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Evaluation of physical properties of rice cultivars grown in Kyrgyzstan

Master´s thesis

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Declaration

I hereby declare that I have written presented master thesis „Evaluation of physical properties of rice cultivars grown in Kyrgyzstan“ by myself with help of the literature listed in references.

21. April 2015, Prague   Bc. Martina Nádvorníková

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Abstract

The purpose of this study was to evaluate physical properties of eight staple rice cultivars grown and consumed in Kyrgyzstan. The objective was to record and discuss values of several analysis in sub-sections of basic physical characteristics, textural characteristics, mechanical characteristics and cooking properties. The physical properties investigated seed dimensions, equivalent diameter, surface area of the grain, sphericity, aspect ratio, volume of the grain, bulk and solid density, porosity, thousand kernel weight, hardness of the grain, colour characteristic, optimum cooking time and water uptake ratio. Those analysis were performed in the laboratory of Czech University of Life Sciences in Prague and given methodology was strictly followed.

The average values measured were recorded and later on compared on the base of local and imported rice varieties grown in Kyrgyzstan. The seed dimensions corresponded to 5.29 – 6.99 mm for length, 2.52 – 3.10 mm for width and 1.88 – 2.13 for thickness. Equivalent diameter was in range 3.14 – 3.47 mm, surface area took 25.35 – 31.90 mm^2, in sphericity analysis were measured values from 0.480 to 0.559, aspect ratio varied from 0.39 to 0.55, volume of the grain was measured in range from 16.25 to 22.02 mm^3, bulk density values equalled to 0.77 – 0.87 $g.cm^{-3}$ while solid density equalled to 1.17 – 1.41 $g.cm^{-3}$. The porosity of grain was measured in values 28.27 – 39.83 %, thousand kernel weight correspond to values from 19.67 to 27.15 g, hardness of grain was measured in range 63.47 – 155.50 N, colour characteristic varied in parameters L*, a* and b* respectively 37.58 - 72.19, -0.22 - 10.17 and 9.65 – 21.12. Optimum cooking time recorded ranged from 19.33 to 33.00 minutes and water uptake ratio showed results in sections of 30 and 60 minutes while soaking in three temperatures: 30 °C, 45 °C and 60 °C. The results of 30 minutes (in respective temperatures) were 1.21 – 1.28, 1.18 – 1.45 and 1.14 – 1.57 while the results of 60 minutes were following: 1.22 – 1.42, 1.19 -1.54 and 1.25 – 1.75.

Keywords: rice, physical properties, Kyrgyzstan, colour, cooking characteristics, hardness

Contents

List of Figures

List of Tables

List of abbreviations

GDP – Gross domestic product

GNI – Gross national income

PPP – Purchasing power parity

HDI – Human development index

UN – United Nations

FAO – Food and Agriculture Organisation of United Nations

FAOSTAT – Food and Agriculture Organisation of United Nations (Statistic division)

B.C. – Before Christ

GRiSP – Global Rice Science Partnership

IRRI – International Rice Research Institute

USSR – Union of Soviet Socialistic Republics

m.a.s.l. – Meters above the sea level

TKW – Thousand kernel weight

GM – Genetically modified

WUR – Water uptake ratio

1. Introduction

Rice is one of the most important food crops around the world. In its production and consumption are involved millions of people and millions depend on it on daily basis. Rice is nutritious and energetically valuable crop which is grown in all continents with arable land. The cradle of this plant is in South-East Asia and Asia is also nowadays the place where majority of rice is produced in worldwide scale. Central Asia is maybe not that typical place for rice production and consumption, however rice is yet the third most consumed cereal in Kyrgyzstan and other Central-Asian countries. The Kyrgyz national festive rice dish “Plov” is traditionally prepared for guests and in case of celebrations so clearly the rice plays crucial role in Kyrgyz cuisine.

This thesis was focused on evaluation of physical characteristics of Kyrgyz rice, whether traditional local varieties or those imported from surrounding countries but domesticated along there as well. The main focus was on recognition of those characteristics since rice cultivars in different regions of the world differ in their composition (depending on variety, climate, irrigation and fertilizer application) (Singh et al., 2005).

In countries where rice is consumed, distinction of grain quality dictate market value and have a crucial role in the adoption of new varieties and their popularity. Quality traits encompass physical appearance, cooking and sensory properties, textural characteristics and nutritional value. The value of each trait, for example the length of the grain, varies according to local cuisine and culture (Fitzgerald et al., 2008). Moreover grain quality indicators such as hardness and colour have great importance in the food industry. There, by differentiation of the varieties, helps to improve the consumer´s acceptability and popularity of the particular rice cultivar.

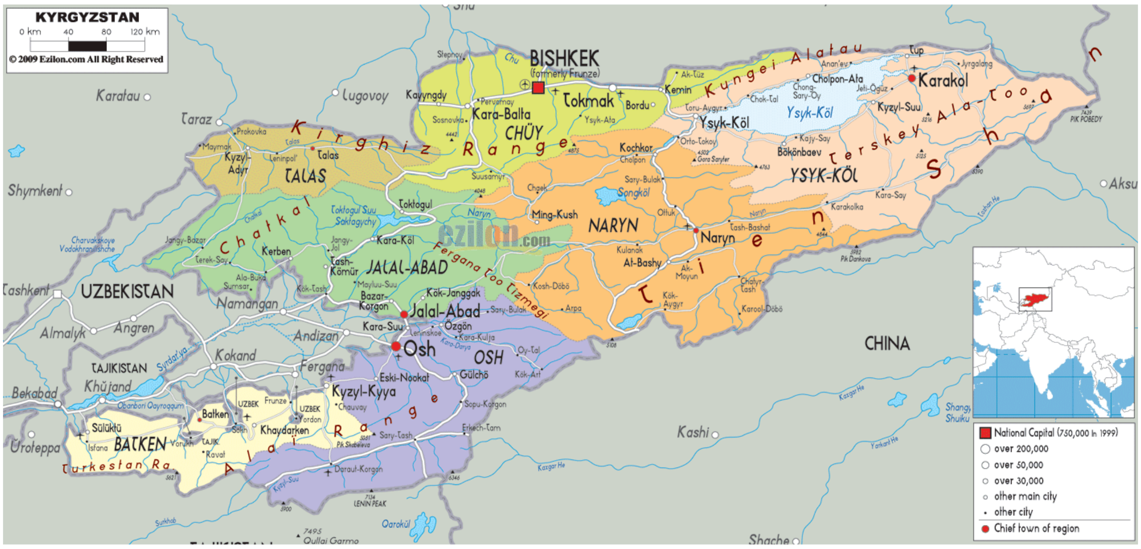
The knowledge of physical properties of grain materials is also useful for designing appropriate machineries for grain processing operations like sorting, drying, heating, cooling, milling and optimization connected to each specific variety (Mir et al., 2013).

