glutinous rice can be found. In each type are written information about origin, grain size and shape, degree of milling, particularities of chemical composition, and method of cooking. In addition are given data about glycemic index (GI) and quality pictures of different varieties. Data regarding nutritional value can be found in Table 12.

LITERATURE REVIEW

4. FROM FIELD TO PLATE

Rice is an annual grass which requires a lot of water, high temperatures and moisturized land in order to produce economically important grains (Vegas, 2009). The entire process of rice production is presented in Figure 1. Rice can be cultivated in lowland or in upper land. If it is cultivated on a higher land it is necessary to make terrace which is a flat part of hill or a mountain. Rice is always planted on heavy muddy soils which detain water. If such land is not available, it can also be planted in paddy fields which are flooded parcel of arable land. About 4 - 6 months later the grain is ripe (Vegas, 2009). It has golden colour and it is ready for harvesting but it is important to pump out water from the fields. Ripening is followed by harvesting, drying, storing, and milling. Main goal of milling is to produce edible rice kernel (Tangpinijkul, 2010). Hence, 4 rice forms can be distinguished (rough, brown, parboiled and white rice) according to degree of milling which differ in nutritive value (see Chapter 8.2). Afterward postharvest processing following steps are packing and selling.

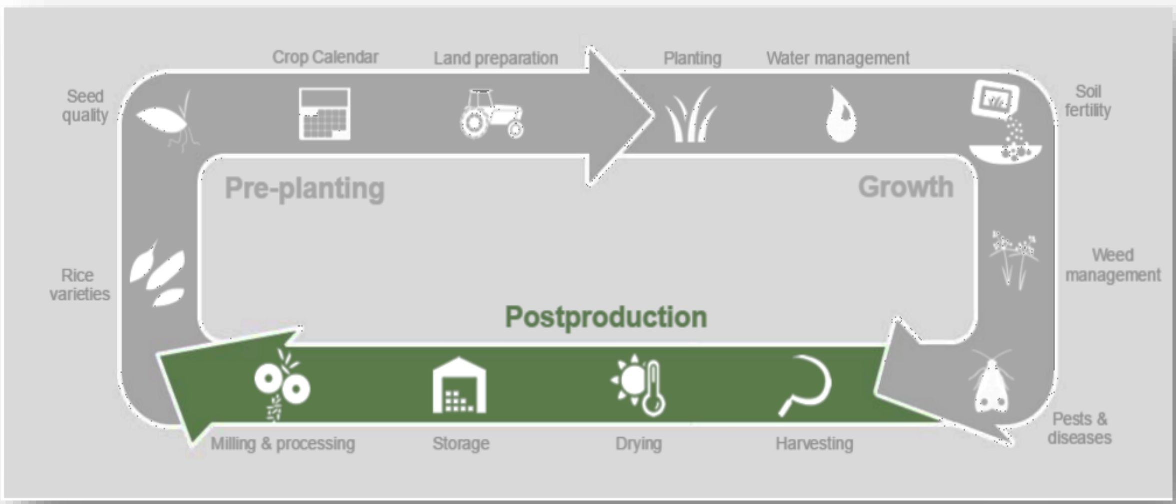


Figure 1. Step by step production of rice (Rice Knowledge Bank, 2009)

5. GENUS ORYZA

Genus *Oryza* which originated in Southeast Asia and Philippines, has two cultivated species which are important for human diet: *Oryza sativa* and *Oryza glaberimma* (Ricepedia, 2013).

5.1. Oryza sativa L.

Oryza sativa (Asian rice) was cultivated 8,000 – 13,000 years ago in China, later spread to South and Southeast Asia. Today it is grown everywhere on our planet except Antarctica. Nowadays exists more than 40,000 varieties of *Oryza sativa* which are classified into four mayor categories: indica, japonica, aromatic and glutionous. Two major subspecies are indica and japonica. Javanica has been considered as a third subspecies.

Primary differences between indica and japonica subspecies are: geographic distribution (latitude), sensitivity to temperatures, cooking characteristics and grain shape (Figure 2).

5.1.1. Oryza sativa **subsp.** ***japonica***

According to Xiong (2011), japonica is limited to latitudes greater than 15° N which implicates it is usually grown in temperate climates and cooler climates of subtropics. It comes from northern and eastern China (IRRI, 2007). The grains are short and round, do not break easily. When cooked, japonica grains are sticky and moist because of 0 – 20 % low amylose content (IRRI, 2007). Mainly, japonica is produced in Japan and Korea. The well - known japonica varieties are komachi and koshihikari, mostly used in sushi and other sticky dishes.

5.1.2. Javanica **or tropical japonica**

Javanica is grown at Philippines, in Indonesia and the grains are long, broad, and thick, do not shatter easily, and have low amylose content (CGIAR, 2013). At the time of being javanica is labelled as intermediate type - tropical javanica.

5.1.3. Orzya sativa subsp. *indica*

It is the mostly grown in tropical and subtropical areas with latitude range from 2° S to 40° N, such as Philippines, India, Pakistan, Java, Sri Lanka, Indonesia, central and southern China, and in some African countries (Xiong, 2011; CGIAR, 2013). Indica rice types are less sensitive to temperature than japonica varieties. Grains are long to short, shatter more easily and contain 23 - 31 % of amylose (IRRI, 2007). When cooked, the rice is dry, fluffy with separate grains. Indica varieties accounts for more than 75 % of global trade (Nipuna rice, 2015). Prominent indica rice types are Basmati and Jasmine rice.

Figure 2. The differences in grain of japonica, indica and javanica (IRRI, 2007)

5.2. Oryza glaberimma

Oryza glaberimma (African rice) is grown in West Africa. It has been cultivated 2,000 – 3,000 years in what is it today Mali. It has brittle grains, poor milling quality and lower yields compared to *Oryza sativa*. On the other side, it is more resistant to fluctuations in water depth, iron toxicity, infertile soils and shows better resistance to various pests and diseases (Ricepedia, 2013). Scientists try to produce new variety of rice - NERICA by combining characteristics of both *Oryza glaberimma* and *Oryza sativa* (Ricepedia, 2013).

6. GENUS ZIZANIA

Genus *Zizania* is commonly known as “wild rice“. Wild rice is not a rice but water grass. Three species are native to North America (*Zizania palustris, Zizania texana* and *Zizania* aquatica) and one to China (*Zizania latifolia)*. The most important species are *Zizania latifolia* and *Zizania palustris* (IRRI, 2013).

Zizania latifolia (Manchurian wild rice) it is native to eastern Asia. Unlike the American wild rice species, *Zizania latifolia* is grown for its edible stems. Terell and Batra (1982) reported that stems are usually parasitized by smut fungus, *Ustilago esculenta* Hennings, causing culm enlargement and failure to produce flowers. Those infected culms have been used as a vegetable in China since 10th century (Figure 3).

Figure 3. Stems of *Zizania latifolia* (Taipei flora exhibition, 2010)

Zizania palustris (Northern wild rice) originated in the area of the upper Great Lakes and it was a staple food of several Native American tribes. Commercialization of wild rice began in the 1950's and today the largest producers of wild rice are Minnesota and California (commercialization started in 1977) (Whole grains council, 2013). Wild rice has black slender grains about 1.24 cm long (Figure 4). When cooked wild rice is tender, not mushy (Los Angeles Daily News, 2003). Cooking time is longer than in white rice and it depends on method of cooking. After cooking kernels elongate three to four times (Los Angeles Daily News, 2003). Wild rice has delicate flavour and it is highly nutritious (Table 12). Compared to white rice, it obtains more proteins, less carbohydrates and calories. It is rich in phosphorus, zinc and magnesium. It is a whole grain rice very suitable for people avoiding gluten. GI of wild rice is medium.

Figure 4. Processed wild rice (Eberhart Wally, 2016)

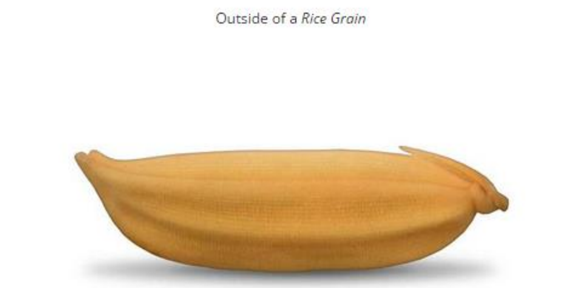
7. GRAIN ANATOMY AND CHEMICAL COMPOSITION

Rice is a monocot, more precisely it belongs to the family of *Poacea* and the grain is the typical fruit (Figure 5). The longitudinal section of rice grain is presented in Figure 6.

The grain consists of five parts:

1) Hull
2) Pericarp
3) Bran layer
4) Endosperm
5) Embryo

Most rice varieties are composed of roughly 20 % rice hull or husk, 11 % bran layers, and 69 % starchy endosperm (Tangpinijkul, 2010).



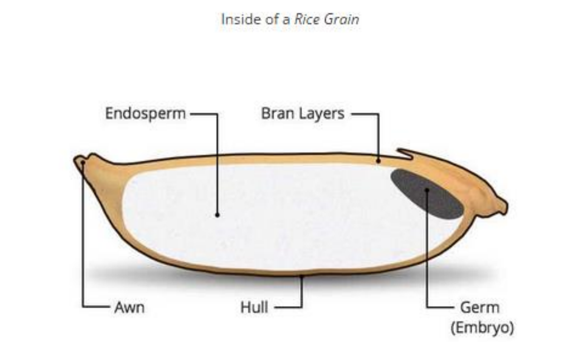


Figure 5. Outside and inside of rice grain (Riceland, 2015)

Hull, also known as a husk is the hard outer part of a kernel. It is made of cellulosic and fibrous tissue. On its surface we can find spines or trichomes which makes it hard and not edible.It is almost always removed. This protecting cover is resistant to the pests like insects, microorganisms, moisture.

Pericarp is the fibrous layer which has no colour or it is slightly grey. Function of this layer is extra protection against molds. Testa or the tegmen layer is thick layer very rich in oil and proteins but poor in starch. It is found under the pericarp.

Bran layer also known as aleurone layer is found under the testa. It has a lot of oil, proteins, vitamins, and minerals.

Endosperm is a starchy part of a grain characterized by tremendous energy value. It is made by subaleurone layer and inner endosperm.

Embryo is the part of a seed that develops into a plant, consisting of a plumule, a radicle and one cotyledon. It is found at the bottom of the grain enclosed by endosperm.

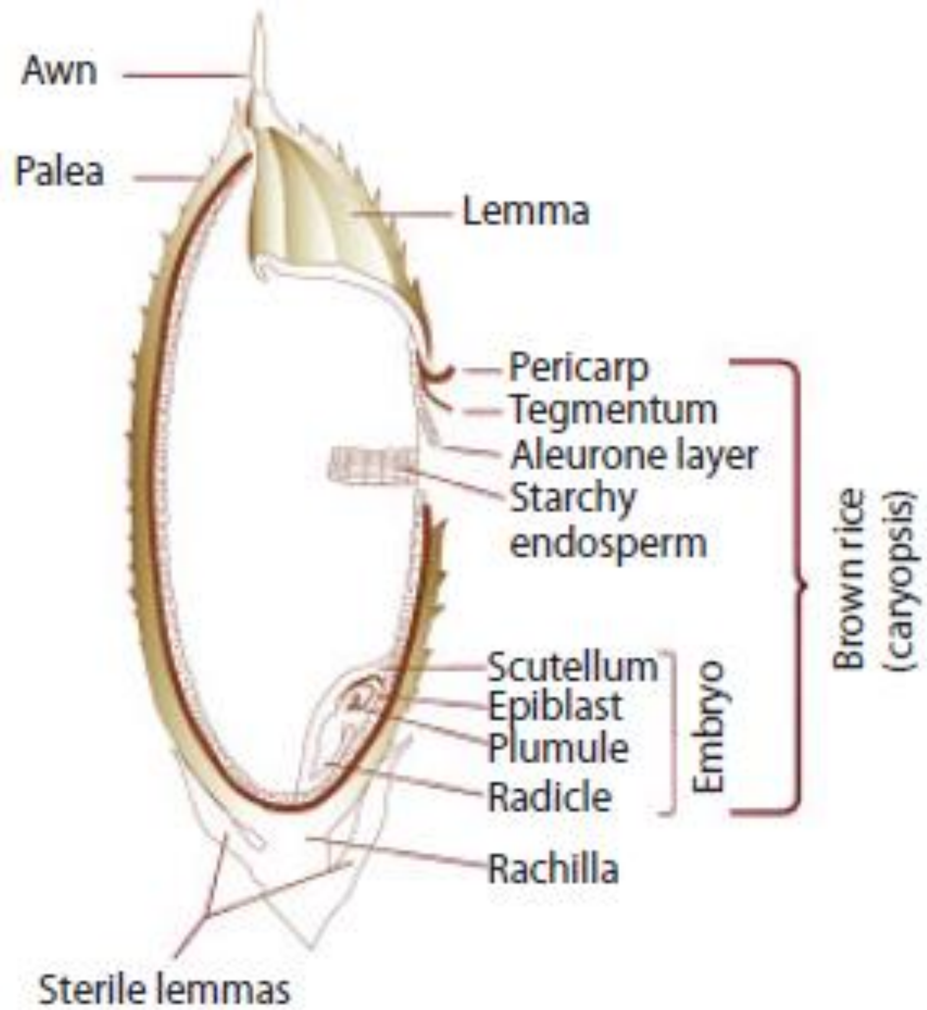


Figure 6. Longitudinal section of rice grain (IRRI, 2010)

Specific parts of rice kernel are removed in milling process in order to get edible rice (brown and white). All varieties of rice can be processed post-harvest to obtain either white/polished or brown/unpolished rice (IRRI, 2013). Removing husk produces brown rice. Further milling to remove the pericarp, seed coat, testa, aleurone layer, and embryo to yield milled rice results in a disproportionate loss of lipid, protein, fibre, reducing sugars and total sugars, ash and minor components including vitamins, free amino acids and free fatty acids (Zhou et al., 2002).

According to what is retained of a rice kernel after milling process, we distinguish rough, brown, white and parboiled rice. Tegmen layer (present in brown rice) contains protein, B complex vitamins, vitamin E (α-tocopherol and tocotrienol) and vitamin K, and also valuable substance γ-oryzanol (Kim et al., 2012). Brown rice has high amount of minerals which includes selenium, potassium, magnesium, iron and zinc (Khairul Kamilah et al., 2007). Polished rice (without the seed coat) contains about 25% carbohydrate, with trace amounts of iodine, iron, magnesium, and phosphorus, and only small amounts of protein and fat (Kim et al., 2012). Table 1 presents chemical composition of rough, brown and white rice.

Chemical constituents of a rice grain are divided into five groups including carbohydrates, proteins, lipids, vitamins and minerals. The chemical composition of grains varies widely, depending on environment, soil and variety (Zhou et al., 2002) and milling process.

Table 1. Proximate composition of rough rice and its milling fractions at 14 percent moisture (Juliano, 1993)

Rice fractions	*Crude protein*	*Crude fat*	*Crude fiber*	*Crude ash*	*Available carbohydrates*	*Neutral detergent fibre*	*Energy content*		*Density*	*Bulk density*
	(g N x 5.95)	**(g)**	**(g)**	**(g)**	**(g)**	**(g)**	**(kJ)**	**(kcal)**	**(g/ml)**	**(g/ml)**
Rough rice	5.8-7.7	1.5-2.3	7.2-10.4	2.9-5.2	64-73	16.4-19.2	1580	378	1.17-1.23	0.56-0.64
Brown rice	7.1-8.3	1.6-2.8	0.6-1.0	1.0-1.5	73-87	2.9-3.9	1520-1610	363-385	1.31	0.68
Milled rice	6.3-7.1	0.3-0.5	0.2-0.5	0.3-0.8	77-89	0.7-2.3	1460-1560	349-373	1.44-1.46	0.78-0.85
Rice bran	11.3-14.9	15.0-19.7	7.0-11.4	6.6-9.9	34-62	24-29	670-1990	399-476	1.16-1.29	0.20-0.40
Rice hull	2.0-2.8	0.3-0.8	34.5-45.9	13.2-21.0	22-34	66-74	1110-1390	265-332	0.67-0.74	0.10-0.16

7.1. CARBOHYDRATES

Carbohydrates are the major source of energy for our body. The most important rice carbohydrates are: polysaccharide starch, sugars and non-starch polysaccharides. Non-starch polysaccharides consist of water soluble polysaccharides and insoluble dietary fiber (Juliano, 1993).

7.1.1. Starch

Relating structure and function

Starch is polymer of D-glucose linked alfa (1 - 4) bonds and usually consists of linear-helical fraction and branched fraction, amylose and amylopectin. It has semi-crystalline structure. Pure starch is a white powder soluble in hot water. Thanks to that characteristic, structure is lost and viscosity of the mixture is increasing due to presence of amylose molecules and it is easier to digest it and to get sugars our body needs, firstly maltose which is hydrolysed by amylase to glucose. Also, by longer cooking starch becomes paste which has found, in addition to its importance in human nutrition, many applications in industry: it is used in the manufacture of paper as adhesive, textiles, pharmaceuticals, biodegradable polymers and as a food additive (Abbas et al., 2014).