2. Literature review

2.1 Kyrgyz republic

Kyrgyzstan (officially Kyrgyz republic) is a small country located in Central Asia, covering 198,000 km². The country is landlocked and predominantly mountainous, bordering Kazakhstan in the north, China in the south-east, Tajikistan in the south and Uzbekistan in the west (Fitzherbert, 2000).

As was stated by Fitzherbert, the state is administratively divided in seven provinces namely Chui, Talas, Issyk-Kul, Naryn, Osh, Jalalabad and Batken as is visible in Figure 1. Those are in addition divided in districts and rayons. The capital city, Bishkek, is located in the north border of the country and has population of 857,711 people (2014). Second largest city is southern Osh, located in Ferghana valley (Fitzherbert, 2000; The World Bank, 2015).



(Ezilon, 2009)

Figure 1 Political map of Kyrgyzstan

2.1.1 Socio-economic information

The population of Kyrgyzstan comes from mixed ethnical origin – the local minorities include Russians, Uzbeks, Kazakhs, Tajiks, Ukrainians, Germans, Tartars, Turks, Dungans (Chinese Muslims), Uigurs, Koreans and smaller groups from the Caucasus. The main ethnic group, the Kyrgyz, make up according to World Bank (2015) about 55 % of the population. Over 64 % of all inhabitants live in the rural areas, although the movement towards big cities is on the rise (Fitzherbert, 2000).

Approximately about 17.3 % (2014) of total GDP is represented by income from agriculture where work 32 % of the population (2013). Quite high is labour participation rate which shows that 71.2 % of the total population in age 15-64 is involved in the working process. As regards the poverty in the country, in 2012 was 2.9 % of population living on less than $ 1.90 a day. The value of GNI (gross national income) per capita PPP (purchasing power parity) in 2014 was $ 3,220 which classify Kyrgyzstan as lower middle income country (The World Bank, 2015).

Kyrgyzstan with HDI (human development index) of 0.655 belongs on 120. place worldwide thus between countries with "medium human development". Life expectancy at birth equals to 70.6 years and the adult literacy rate for people older than 15 shows that almost total Kyrgyz population is literate (99.2 %). Child labour rates oscillate around 3.6 % (UN, 2015).

2.1.2 Geographic conditions

About ninety-four percent of the area lays above 1000 m.a.s.l. and actually over forty percent of the land is situated even above 3000 m.a.s.l. from which three quarters are covered with permafrost. The highest peak of Kyrgyzstan (Jengish Chokusu) is also with 7,439 m.a.s.l the highest mountain in the whole Tian Shan mountain system (Fitzherbert, 2000; Michell, 2015).

The north part of the country is mainly covered by great Kazakh steppe which stretch for hundreds of kilometres. On the tectonic basin in the altitude of 1,600 is situated great lake Issyk-Kul. The 170 kilometres long and 70 kilometres wide lake is the second largest alpine lake in the world, which is based on the large dimensions creating its own small microclimate (Fitzherbert, 2000).

In the south of Kyrgyzstan are situated agricultural lowlands wedged next to Pamir Alay Mountains, which are stretching alongside the borders with Tajikistan. Those lowlands production (mainly Ferghana valley production) represent a significant part of agricultural output of the whole country (Fitzherbert, 2000; Kalb and Mavlyanova, 2005).

As written by Mamatov et al., (2007) Kyrgyzstan has huge resources of surface and underground water, stocked in rivers, glaciers, lakes and other reservoirs. There are 1923 lakes and other water bodies in Kyrgyzstan, with the total area of 6836 km². More than 3500 rivers are crossing the territory of the country and supply water to the surrounding states.

Most of the territory is covered with vermosoils – dry soils lacking humus. The western part of the country also have some problems with higher soil salinity. Several exceptions such as Ferghana valley has higher percentage of humus however still not the optimal conditions for land cultivation (FAO, 2006).

According to research done by Fitzherbert (2000), the area of Kyrgyzstan offers high diversity in types of ecosystems therefore even the local fauna and flora biodiversity display broad variations. Kyrgyzstan represent countryside consisting of *deserts and open steppes, high grass lands, broad leafs and coniferous forests, alpine ecosystems* (some of them permanently covered in snow) *and a variety of aquatic habitats, wet-lands, perennial and intermittent streams, rivers, fresh and saline lakes.*

In the country area of Kyrgyzstan could be found more than 12 300 species of animals, 7 723 plant species, from which cover 3 780 the species of higher plants (for example 200 medicinal plants, 62 oil-plants and 50 food crops), 3 676 of lower plants and 261 species of microorganisms (virus, bacteria or elementary organisms). From total number of plant species grown in Kyrgyzstan the endemic plants made it up to 3 % (233 species). Also 88 species of rare plants have been discovered and out of the number 16 species are on the list of disappearing species, 9 are critically disappearing and 3 of the plants are already lost. The reason of vanishing those endemic and rare plants is destruction of their natural habitat and expanding anthropogenic zones of local inhabitants (Dzunusova et al., 2008).

There are also several ecological problems connected with the Kyrgyz nature. Increasing share of land designated for agricultural reasons is usually transformed without needed attention towards endangered plants, animals and fragile ecosystems. Also over-use of natural resources such as cutting forests, poaching, extensive utilization of arable lands and monoculture crop production occur more often in the country and leads directly to greater ecological damage. Although Kyrgyzstan has very large resources of water, due to insufficient irrigation system are large territories (agricultural or natural) lately affected by droughts (Dzunusova et al., 2008; Fitzherbert, 2000; Kolov, 1998).

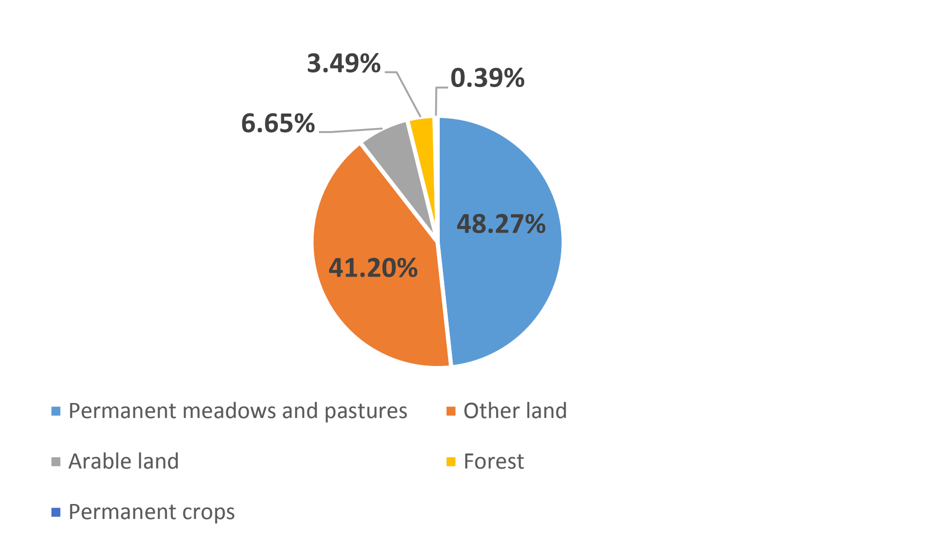
2.1.3 Climatic conditions

The climate of Kyrgyzstan is continental, but greatly dependent on the attitude, mountain position and wind currents. Generally the winters are cold and summers are hot, when the average temperature moves around 27^{o} C (can even outreach 40^{o} C) and at the same times in the high mountains temperature do not exceed 10^{o} C. In winter falls the temperature down and frequent precipitations occurs mainly in the form of snow.

Although some parts of high-located valleys stay free of snow whole winter, due to their position locked into the mountains and provide spot for the livestock. The precipitations range according to the region and could move from 200 mm a year (western side of Issyk-Kul Lake) to 600 mm a year (on the eastern side). The quite high precipitations which fall in the mountainous areas feed the stream of rivers which are originating there. Summers are in general dry but sometimes storms, hail and even exceptional snow can occur (Fitzherbert, 2000).

2.1.4 Agriculture system and main products

The Kyrgyz republic states that 55.2 % of its territory occupies agricultural land. Majority of the area is used as permanent pastures and because mountainous terrain offers very difficult conditions to any kind of land cultivation the share of arable land in whole country is only 6.7 % (World Bank, 2013) while the rest is mainly used for pastoralism (see Figure 2). In overview, both mountain and lowland agriculture can be defined as mixed structured combining cultivation of plants and animal husbandry.



(FAOSTAT, 2011)

Figure 2 Land use of Kyrgyzstan

The primary agriculture zones are located in the north (Talas and Chuy province) and in the south (Osh province). Those zones are from large part valleys provided with water from crossing rivers. Fitzherbert (2000) stated, that *the total area of crops is estimated at about 12 200 km^2 of which 7 300 km^2 (59 %) are irrigated and 4 900 (41 %) are rain-fed.* Major crops produced in Kyrgyzstan (the highest yielded are mentioned in the Table 1) are wheat (*Triticum spp*. L.), barley (*Hordeum vulgare* L.), maize (*Zea mays* L.), several varieties of rice (*Oryza sativa* L.*)*, cotton (*Gossypium hirsutum)*, tobacco (*Nicotiana spp.*), sugar beet (*Beta vulgaris*), oilseed crops (sunflower, cotton), potatoes (*Solanum tuberosum* L.), melons (diverse species from *Cucurbitaceae* fam.), grapes (*Vitis vinifera* L.) and various kinds of vegetables – tomatoes (*Solanum lycopersicum* L.), cabbage (*Brassica oleracea* L.), peppers (*Capsicum* spp.) and carrots (*Daucus carota* L.) (FAOSTAT, 2014).

Most typical crop tree species are walnut (*Juglans regia*) and maple (*Acer turkestanica*). There are lot of fruit trees as well, such as apple (*Malus siversiana*), pear (*Pyrus korshinsky*), apricot (*Prunus armeniaca* L.), plum (*Prunus sogdiana*), barberry (*Berberis oblonga*), cherry (*Prunus avium* L.), sour cherry (*Prunus cerasus* L.) and mullberries (*Morus* spp.). The fruit and nut forest has very long tradition in Southern Kyrgyzstan and represent great recreational spot for locals even foreigner tourists. However they are nowadays often transformed into peasant farms and also repeatedly threatened by grazing livestock. The walnut trees and some other species had originally formed in those areas and afterwards spread to the world (Kolov, 1998).