Granule size and shape

Starch is the energy store form of carbohydrate in green plants and the most important source of carbohydrate in human diet and it can be found among staple foods. It is stored in amyloplasts in form of granules. According to Hegenbart (1996), rice has small granule sizes ranging from 3 to 8 microns and granules are irregularly shaped polygons with the waxy rice exhibiting some compound granules (Figure 7).

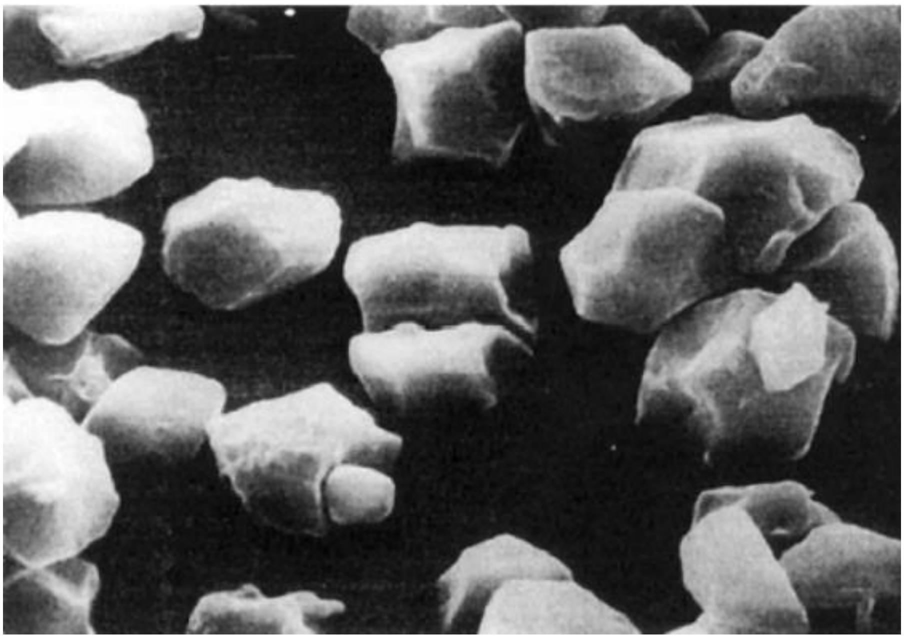


Figure 7. Scanning electron micrograph of rice starch granules, 5000x (Sivak & Preiss, 1998)

Amylose: amylopectin ratio

All starches are made by two components: amylose and amylopectin in different rations. Ratio depends on type of starch and plant varieties within a type. Generally, rice starch is made by 20 – 25 % of amylose and 75 – 80 % of amylopectin. Amylose content can vary and therefore we can differ waxy rice, very low amylose rice, low amylose rice, intermediate amylose rice, and high amylose rice (Badi, 2013) (Table 2).

Table 2. Categorization of rice based on amylose content (Badi, 2013)

Category	*Amylose content (in %)*
Waxy	1-2
Very low	2-9
Low	10-20
Intermediate	20-25
High	25-30

7.1.2. Non-starch polysaccharides

Dietary fibers comes from plants and they cannot be broken down by enzymes in our digestive system and thus stayed undigested. In plants they can be found in grain cell walls. Two types are known, soluble and insoluble fiber, both beneficial to health. Main role is to lower glucose and blood cholesterol level and to move food trough digestive system. Water insoluble fibers are hemicellulose, arabinoxylanose, cellulose and lignin. Water soluble is pectin. According to Juliano (1993), the endosperm has a lower content of dietary fibre than the rest of brown rice. As it is shown in Table 1, the richest in dietary fiber is the rice hull followed by rice bran, rough rice, brown rice, and milled rice. As a result, the bran is used as ingredient for animal foods. Reported values for neutral detergent fibre are 2.9 to 3.9 % for brown rice (Juliano, 1993).

Table 3. Yield and composition of deffated and protease-amylase treated cell wall preparations obtained from different histological fractions of milling of brown rice (Juliano, 1993)

Rice fraction	*Yield (% deffated tissue)*	*Composition (% of total)*				*Uronic acid in pectin (%)*	*Arabinose: xylose ratio*	
		Pectin substances	**Hemicellulose**	**α-cellulose**	**Lignin**		**Pectin substances**	**Hemicellulose**
Caryopsis coat	29	7	38	27	32	32	1.63	0.82
Aleurone tissue	20	11	42	16	25	25	1.78	0.84
Germ	12	23	47	9	16	16	2.29	0.96
Endosperm	0.3	27	49	1	34	34	1.09	0.64

Unlike endosperm of white rice, brown rice endosperm has high lignin content. Endosperm pectin has a higher uronic acid content but a lower arabinose-to-xylose ratio than the other grain tissues and hemicellulose of endosperm also has a lower arabinose-to-xylose ratio than the three other grain tissues (Table 3) (Juliano, 1993).

Table 4. Glycemic index (ADA, 2013)

GI rating system	GI (glucose=100)
Low	0 - 55
Medium	56 - 69
High	70 or more

In food having carbohydrates we can determine glycemic index (GI). GI measures how does the food containing carbohydrates raises blood sugar-glucose. We distinguish food with low, medium and high GI (American Diabetes Association ADA, 2013). GI of various rice is presented in Table 5.

Table 5. Glycemic index of various rice (ADA, 2013)

	GI (GLUCOSE=100)	SERVING SIZE (g)
Brown rice	50	150
White ice	89	150
Parboiled rice	38	150
Wild rice	Medium	
Basmati rice	Medium	
Waxy rice	86	

The glycemic index and glucose response of different varieties of rice depended on their fiber content and amylose content. Generally, the rice with the lowest amylose content had a high glycemic index (75) while rice with the highest amylose content had a low glycemic index (50) (Trinidad et al., 2012). Low fiber was associated with a high glycemic index while rice with higher fiber had a lower glycemic index (Trinidad et al., 2012).

7.2. PROTEINS

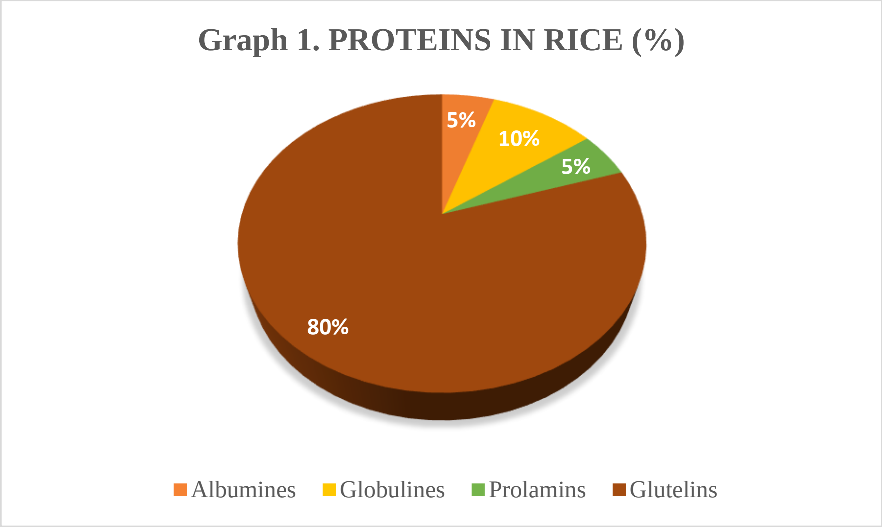
Proteins have great importance for the life and they are called after Greek word protos meaning first, the most important. Proteins are macromolecules made by amino acids which are connected to each other in long chains. In rice, the most important proteins are albumins (water soluble), globulins (salt soluble), prolamins (alcohol soluble) and glutelins (alkali soluble) (Graph 1). Albumins have the highest lysine content, followed by glutelins, globulins and prolamins. Recent data for protein contents ranged from 6.6 to 7.3% for brown rice, from 6.2 to 6.9% for milled rice and for basmati rice 8.2 to 8.4% (Saeed et al., 2011). Compared to other cereals, rice is low in proteins but has higher lysine content (Salunkhe, 1992). Main reason for that is low content of prolamin fraction. Unlike the other crops, up to 80 % of the total storage protein in rice is glutelin and prolamin takes 20 to 30 % (Chen et al., 2011). Thus the composition and structure of glutelin and prolamin have the decisive role in determining the nutritional traits in rice. Table 6 presents solubility fractions of rice protein of non-aromatic white rice and brown rice.

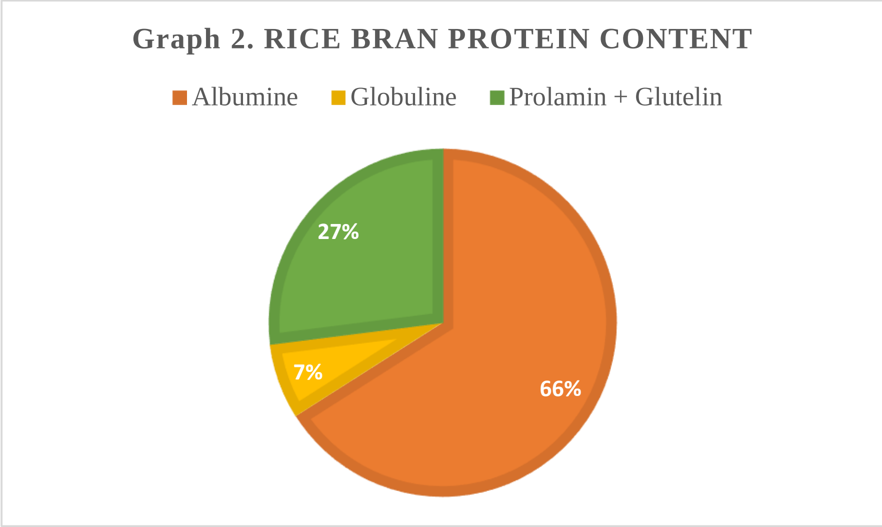
Table 6. Solubility fractions of rice protein (Juliano, 1993)

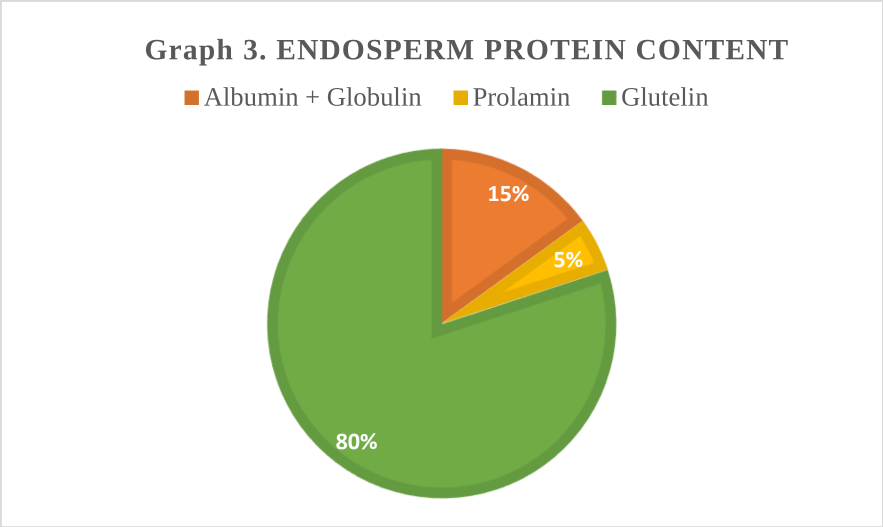
	Albumins (%)	***Globulins (%)***	***Prolamins (%)***	***Glutelins (%)***	***Albumins + globulins (%)***
White rice	9.7-14.2	13.5-18.9	3.0-5.4	63.8-73.4	/
Brown rice	/	/	12.5-14.5	66.0-67.7	18.8-20.8

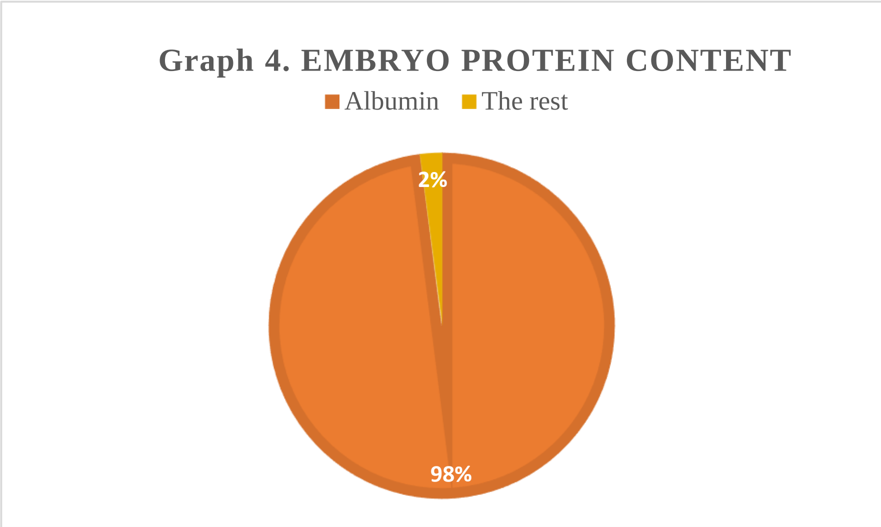
Protein is most abundant in the subaleurone layers but is also present in aleurone cells (Azhakanandam et al., 2000). The starch granule amylose bound up to 0.7% protein that was identified as mainly the waxy gene protein or granule-bound starchy synthase (Juliano, 1993). The waxy gene protein was rich in disulphide linkages, and was found in higher amounts in high-amylose compared with low-amylose rice (Hamaker, 1993).

Protein content of rice and its grain parts (own work)









Reserve proteins in rice are located mainly in the endosperm in form of protein bodies (grains). Protein bodies (PB) in rice can be divided into two groups, PB-I and PB-II, according to their morphologically characteristics. PB-I are spherical, with a diameter of about 1 to 2 µm, rich in prolamin. In contrast, the crystalline (PB-II) protein bodies are larger (3-4 µm), irregularly shaped and rich in glutelin (Chen at al., 2011). As it is shown in Graph 3, endosperm proteins were composed of 60 - 65 % PB-II proteins, 20 - 25 % PB-I proteins and 10 - 15 % albumin and globulin in the cytoplasm (Juliano, 1993). Proteins of rice bran and embryo are rich in albumin (see Graph 2 and 4).

Glutelin in rice is synthesized as a 57 kDa precursor and then cleaved into a 37 to 39 kDa acidic subunit and a 19 to 25 kDa basic subunit (Juliano, 1993; Chen et al., 2011).

As the second abundant protein in rice endosperm, the prolamins have molecular masses of ranging from 12 to 17 kDa but mainly (90 %) 13 kDa subunit plus two minor subunits of 10 and 16 kDa (Juliano, 1993; Chen et al., 2011).

The "completeness" (or quality) of a protein is determined by its amino acid composition. A complete protein source is one that provides all 9 indispensable amino acids (McNeil, 2008). Essential amino acids are those amino acids which human body cannot synthesize and must be in appropriate amounts obtained food. Those are phenylalanine (Phe), valine (Val), threonine (Thr), tryptophan (Try), methionine (Met), leucine (Leu), isoleucine (Ile), lysine (Lys), and histidine (His). To evaluate quality of protein, Amino Acid Score method is used. Amino Acid Score of 100 or higher indicates a complete or high-quality protein (Clark CJ and Morel JL, 2014). If the Amino Acid Score is less than 100, additional sources of protein should be found. The essential amino acid contents of the glutelin and prolamin subunits (Table 7) showed lysine as limiting in these polypeptides except fraction of the 13 kDa prolamin subunit, which is limiting in methionine plus cysteine. Thus, glutelin has a better amino acid score than prolamin except for the 16 kDa prolamin subunit. The 10 kDa prolamin subunit has a high (6.8 %) cysteine content (Juliano, 1993).

Table 7. Aminogram (9/16 N) of the acidic and basic subunits of rice glutelin and the mayor and minor subunits of prolamin (Juliano, 1993)

Amino acid	*Glutelin subunits[1]*		*Prolamin subunits*		
	30-39 kDa (acidic)	**19-25 kDa (basic)**	**13 kDa**	**10 kDa**	**16 kDa**
His	2.2-2.5	2.6-2.7	2.0-2.4	1.7	4.2
Ile	3.2-3.3	4.1-4.9	3.8-5.4	1.6	3.6
Leu	6.4-7.5	7.0-8.5	17.9-26.4	4.7	8.1
Lys	2.2-3.0	3.0-4.1	0.4-5.5	1.0	3.3
Met + Cys[2]	0.2-1.9	0.1-2.4	0.7-1.2	22.5	5.3
Phe +Tyr	10.0-10.5	10.1-10.8	12.7-21.6	4.3	7.6
Thr	2.8-3.7	2.5-3.7	1.8-2.8	6.8	2.7
Val	5.1-5.7	5.7-7.0	2.7-3.9	4.4	3.9
Amino acid score[3] (%)	38-52	52-71	7-8[4]	18	57

1 - S-cyanoethyl glutelin subunits.