Table 1 Crop production in Kyrgyz republic (2013 - 2014)

Crops	2013 (tonnes)	2014 (tonnes)
Cereals and pulses		
Wheat	819,383	572,734
Barley	309,926	197,084
Rice	27,220	28,230
Maize	568,186	556,142
Pulses (total)	1,200	1,300
Industrial crops		
Cotton lint	21,800	n/a
Sugar beet	195,415	173,609
Tobacco	6,498	n/a
Oil crop (sunflower seeds)	42,515	34,334
Vegetables and Fruits		
Potatoes	1,332,020	1,320,700
Vegetables (total)	1,070,480	n/a
Pumpking, squash, gourds	11,000	n/a
Onions	152,055	n/a
Tomatoes	195,053	n/a
Apples	143,000	n/a
Grapes	8,106	n/a

(FAO, 2016)

According to official classification mentioned by Akramov and Omuraliev (2009), are *farms in Kyrgyzstan currently classified into three major organizational categories: household plots, peasant farms and corporate farms*. The first two mentioned belongs to individual, family farming which is mostly spread in the agricultural areas in the country, mainly in the Osh region. Between the years 1991 and 2007 the share of the private sector in agriculture increased greatly to the point, when the *sector presently produces 97 percent of aggregate agricultural output in Kyrgyzstan, including almost 95 percent of crop production and nearly all of the livestock production.* The main reason behind those changes is replacing former state-owned and collective farms from the times of USSR for the small family-owned farms which proved over the time that their productivity is competitive and even more efficient than the costly large farm operations (Akramov and Omuraliev, 2009).

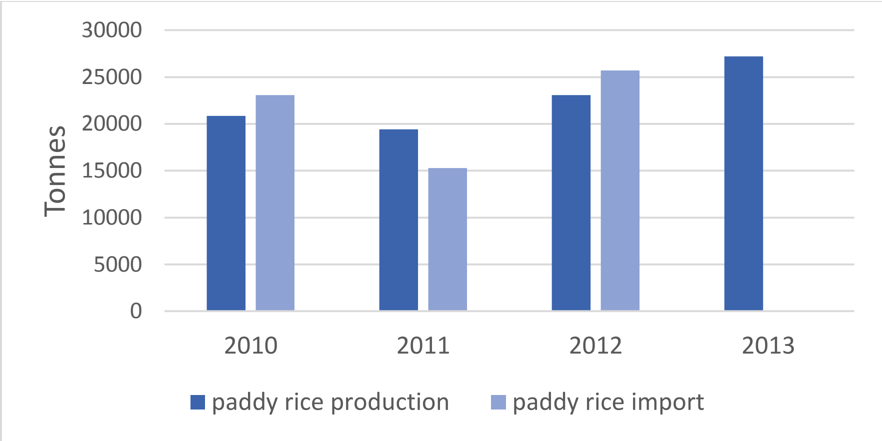
Water scarcity has grown into an issue during several past years. In the Ferghana valley, the main agricultural area in Kyrgyzstan (which according to De Martino et al. (2005) holds also 50 % of Kyrgyzstan population) and important even to the whole Central Asia gets the problem another dimension. Those issues are connected to water distribution systems, because they were built in the Soviet era and shared with all the nations involved (Kyrgyzstan, Tajikistan and Uzbekistan). Now go the irrigation routes through territory of several independent states while crossing the state boarders. Additionally, the countries sharing irrigation systems around Ferghana valley are multi-ethnic, therefore those disputes can grow easily into ethnic conflicts (De Martino et al., 2005).

2.1.5 Rice production and consumption in Kyrgyzstan

According to the Table 1, rice is in Kyrgyzstan one of top 3 produced cereals. Rice is also the third major food crop in terms of area and production in whole Central Asia. However the area compared to other top two crops is much lower, its importance in the food culture and habits is undeniable (Zanca, 2003; FAO, 2016; Devkota, 2011).
Despite some problems with availability of irrigation water it is very cheap in Kyrgyzstan, far below the fees for irrigation water for example in South and South-East Asia. Accordingly the traditional irrigation and production systems in south Kyrgyzstan are very profitable (Devkota, 2011).

In the country report written by Dzunusova et al. (2008) is stated that the main area where the rice is cultivated in Kyrgyzstan is located in the south in provinces of Osh, Batken and Jalal-Abad. Here with the low altitude, high temperatures and good precipitations the climate represent relatively good conditions for rice cultivation.

As stated in the Figure 3, the overall production of rice rises over the years (with certain down-point in 2011). Also the import of rice from the foreign countries is increasing accordingly. At the same time, no data about export of rice was found, hence all the amount of rice is presumably consumed within the country. When compared to information about production from previous years (FAO, 2015) it is obvious that popularity and production of rice is on the rise.



(FAOSTAT, 2013)

Figure 3 Rice production and import (2010 – 2013)

According to study done by Zanca (2003) rice is very important in Kyrgyz republic and not only in terms of staple grain consumption but as well traditional and cultural element, deeply embedded into Kyrgyz national habits.

Some of the main traditional dishes are *kuiruk boor (cooked fat and liver served with a clear soup)* and from the rice involved dishes it is *byjy (sausage made from sliced liver with fat, onion, garlic and rice)* and its southern variation *olobo byjy (sausage made of sliced meat with rice and flour), as well as sausages made from brains, fat and blood in the Talas Valley).* The basic meal usually contains boorsok (fried dough), flat bread, melons, vegetable with dipping salt, dried fruits, nuts, and meat dishes such as plov - mainly in southern regions (Kochkunov, 2010; Pelkmans, 2007; Zanca, 2003).

Pilaf (or as called by Kyrgyz *Plov*) as mentioned by Zanca (2003) is popular rice dish consisting of carrots, lots of oil (preferred is animal but plant based is sometimes used as well), onions, rice, spices and meat – usually from mutton. It is almost a symbol of hosting visitors, because in Southern Kyrgyzstan is plov the most common dish offered when company is expected. *When plates of plov are presented, they have the form of a rice pyramid, piled with a large chunk of fried beef or mutton on top.*

In the past times, when meat was not accessible to rural farmers, plov was festive meal only for landlords and wealthy Kyrgyz. However nowadays is eating of plov very common, almost every family serve it once a week as something we call “Sunday dish”. Plov is basically a symbol of good life of the family and most certainly is inextricable dish on weddings, funerals, celebrations and all other festive occasions. The festive plov´s are made sometimes for more than hundred people therefore several cooks has to be involved in the making process. In those occasions, only men are allowed to cook the meal, women are cooks only for family-sized plov´s (Zanca, 2003).