2 - Only the IEF3 fraction of the 13-kd, 10-kd and 16-kd prolamin subunits had cystine. All glutelins had substituted cysteine residues

3 - Based on 5.8% lysine as 100%

4 - AIternative value is 34% based on 2.5% methionine + cysteine as 100%

Table 8. Amino acid content of rough rice and its milling fractions at 14 percent moisture (9 per 16 9 N) (Juliano, 1993)

Rice fraction	*His*	*Ile*	*Leu*	*Lys+cys*	*Met + Tyr*	*Phe*	*Thr*	*Trp*	*Val*	*Amino acid score [1]*
Rough rice	1.5-2.8	3.0-4.8	6.9-8.8	3.2-4.7	4.5-6.2	9.3-10.8	3.0-4.5	1.2-2.0	4.6-7.0	55-81
Brown rice	2.3-2.5	3.4-4.4	7.9-8.5	3.7-4.1	4.4-4.6	8.6-9.3	3.7-3.8	1.2-1.4	4.8-6.3	64-71
Milled rice	2.2-2.6	3.5-4.6	8.0-8.2	3.2-4.0	4.3-5.0	9.3-10.4	3.5-3.7	1.2-1.7	4.7-6.5	55-69
Rice bran	2.7-3.3	2.7-4.1	6.9-7.6	4.8-5.4	4.2-4.8	7.7-8.0	3.8-4.2	0.6-1.2	4.9-6.0	83-93
Rice hull	1.6-2.0	3.2-4.0	8.0-8.2	3.8-5.4	3.5-3.7	6.6-7.3	4.2-5.0	0.6	5.5-7.5	66-93

Based on 5.8 g lysine per 16 g N as 100% (WHO, 1985)

7.3. LIPIDS

Lipids are molecules made by carbon, hydrogen and oxygen which are generally insoluble in water. Carbon to hydrogen bonds are non-polar covalent, soluble in non-polar organic solvents. Due to structural variety, lipids can be classified into four major categories: fats, phospholipids, steroids and waxes. Lipids are of crucial importance for energy storage (lipids contain more energy than carbohydrates) and cell membrane structure.

Rice lipids mostly can be found at bran layer in form of lipids bodies also known as spheromones but also in endosperm and germ. The principal groups of rice lipids are: neutral lipids (NLs), glycolipids (GLs) and phospholipids (PLs). The ratio of these lipid classes did not differ between japonica and indica rice (Mano et al., 1999), but their distribution within the grain was not uniform and the endosperm lipids contained a higher proportion of polar lipids (Fujino and Mano, 1972; Choudhury and Juliano, 1980). Based on cellular distribution and its association, rice lipids are generally classed as starch lipids, which are associated with starch granules (Choudhury and Juliano, 1980; Juliano, 1983) and non-starch lipids distributed throughout the grain (Choudhury and Juliano, 1980) but concentrated in the bran.

7.3.1. Starch lipids

Starch lipids are mainly monoacyl lipids (fatty acids and phospholipids) complexed with amylose (Ito et al., 1979; Choudhury and Juliano, 1980) making starch-lipid complex which has impact on pasting behaviour. The predominant bound free fatty acids in rice starch were palmitic (C16: 0) and linoleic (C18: 2) acid (Kitahara et al., 1997).

7.3.2. Non-starch lipids

- NEUTRAL LIPIDS (NLs)

Neutral lipids are non-starch homolipids formed by alcohol glycerol and 3 molecules of fatty acids forming an ester. They are located mostly in bran. According to Hemavathy and Prabhakar (1987), NL are consisted mostly of triacylglycerols (83.0 - 85.5 %), monoacylglycerols (5.9 - 6.8 %) and small amounts of diacylglycerols, sterols and free fatty acids. The major fatty acids of non-starch lipids are linoleic (C18 : 2), oleic (C18 : 1) and palmitic (C16 : 0) acid (Hemavathy and Prabhakar, 1987; Taira et al., 1988; Lásztity, 1999).

- GLYCOLIPIDS (GLs)

GLs are hetero lipids with attached molecule of sugar. Sugar components in rice lipids are always galactose and glucose (Fujino, 1978).

- PHOSPHOLIPIDS (PLs)

PLs are hetero lipids made of covalently bound phosphate and lipid. They are mostly found in bran but also in germ. We can differ two main groups of PLs: glycerophospholipids (GPLs) and sphingophospholipids. Until now, only GPLs have been found in rice grain. Dietary PLs have beneficial effects on a range of human diseases and conditions, such as coronary heart disease, cancer or inflammation (Kullenberg et al., 2012).

7.4. VITAMINS

Vitamins are organic compounds with low molecular weight. Although, our body needs it only in very small quantities, vitamins have important biological functions. For instance, vitamins are parts of some coenzyme. Additionally, vitamins are an essential component of diet. Humans receive vitamins by food, which were synthetized by plants. Vitamins have diverse chemical structure. The basic criterion for their separation is their solubility in water and fats. Vitamins soluble in fats are A, D, E and K. Vitamins soluble in water are vitamins B and vitamin C. Together with enzymes and minerals, vitamins belong among antioxidants and they may protect our cells against the effects of the free radicals.

As it can be seen in Table 9 vitamins are mostly concentrated in bran but they can also be found at embryo. Rice is rich in vitamin B and vitamin E but rice grain has no vitamin A, vitamin D or vitamin C (Juliano, 1993).

Vitamins B1 (thiamine), B2 (riboflavin) and B3 (niacin) are located in bran layer together with α-tocopherol (vitamin E). About 50 % of the total thiamine is in the scutellum and 80 - 85 % of the niacin is in the pericarp plus aleurone layer (Hinton and Shaw, 1954). Vitamin E is an antioxidant that protects cell membranes and tissues from damage caused by oxidation. Embryo accounts for more than 95 % of total tocopherols (of which α-tocopherols account for one-third) and nearly one-third of the oil content of the rice grain (Krishna et al., 1984).

Table 9. Vitamin and mineral content of rough rice and its milling fractions at 14 percent moisture (Juliano, 1993)

Rice fraction	*Thiamine (mg)*	*Riboflavin (mg)*	*Niacin (mg)*	*Vitamin E (mg)*	*Calcium (mg)*	*Phosphorus (g)*	*Phytin P (g)*	*Iron (mg)*	*Zinc (mg)*
Rough rice	0.26-0.3	0.06-0.11	2.9-5.6	0.90-2.00	10-80	0.17-0.39	0.18-0.21	1.4-6.0	1.7-3.1
Brown rice	0.29-0.61	0.04-0.14	3.5-5.3	0.90-2.50	10-50	0.17-0.43	0.13-0.27	0.2-5.2	0.6-2.8
Milled rice	0.02-0.11	0.02-0.06	1.3-2.4	75-0.30	10-30	0.08-0.15	0.02-0.07	0.2-2.8	0.6-2.3
Rice bran	1.20-2.40	0.18-0.43	26.7-49.9	2.60-13.3	30-120	1.1-2.5	0.9-2.2	8.6-43.0	4.3-25.85
Rice hull	0.09-0.21	0.05-0.07	1.6-4.2	0	60-130	0.03-0.07	0	3.9-9.5	0.9-4.0

7.5. MINERALS

Minerals are essential trace elements, usually part of biochemically active substances, which are needed in small amounts. Minerals like calcium, magnesium, phosphorus are present along with some traces of iron, copper, zinc and manganese (Shabbir, 2008).The mineral content is linked to processing and the type of rice and thus, definite difference exists between varieties of brown and white rice in vitamins, minerals, and fiber and fat contents. Minerals are chiefly located in the outer layers of brown rice or in bran fraction (Juliano, 1993) as it can be seen in Figure 8. Milling has no apparent effect on Zn concentration (Bryant et al., 2005). Hence, more than half of the total Zn is presented in the polished rice (endosperm), while Fe was relatively evenly distributed in the hull, bran and polished rice. The potassium was preferentially distributed to the bran. Both Ca and Mn were mainly located in the hull, of 63.8% and 70.8%, respectively (Lu et al., 2013). Phytic acid (myo-inositol-1,2,3,4,5,6-hexakisphosphate) is the most abundant form of phosphorus (P) in cereal grains and is important to grain nutritional quality. In mature rice (*Oryza sativa L.*) grains, the bulk of phytic acid P is found in the germ and aleurone layer, deposited primarily as a mixed K/Mg salt (Bryant et al., 2005). Study of Lue et al. (2013) showed that half of the total Zn, two thirds of the total Fe, and most of the total K, Ca and Mn were removed by the milling process resulting in decreased mineral content in polished rice.

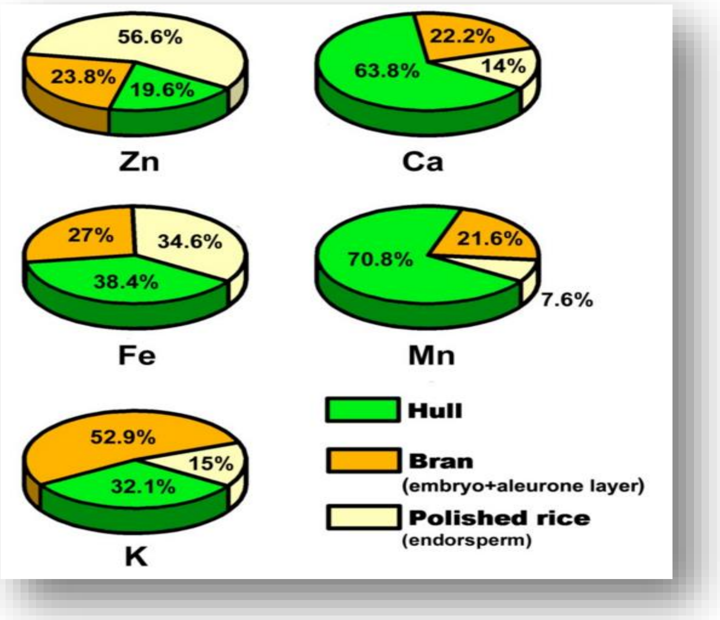


Figure 8. Percentage distributions of Zn, Fe, K, Ca, and Mn in different fractions of rice grains (Lu, 2013)

8. RICE TYPES

8.1. Classification according to the size of the grain

Rice types differ in size and shape which are physical properties of rice and have big impact on yield and grain quality. Rice length is measure of rice grain in its highest dimensions. Grain shape is characterized based on length-to-width ratio (L/W ratio) (FAO, 2013). FAO scales for size (Table 10) and shape (Table 11) are presented below:

Table 10. Grain size (FAO, 2013)

SIZE	LENGTH
Extra long	Over 7.5 mm
Long	6.61 – 7.50 mm
Medium	5.51 – 6.60 mm
Short	5.50 or less

Table 11. Grain shape (FAO, 2013)

SHAPE	L/W RATIO
Slender	Over 3.0
Medium	2.1 – 3.0
Bold	1.1 – 2.0
Round	1.0 or less

8.1.1. Long grain rice

The length of long grain rice is exceeding 6.61 mm and L/W ratio is over 3.0 which means the grains are long and slender (Figure 9). Once it is cooked, grains are separated, dry and fluffy. Thanks to high amount of amylose in starch, it absorbs a considerable amount of water during boiling and has pleasing, non-sticky character when being chewed compared to medium or short grain rice (Mcwilliams, 2007).

Figure 9. Long grain rice (Ricepedia, 2015)

8.1.2. Medium grain rice

Medium grains are having characteristics of both long and shorts grains. In comparison with long grain rice, medium grains are wider, shorter and when cooked more moisturized and stickier thanks to reduced amount of amylose. Medium rice grain is presented in Figure 10.

Figure 10. Medium grain rice (Ricepedia, 2015)

8.1.3. Short grain rice

This type of rice has grains which are of a length not exceeding 5.2 mm and of a length/width ratio of less than 2 and has a short, plump, almost round kernel (Figure 11). When cooked, grains are sticky and stay together. The stickiness is thought to be due to the tendency of short grain to split on the ends during cooking, thus releasing some starch into cooking water and also disrupting the general structure of individual grains (McWilliams, 2007).

Figure 11. Short grain rice (Ricepedia, 2015)

8.2. Classification according to the stage of processing

8.2.1. Rough rice

Rough rice is also known as husked rice, rice in a hull and paddy rice. It does not undergo milling process, which means rice kernels are still enveloped by husk. Rough rice obtains more proteins and lipids than a white rice. Also, it is high in lysine content. Rice husk ash (acronym RHA) is rich in silica.

8.2.2. Brown rice

Brown rice (also called natural rice, unmilled rice, hulled rice or unpolished) is an intermediate product of milling process. It is a whole grain rice without a husk. Brown rice is considered to be healthier and more expensive than white rice because of its nutritional value. Dietary fiber found in brown rice slow digestion and make us feel fuller. Thanks to bran layers it has light brown colour. Nevertheless, majority of phosphorus, iodine and zinc are found in bran layers. Cooking time of brown rice is longer compared to white rice. Cooked brown rice has a different taste and texture, being generally more nutty and chewy than white rice (IRRI, 2007). Glycemic index of brown rice is high.

8.2.3. White rice

Thanks to its taste which is preferred in rice-consuming countries, white rice (acronym milled, polished rice) is the most consumed form of rice. In dehusking process, husk, bran layer and germ are removed. Only starchy endosperm is left. Due to removed parts of rice kernel, white rice is not as nutritious as brown rice but it cooks faster. Also it is easier to chew. Its whiteness comes from whitening (removing a rice bran) and polishing in milling process. White rice has low GI.

8.2.4. Parboiled rice

Prior to milling or storing, rice may be parboiled - a process which involves soaking the rice in warm water, steaming and drying. Parboiling rice (acronym converted rice) prior to cooking preserves some of the nutrient content, as micronutrients are transferred from the aleurone and germ into the starchy endosperm (FAO, 2003). Parboiled rice is easily identified by its glassy look (it is translucent) and yellowish tinge, it cooks up firmer and less sticky (Tanumihardja, 2013). Converted rice has low GI.

8.3. AROMATIC RICE

Aromatic rice is known by its specific popcorn-like aroma. Over 100 volatile compounds have been detected in fragrant rice varieties, but the major compound responsible for the characteristic aroma is 2-acetyl-1-pyrroline (2AP) (Paule and Powers, 1989; Buttery et al., 1982) which is present also in non – aromatic rice in lower amount. Concentration of 2-acetyl-1-pyrroline in all rice is 0.04 ± 0.06 ppm but it is present in significantly higher (ten times) concentration in aromatic cultivars, especially Basmati (Bhattacharjee et al., 2002). Fragrance is considered as the most important quality indicator. At the international market, scented rice are known by better quality, higher prices than non – aromatic rice due to its aroma. Commonly are used in Middle Eastern and Indian dishes. Among fragranced rice we can found medium and long grained rice. The most known varieties of aromatic rice are Basmati, Jasmine and Patna rice.

8.3.1. Patna rice

This variety is called after capital of Bihar state in India – Patna where is cultivated. Patna lies on banks of Ganges River which has influence on its mild flavour and firm texture. Patna rice has grains greater than 6 mm. When cooked, it is dry fluffy and grains do not stick together. Patna rice is staple food for years in this region because it is highly nutritious. Locals call it Parimal. Patna rice is also known as Carolina rice. Carolina rice is Patna rice brought and cultivated in USA in 17th century and later transferred to Britain.

8.3.2. Basmati rice

Basmati rice is the most common type on the Indian subcontinent. For its fine nutty flavour and distinctive scent locals call her the queen of fragrance, which makes it unique and different from other varieties. Basmati rice of India and Pakistan is characterized by long slender grains, intermediate amylose, intermediate gelatinization temperature, high elongation ratio and strong popcorn aroma (Singh et al., 2000). Grains vary considerably in colour, mostly are creamy white or brown being chalky (white centre) and generally have a low transparency (Figure 12). Basmati rice has to be soaked for at least 30 minutes before cooking. The most common cooking method is by boiling in water. By cooking the grains elongate by more than 75% and swell only lengthwise (Figure 13) (European Commission, 2016; Bhattacharjee et al., 2002). Upon cooking grains are curved, separated, very dry, fluffy and non-sticky (European Commission, 2016). Basmati rice can be consumed as brown or white rice. GI of Basmati rice is low (Patel, 2009).

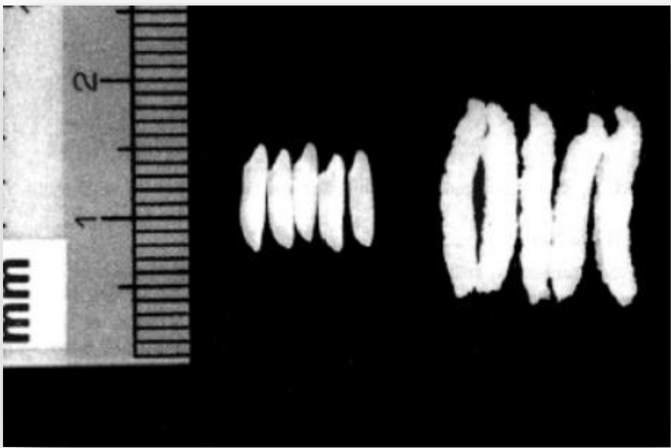


Figure 12. Basmati rice (Cucku, 2013) **Figure 13. Grain elongation (Singh, 2000)**

8.3.3. Jasmine rice

Jasmine rice also called Thai Fragrant Rice is the most widespread in Thailand and Asian cuisine. Jasmine rice is native to Thailand but it is also grown in Cambodia, Laos and Vietnam. It is long grained rice shorter than Basmati rice but comparatively it is stickier due to higher amount of starch. Jasmine rice grains are white to golden - brown colour which has delicate scent reminiscent of jasmine (Figure 14). Before cooking, Jasmine rice should be rinse to remove any dust and excess starch. Traditionally cooking method is steaming or using the absorption method (rice is cooked in a measured amount of water which is completely absorbed by the rice). When cooked Jasmine rice is soft, moist and sticky and has nutty flavour. It is sodium free and low in fats (Diet Health Club, 2014). It can be consumed as white, brown or black rice. Thai Black Jasmine rice has a dark black bran. Compared to black glutinous rice obtains less calories, carbohydrates and proteins (Biscardi, 2011). It does not contain fat or dietary fiber. Brown Jasmine rice has oats aroma and it is rich in manganese, selenium and fiber. Also it contains γ-oryzanol which can decrease blood cholesterol (Diet Health Club, 2014).