According to Vlkova et al. (2015) when the local people from Ferghana valley are questioned about the most traditional Kyrgyz dish, they answer - it is plov.

2.2 Rice

Rice is the most important crop represented in human nutrition all over the world. More than half of the population relies on rice in everyday diet. It is the most common staple crop in Asia, Western Africa and it is playing major role in the rest of the world as well. Rice is part of great group of cereals, which are the basics of human nutrition. Cereals cover around 30 % of the energy income from food staples in the developed countries, in the developing countries the share could cover up to 90 % of all the calories (Se et al., 2015; Fernando, 2013).

Worldwide, the rice ranks second after wheat in the overall area where it is harvested, but in the nutritional point of view, rice provide more calories per hectare than any other cereal. For example, the average yield from hectare of rice sustain 5.7 persons per year, while maize sustain 5.3 persons and wheat sustain 4.1 persons (De Datta, 1981).

Rice plant occupies about 160 million hectares annually (2013), which stands for about 11 % of the world’s cultivated land. Second most common grain - wheat, takes up slightly larger area, but a considerable part of wheat production is used as animal feed. Rice is the only major cereal crop that is consumed almost exclusively by humans (Khush, 1997; FAO, 2013).

The rice plant is able to grow in large range of climatic conditions such as the wet water fields in South-East Asia or the mountainous dry fields in central Asia or Africa. It can be grown in the places like Myanmar coast, where the average rainfall in rainy season climbs up to 5,100 mm and also in some places in Saudi Arabia, where the overall rainfall is not larger than 100 mm per year. The temperature and altitude, which can be optimal for rice plant also very greatly (Ricipedia, 2016).

2.2.1 History of rice

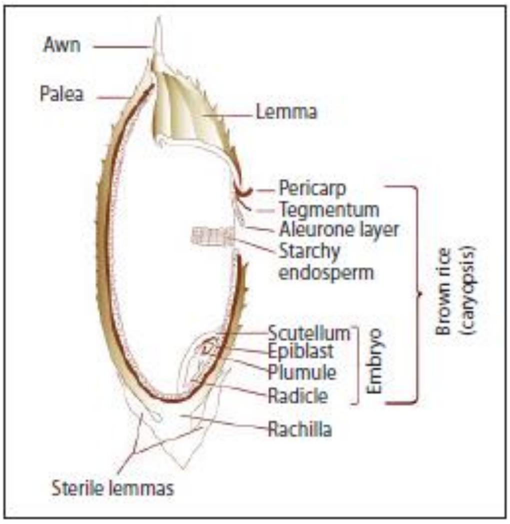
The cradle for rice plant is monsoonal Asia. The oldest remains of the plant has been discovered on Myanmar – Thailand border and had been dated to 8000 years B.C. In those times, ancient people start to collect and consume wild ancestor of modern rice – *Oryza rufipogon*. This wild grass grew in the swamps of the tropical and subtropical Asia. Continuously, through the careful selection of the preferred features, the first rice farmers transformed this promising crop into *Oryza sativa*, which is the nowadays essential crop in the nutrition of billions of people and its produce had spread to all continents with arable land (Khush, 1997).

This domestication process was long, evolutionary selection of profound genetic characteristic which created rice more suitable for cultivation and consumption. This process continues till nowadays, when the genetic cultivation and cultivars breeding still takes an important part of modern rice production (Gepts, 2004).

As Kovach et al. (2007) mentioned, *In addition to traits that resulted in major alterations of plant structure and/or reproductive physiology, humans have selected for characteristics that made rice grains more appealing as a food source, including grain size, shape, colour, fragrance and amylose content*.

2.2.2 Botanical characteristic of rice

Oryza belongs to the botanical species of grasses, which belong to the large family of cereals. Many different varieties are grown around the world and each need to have specific conditions for its successful development. The rice is growing usually in the standing water or at least in a very wet soil. It is perennial crop, but is usually treated as annual for increasing its production. Every year a new seeds are planted for increasing the yield from the field. The plant has several phases in the reproduction. The seed is planted, afterwards it grow up to the seedling (young plant after germination), afterwards the plant develop root system and plant body and after that is prepared for production of grains (GRiSP, 2013).

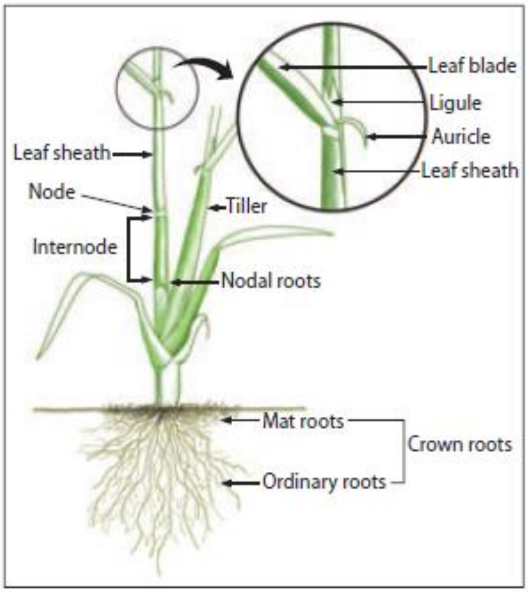


(IRRI, 2013)

Figure 4 Rice grain

The rice seed consist of two parts - outer inedible husk (protection of the seed) and the inner edible rice grain (see Figure 4). For growing a new seedling or to receive an edible rice grain, the husk has to be in most cases retained. Under it is bran, thin layer covering the kernel. When the bran is attached, the rice is called "brown", and when it is removed by milling, the rice is called "white". The rice grains can be stored for up to a year in good conditions (moisture of the air bellow 14 %), but it is preferred to be stored in the un-milled form, since the husk form certain kind of protection against pests. The physical properties of the grain (as length, width, thickness and others) may vary broadly according to the variety (GRiSP, 2013).