Figure 14. White and brown Jasmine rice (Importfood, 2015)

8.4. PIGMENTED RICE

The colour rice refers to rice kernel with red, purple or black colour, which are formed by deposits of large amount of anthocyanin pigment in different layers of pericarp, seed coat and aleurone (Chaudhary, 2003). Anthocyanins are phenolic compounds with antioxidant activity (Goufo and Trinidade, 2014). About 18 anthocyanins have been identified in rice, of which only four have been quantified (cyanidin-3-O-glucoside, peonidin-3-O-glucoside, cyanidin-3-O-rutinoside, and cyanidin-3-O-galactoside) (Goufo and Trinidade, 2014). Black rice varieties has highest antioxidant activities, followed by purple, red, and brown rice varieties and japonica rice varieties were found to be richer in antioxidant compounds compared with indica rice varieties (Goufo and Trindade 2014). The health benefits of pigmented rice are attributed to the presence of phenolic compounds that possess antioxidant, anticarcinogenic, antiallergic, anti-inflammatory, antiatherosclerosis and hypoglycaemic activities (Paiva et al., 2014). For years, pigmented rice is consumed in China, Japan and Korea. When cooked, pigmented rice releases its colour to the rest of the dish and often is used like ornament in cooking. Hence, extracted pigment can be used like natural food colorant (Abdel-Aal et al., 2006). The most known pigmented rice are Black rice and Red rice.

8.4.1. Black rice

Black rice contains a wide range of total anthocyanin content (TAC), with cyanidin 3-glucoside being the most common anthocyanin (0.0 - 470 mg/100 g), whereas peonidin 3-glucoside (0.0 - 40 mg/100 g) was the second dominant anthocyanin (Goufo and Trindade, 2014). Black rice, with an average of 3276 µg/g, was found to possess the highest TAC among all of the coloured grains, which is 35 times higher than that of red rice (94 µg/g) (Abdel-Aal et al., 2006). Indonesian black rice is sticky rice which has nutty flavour and grains unevenly coloured (Figure 15). After soaking for a few hours, the water will turn into a deep burgundy, showing that "black" sticky rice isn't really black at all (Kasma, 2016).

Figure 15. Forbidden rice (Gourmet store, 2016)

8.4.2. Red rice

Red rice is distributed in many countries of Asia but in Southwest and East China, red rice mostly belong to *indica* group (Chaudhary, 2003). Dominant phenolic antioxidant components in all traditional red-grained rice varieties are proanthocyanidins (catechin and epicatechin) (Goufo, 2014). Red rice is grown on acidic soils which are rich in iron. Therefore, by evolution red rice adapted to higher iron uptake. Red rice has a rusty-brown color, distinct nutty taste and a firm, slightly chewy texture (Figure 16) (Holiis, 2006). Generally, red rice should be soaked in water before cooking for about 30 minutes to get softer. Cooking method is boiling (ratio of water to rice is 2:1, for Camargue rice is 3.5:1) and cooking time is longer than in polished rice. This high quality rice is not cheap due to low yield. Red rice has a low glycemic index (55). Well known red rice are Camargue rice, Thai cargo rice and Bhutanese red rice. Camargue long to short grain rice is cultivated in swamps in southern France and among gourmet chefs is considered to have the highest quality. Today's red rice of France is product of cross-pollinating red wild rice native to swamps of Camargue and white rice which was grown in France according to Marshall's plan. Thai cargo rice is long grained non-waxy rice similar to white jasmine rice but comparatively cargo rice is more nutritious. Bhutanese red rice is medium grained, semi-milled japonica rice which is staple for Bhutanese people.

Figure 16. Red rice (Rice today, 2014)

8.5. Golden rice

In predominant rice consuming countries which are developing countries with specific political, economic and cultural issues vitamin A deficiency (VAD) is main problem. In these countries diet is based on monoculture crop because of high rate poverty. VAD affects pre-school children and pregnant women causing irreversible blindness and weakened immune system and leads to premature death of small children. Edible parts of rice; i.e. endosperm, do not contain β-carotene, it is only present in leaves. Like cure for VAD scientist genetically engineered variety of rice which is capable of biosynthesising precursor of vitamin A in endosperm named Golden Rice. Golden rice grains are easily recognisable by their yellow to orange colour (Figure 17). The stronger the colour the more β-carotene (Golden Rice Project, 2015). First Golden rice was produced in 2000 and Golden rice 2 in 2005. Golden Rice 2 produces 23 times more carotenoids than Golden Rice (up to 37 µg/g), and preferentially accumulates beta-carotene (up to 31 µg/g of the 37 µg/g of carotenoids) which contains sufficient provitamin A to provide the entire dietary requirement via daily consumption of some 75 g per day (Paine et al., 2005). However, Golden rice may have negative impact on environment and human health and as a result Golden rice is not yet approved for commercial use. It has not been determined whether daily consumption of Golden rice does improve the vitamin A status of people who are vitamin A deficient (IRRI, 2016).

Figure 17. Golden rice (Golden Rice Project, 2015)

8.6. Other rice types

8.6.1. Glutinous rice

Glutinous rice (also known by name waxy, sticky, sweet and pearl rice) is grown mostly in Southeast Asia. An estimated 85 % of Lao rice production is of this type (Delforge, 2001). It has 0 - 2 % of amylose and the rest is amylopectin. The name glutinous does not have anything in common with obtaining gluten (glutinous rice is gluten free) but with its stickiness. When cooked due to low amylose content it is sticky (being glue - like) and mostly is used for making desserts or sweet dishes (reason for which is called sweet). Glutinous rice varieties are seen in both indica and japonica main types of rice (Nipuna rice, 2016). Therefore, waxy rice can be milled or unmilled. Non-waxy rice (containing amylose in addition to amylopectin) has a translucent endosperm, whereas waxy rice has an opaque endosperm because of the presence of pores between and within the starch granules (Figure 18) (Juliano, 1993). The bran can give unmilled glutinous rice a purple or black colour. The rice with the highest glycemic index value (90s range) is sweet rice (Fitzgerald, 2012).

Figure 18. Waxy rice (Nguyen, 2010)

8.6.2. Arborio rice

Arborio is a cultivar of the Japonica group of varieties of *Oryza sativa*. It is native to Italy, town of Arborio. Arborio rice has white medium or short round grain with high amylopectin content. Arborio rice grains also have one of the ends of the grain “chipped” off, which looks like an accidental little dent (Figure 19) (Beaulieu, 2011). When cooked, the grains are firm, creamy and chewy (Cooks illustrated, 2008). Also it has a starchy taste but blends well with other flavours. It is used to make risotto due to a defect in Arborio rice called chalk. During maturation, the starch structures at the grain's core deform, making for a firm, toothy centre when cooked (Cooks illustrated, 2008). Glycemic index of Arborio rice is medium - 69.