When the seedling develop about five leaves and starts to support its own weight, it become a tiller. The plant further develop, and each individual stem is called tiller (process of tillering – see Figure 4). Each of them become independent and create its own roots, but at the same time the tiller is still attached to the main plant. Number of tillers is mainly dependent on the rice variety. When the plant has fully developed, on the top of each tiller grow flower cluster, which after is pollinated, create rice grains. The rice flower is called by scientific term “panicle” and it occur on the top of the tiller (GRiSP, 2013).



(IRRI, 2013)

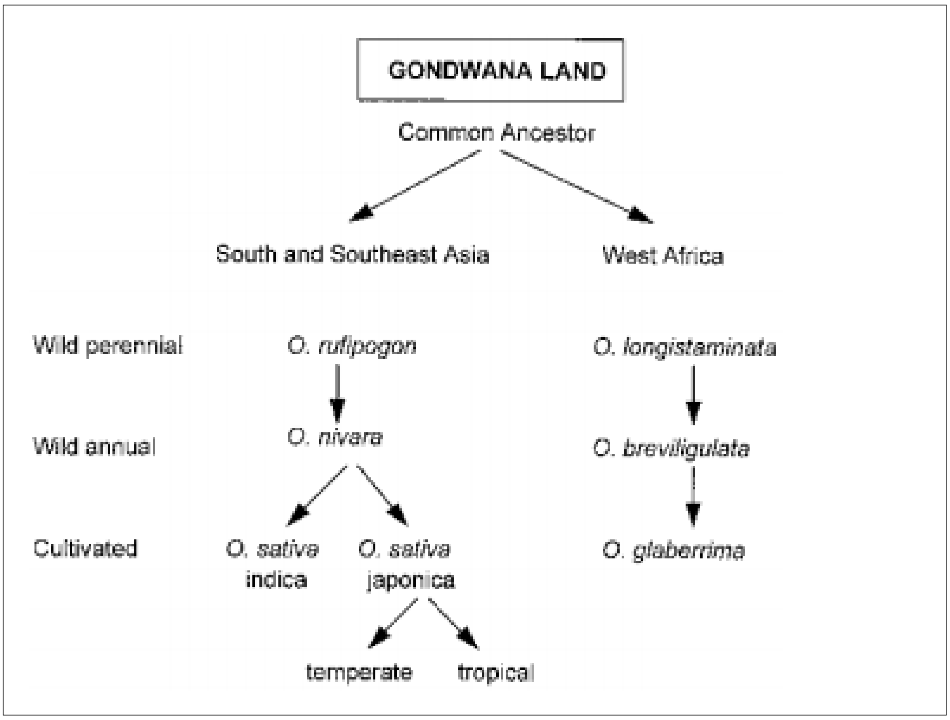
Figure 5 Rice plant developing

Since the seedling creates first stems, the plant needs to develop stronger root system as well. The roots grow stronger and develop many rootlings. The root system is defined as shallow, since 95 % of the roots are disposed in the top 20 centimetres of the soil. The roots have crucial role to absorb the moisture and nutrients from soil to the plant to nourish it. The plant´s root system consist of crown roots and nodal roots. The nodal roots are developed above the soil surface and are often found in the rice plants growing at water above 80 centimetre deep (GRiSP, 2013).

As was mentioned in the Rice almanac by IRRI (GRiSP, 2013), rice is in the most of the cases self-pollinating, which is described as fertilisation itself with its own pollen. Cross-pollination between different rice plants can occur, but in a case when the plant stands close to each other it is very rare. Pollination is performed by wind (no insects are involved). When the panicle is pollinated, the process of grain development begins.

Rice species

There are two cultivated species of rice - *Oryza sativa* (Asian rice) which is grown worldwide, and *Oryza glaberrima* (African rice), which is grown solely in Western Africa. They both are an example of parallel evolution if the crop *Oryza* which is described in Figure 6.



(Khush, 1997)

Figure 6 Evolution of two main rice species

Since the beginning of shaping the Oryza plant, all further evolutionary steps showed various characteristics and differ in annual/ perennial planting type. The perennial types shows overall lower seed productivity. In monsoonal Asia both types have its use, since the perennial types grows in permanent swamps (which has sufficient moisture all year) and the annual types grows in temporary marshes, which remains wet only in the raining season (Khush, 1997).

The *Oryza* species had developed into several groups. *Their genomes can be classified into 11 groups labelled AA to LL, and most of the species can be grouped into four complexes of closely related species in two major sections of the genus. Just two species, both diploids, have no close relatives and are placed in their own sections of the genus: O. australiensis and O. brachyantha* (GRiSP, 2013).

In the late 1990s, the Africa Rice Centre, WARDA, managed to cross the two species into an inter-species hybrid called "NERICA" (standing for "New Rice for Africa"), which combines the ruggedness of local African rice with the high productivity of the Asian rice (Calpe, 2006).

Since decoding the genome of rice in 2002, and later on when in 2006 had been rice released for commercial breeding purposes, several scientific studies have been taken with clear results. The main characteristic, which have been followed in breeding new GM species include: improving nutritional values (increasing levels of micronutrients, for example so called "Golden rice" with high amounts of vitamin A), reducing amount of input substances, developing pest or fungi-resistant varieties, herbicide tolerant varieties or developing varieties with higher resistance to drought or water salinity (Calpe, 2006). Nowadays are according to Deepa et al. (2008) cultivated and consumed more than two thousand varieties of rice around the globe.

2.3 Production of rice

Rice is able to grow and it is produced around the world in different conditions, which were for simplification distributed by Khush (1997) in four main categories - Irrigated, Rain-fed lowland, Upland, and Flood-prone as following:

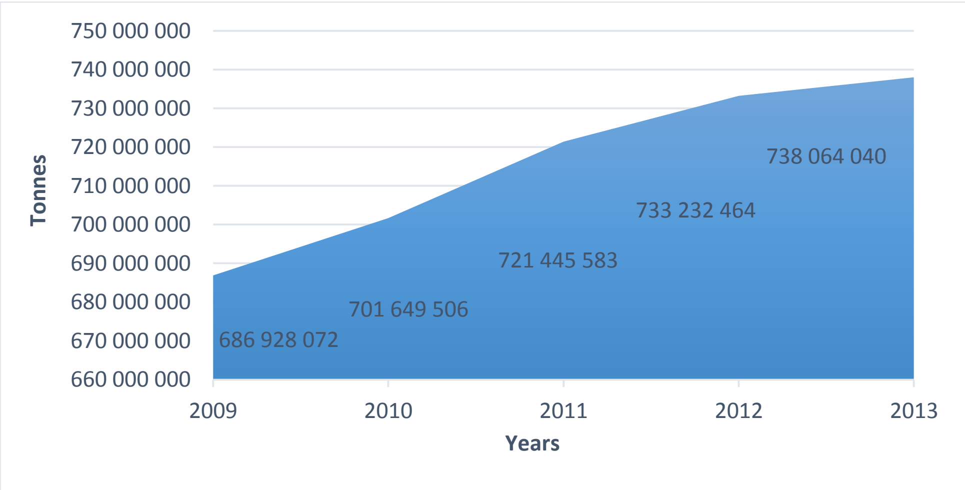
Irrigated rice fields take up about 55 % of the world´s rice area in total and in Asia it is almost a synonym for rice farming. This system is in addition to it the most productive of all – ¾ of rice in the global production comes from just this method (around 5 tonnes per hectare). In last decades plenty new irrigation system techniques was invented and also modern rice varieties are mostly planted in these conditions. There are some disparity between dry and wet season, when in the dry season the yields are higher due to more intensive solar radiation (Khush, 1997; De Datta, 1981).

Rain fed lowland takes approximately 25 % of world rice area with production oscillating around 2 tonnes per hectare. This farming type is very various in the terms of external conditions (amount of rainfall, depth of the water, flooding frequency, soil type etc.).

During the wet season, or any time when the water is available in the field, this system is similar to the irrigated (Khush, 1997).

Upland or also dry-land rice farming is defined by Khush (1997) as growing of rice under the rainfall without permanent surface water coverage. This system allows rice planting in the mountainous areas, where the rice is planted as a regular cereal (for example wheat) and can even resist limited levels of drought. Due to the poor moisture levels and poor soil nutrition, the yields are no higher than 1.2 tonnes per hectare. This type of farming is intensive in the land preparations and is necessary to obtain special rice cultivar, able to grow within those conditions (De Datta, 1981).

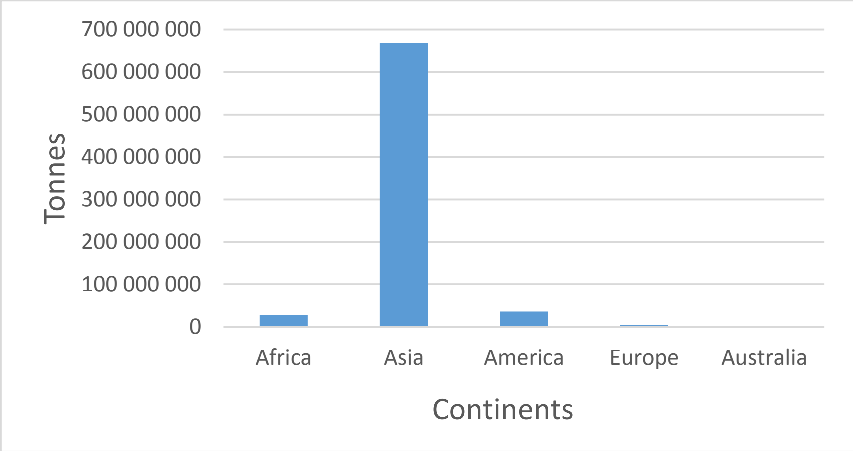
Flood prone is the least developed rice farming system, located next to the river deltas in lowlands. The water cover is permanent but various in depth and intensity – according to the river cycle. The flooding occurs only seasonally but the overall depth of standing water can reach up to 3 meters. Only deep water or floating rice cultivars are grown there, with especially tall plant body and potentiality to elongation. The yield is around 1.6 tonnes per hectare but can widely fluctuate. The flood prone system is nowadays on decay, since the river stream control increased, for example in the form of dam construction (De Datta, 1981; Khush, 1997; GRiSP, 2013).



(FAOSTAT, 2013)

Figure 7 Rice production worldwide (2009 – 2013)

As could be seen in Figure 7 the world´s production in 2013 was equal to 738,064,040 tonnes of paddy rice. From that above 90 % still belongs to output coming from the Asian continent and furthermore all the main producers of rice come from Asia. Largest producer, China, had a yield of 205,201,696 tonnes which is over seven times more than the aggregate production of Africa in the same year. China was followed by India (159,200,000 tonnes), Indonesia (71,279,712 tonnes), Bangladesh (51,500,000 tonnes) and Vietnam (44,040,457 tonnes) (FAOSTAT, 2013).



(FAOSTAT, 2013)

Figure 8 Rice production worldwide - 2013

The statistics data in the Figure 8 with the latest numbers about the global production make clear statement: Asia is the most important rice-growing region in the world.

2.4 Nutritional content

Rice is the major source of caloric intake in many countries of the world. The two main consumers of rice and also the most populated countries, India and China, together stand for around 42 % of whole calories consumption of the world´s population. Severe studies display that low income and middle-low income populations tends to consume more rice than any other cereal crop. This could be caused by limited access or extensive price of these products. Therefore could be concluded that *rice is also clearly the world´s most important food crop for the poor* (GRiSP, 2013).