Figure 19. Arborio rice (Späth Christian, 2004)

Table 12. – Nutrition facts about various rice types (own work)

	Wild rice	**DV %*	**Brown rice**	**DV %*	**White rice**	**DV %*	**Parboiled rice**	**DV %*	**Basmati rice (uncooked)**	**D V %*	**Jasmine rice (uncooked)**	**DV %*	**Waxy rice**	**DV %*
Serving size	100g		100g		100g		100g		100g		100g		100g	
Calories	101		111		130		123		333		352		97	
Calories from fat	3		8		2		3		0		0		2	
Total fat	0g	*1%*	1g	*1%*	0g	*1%*	0g	*1%*	1g	*2%*	0g	0%	0g	*0%*
Saturated fat	0g	*0%*	0g	*1%*	0g	*1%*	0g	*0%*	0g	*0%*	0g	0%	0g	*0%*
Trans fat	0g													
Cholesterol	0mg	*0%*	0mg	*0%*	0mg	*0%*	0mg	*0%*	0 mg	*0%*	0 mg	0%	0mg	*0%*
Total carbohydrates	21g	*7%*	23g	*8%*	28g	*9%*	30g	*10%*	74.5g	*25%*	79.12g	26%	21g	*7%*
Dietary fiber	2g	*7%*	2g	*7%*	0g	*2%*	1g	*4%*	0g	*0%*	2.19g	9%	1g	*4%*
Sugars	1g		0g		0g		0g		0g		0g		0g	
Protein	4g	*8%*	3g	*5%*	3g		3g	*6%*	7.8g		6.59g		2g	*4%*
Vitamins														
Vitamin A	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*
Vitamin D	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*	0%	*0%*
Vitamin B6 (mg)	0.1	*7%*	0.1	*7%*	0.1	*5%*	0.2	*8%*					0.0	*1%*
Minerals (mg)														
Calcium	3	*0%*	10.0	*1%*	10.0	*1%*	19.0	*2%*				0%	2.0	*0%*
Magnesium	32	*8%*	43.0	*11%*	12.0	*3%*	9.0	*2%*					5.0	*1%*
Iron	0.6	*3%*	0.4	*2%*	1.2	*7%*	0.2	*1%*				4%	0.1	*1%*
Zinc	1.3	*9%*	0.6	*4%*	0.5	*3%*	0.4	*2%*					0.4	*3%*
Sodium	3	*0%*	5.0	*0%*	1.0	*0%*	2.0	*0%*					5.0	*0%*

** Percent Daily Values are based on a 2000 calories diet. Your daily values may be higher or lower depending on your calorie need.*

9. DISCUSSION

Chemical composition of rice has been studied extensively (Pomeranz and Ory, 1982; Houston and Kohler, 1970; Juliano, 1972; Deosthale and Pant, 1970; Chavan and Duggal. 1978; Fujino, 1978; Bechtel and Pomeranz, 1980; Juliano, 1985; Juliano, 1993) (Salunkhe, 1992) trough years and still it is studied (Singh et al., 2000; Bhattacharjee et al., 2002; Zhou et al., 2002). Data have been changing with technology improvement and development of different methods.

The chemical composition of rice grain varies widely and depends on environment, soil and variety. Major constituents of a rice grain are starch, protein and lipids. Values for starch, lipid and protein also vary with the method of analysis, which means that comparisons can be misleading. (Zhou et al., 2002). However, nowadays is generally regarded that most of starch proteins are located in the endosperm, while part of the proteins and most of the fat, fiber, ash and B-group vitamins are concentrated in outer aleurone, pericarp and germ (Salunkhe, 1992; Juliano, 1993; Zhou et al., 2002). Hence, milled rice is considered to have lower nutritional value compared to brown rice. Nonetheless, brown rice is commonly accepted as having the lowest protein content among cereals and also is low in lipid and fiber content but the net protein utilization and digestible energy in rice are the highest amongst the common cereal grains (Zhou et al., 2002).

The book Rice in human nutrition written by expert in rice chemistry Juliano OB, gives a complete review on chemical compound of a rice grain among other information which contributed to this work. That is the reason why this book has been used as first pillar of this thesis.

More than 20 years volatile components of rice have been studied (Maga, 1978; Yajima et al., 1979; Buttery et al., 1982, 1983, 1986; Paule and Powers, 1989; Tanchotikul and Hsich, 1991; Singh et al., 2000; Bhattacharjee et al., 2002) by a number of researchers. Buttery et al. (1982), first mentioned and identified 2-acetyl-1-pyrroline (2AP) as the principal aroma compound in fragranced rice among other 100 compound. Later studies confirmed 2AP present in all rice varieties but in lower concentration (Singh et al., 2000; Bhattacharjee et al., 2002). Quantitative determination of this compound is difficult because of its instability and potential interfering with others substances. Firstly, it was thought the 2-acetyl-1-pyrroline is formed from the rice during the cooking process (Buttery et al., 1986). Later, the results revealed that 2-acetyl-1-pyrroline present in aromatic rice samples did not form during cooking or postharvest processes (Yoshihashi, 2006).

Literature analysis shows that scientists still does not have enough information to say exactly where is this compound located and in which amount. Hence, they improving methods for its determination and expectantly in future we will have results which will not be misguided.

In the recent years, the pigmented rice varieties is becoming more popular due to its antioxidant properties and phenolic content. It is almost 30 years since Ramarathnam et al., (1989) firstly identified antioxidant components in rice. Ever since, abundant number of studies has been published regarding identification and quantitation of antioxidant and phenolic compounds (Rogers et al., 1993; Terahara et al., 1994; Harukaze et al., 1999; Marfo et al., 1990; Lee et al., 1997). Between years 2000 and 2013 more than 1,000 papers were published on rice antioxidant activity. The reason was discovery of Hudson et al., (2000) which explains a positive relationship between the lower incidence of cancers and heart diseases in Asian populations and rice consumption. Although review papers have kept pace with the high number of publications, they have thus far only focused on the pharmacological properties of rice antioxidant extracts (e.g., Cicero and Gaddi, 2001; Fardet et al., 2008; Walter and Marchesan, 2011) and not their composition and contents (Goufo and Trinidade, 2013). Goufo and Trinidade (2013) in their study quantificate antioxidant compounds in rice and those data have been used in this thesis. Among rice ranked by color, black rice varieties emerged as those exhibiting the highest antioxidant activities, followed by purple, red, and brown rice varieties. However, on a whole grain basis and with the exception of γ -oryzanol and anthocyanins, the contents of antioxidants in other cereals appear to be higher than those in rice (Goufo and Trinidade, 2013).

10. CONCLUSION

International organizations and authorities on rice like CGiAR and IRRI provide information regarding rice history, production, trade etc.; indeed, most of the publications focus on ecology, management and postharvest handling. Insufficiency of research papers or books which obtain at one place data on chemical composition of different types of rice and in addition all important information to understand differences between mostly consumed types of rice worldwide is apparent. Most of the information is scattered in literature. Considering that fact, this thesis intended to present important information about rice chemical composition and its diversity. As a result of this review, summary table of definite markers (Annex 1) pinpointed major characteristics of mostly used rice varieties across the globe which make it unique. Hence, data written in summary table can provide great help and facilitate work of experts. For instance, Czech Agriculture and Food Inspection Authority can reveal food fraud in the most offered rice varieties on the market in Czech Republic. Nevertheless, the same data can be used as guidance for customers to choose convenient rice type from a wide range on the market for everyday use.

Even though rice consumption started about 8, 000 years ago most of the people are not able to recognize, distinguish different rice varieties and choose one that fits their need the best. Average consumer presents to themselves rice diversity as colourful boxes on shelfs in supermarket differing in price and it is so much more than that. Expectantly, this thesis will make difference by giving reader closer insight about diverse world of rice and its chemical composition.

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LIST OF FIGURES

LIST OF TABLES

Annex 1. Definite markers for special rice varieties

RICE TYPES	SPECIAL CHARACTERISTIC
Wild rice	Grain size and shape: awl shaped slender grains about 1.24 cm long; Grain colour: black; Texture: tender, not mushy, after cooking elongates 3 to 4 times; *not rice variety just rice-look-alike!*
Glutinous rice	Grain size and shape: short to long grains; Grain colour: white to purple-black, endosperm is opaque; Amylose content: very low (0 - 2%); Texture: sticky
Arborio rice	Grain shape and size: medium or short round grain; grain has chalky* centre, also one of the ends of a grain has little dent; Grain colour: white; Amylose content: low; Texture: firm, creamy and chewy grains
Aromatic rice	
Basmati rice	Grain shape and size: the longest slender chalky grains which by cooking elongates more than 75%; Grain colour: creamy white or brown with low transparency; Amylose content: intermediate; Texture: grains are very dry, fluffy and non-sticky; Aroma: determined by 2-acetyl-1-pyrroline which gives it distinctive aroma; Flavour: nutty
Jasmine rice	Grain size and shape: long grains but shorter than Basmati; Grain colour: white, brown or black; Amylose content: lower than in Basmati; Texture: moist and sticky; Aroma: sweet, delicate jasmine fragrance; Flavour: nutty
Pigmented rice	
Red rice	Grain size and shape: long to short grain; Grain colour: red to brown made by catechin; Amylose content: 23 - 31%; Texture: firm, slightly chewy; Flavour: nutty
Black rice	Grain shape and size: short grain; Grain colour: purple to dark-black made by cyanidin-3-glucoside; Amylose content: varies depending on variety; in waxy variety is very low; Texture: varies depending on variety; in waxy variety is sticky; Flavour: nutty
Golden rice	Genetically modified rice containing β-carotene in endosperm which makes its grains yellow

**Chalk is the dense area of the rice grain (white centre)*