The raw rice contain in 100 g many important elements and as well is high in calorific content: 361 kcal (362 kcal in brown rice), 6 g of protein (7.40 g in brown rice), 8 mg of calcium and also Potassium, Phosphorus, Dietary fibre, Sodium and Vitamins B1, B2 and B3 (Calpe, 2006).

2.4.1 Nutritional composition

As mentioned before, rice is a great source of energy and protein. As Khush (1997) says, rice contains about 8-9 % of protein in its milled form. It provides also significant amounts of important vitamins (thiamine, riboflavin, niacin) and minerals (zinc and selenium), which sufficiently cover the daily nutritional requirements in populations, which are reliant on rice as an essential source of (Juliano, 1993).

However nutritional composition of rice varieties can diverge greatly. The nutritional content can be influenced by rice variety, location of production, further cooking practices and mainly, by the degree of processing. That mainly mean the division into white and brown rice. Since the white rice contains only the starch centre of the grain (which is the source of carbohydrates), it can lack fibre, vitamins, minerals and others which are included in the rice husk but it is still the type consumed by far more then brown rice (Se et al., 2015; Fernando, 2013). The rice milling process generates basic three types of rice: *brown rice (only hull removed), unpolished rice (hull, bran and most of the germ removed), and polished rice (aleurone layer removed from unpolished rice)* (Haard et al., 1999; Calpe, 2006).

As Fernando (2013) states, the brown rice on the other hand is rice kernel only divided of the hull. Thus the bran, endosperm and embryo of the grain remains. It is the bran, which mainly contains higher level of fibre, proteins, lipids, vitamins and minerals hence is more suitable for healthy diet. Some of the macronutrient elements comprised in brown rice are iron, magnesium, manganese, zinc, selenium and vitamins from the B-complex spectrum as stated above (Se et al., 2015).

Nevertheless several authors suggest (Zhang et al., 2010; Se et al., 2015; Shobana et al., 2012) that there is a direct link between consumption of white, milled rice and increased incidence of B-type diabetes. That incidence is according to them directly linked to the high glycaemic index of the cooked white rice.

2.5 Rice varieties grown in Kyrgyzstan

As is written by Smanalieva et al. (2015) *in Central Asia rice is after wheat the most popular cereal crop and staple food. In Kyrgyzstan, according to the Ministry of*

Agriculture, rice was planted in 2011 on 6.46 thousand hectare (ha) and the average yield was 30.4 kg/ha. The local variety of rice [Oryza sativa] called Ozgen rice, grown in the Osh province (Ош Областы) is famous for its extraordinary taste. The grains are known to be in white shades and also in preferable red-brown shade. This colour is created by specific climate, soil´s mineral composition and other conditions. Several other rice varieties are grown in the area as well.

Rice is produced by peasant farmers and collected manually or with help of light machines on the fields. Afterward is the rice stored in heap stacks where is evaporates the surplus water and slowly change the colour. The rice is also often milled and then transported to the markets where is sold to the local population (Smanalieva et al., 2015).

3 Aims of the thesis

The main objective of this diploma thesis is to examine and evaluate the physical properties of eight staple rice varieties grown and consumed in Kyrgyzstan. The cultivars will be studied in sections of physical properties, textural properties and cooking characteristic, where several analysis methods will be applied.

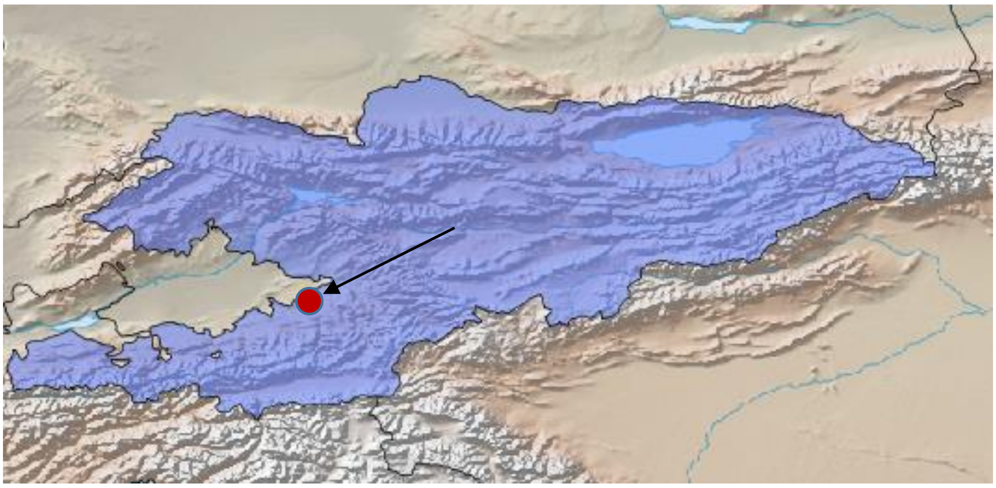
The objective is to find out main information about each cultivar, compare them between each other and implement them into the rice system, by categorizing and analysing.

4 Materials and methods

4.1 Materials

The dried rice kernels were purchased in February 2015 from the city market in Osh, South Kyrgyzstan. In total 8 different rice cultivars were bought at the market. From those are five cultivars local varieties (Ozgen Champion, Batken, Ozgen Kakyr, Ozgen Uchuk and Ozgen Cerza), and three are imported varieties namely Elita Krasnodar Russia (from Russia), Pakistan (from Pakistan) and Kapchygai Kazakstan (from Kazakhstan). The samples were collected from 3 different sellers, to sustain average sample quality of each variety. Each sample in average amount of 700 g was sent to the Czech Republic, to the Czech University of Life Sciences in Prague.

Cultivar samples were cleaned from small particles (as stones and dried weeds) and kept in closed plastic bags in room temperature till the laboratory tests. Only good quality rice grains were used during the analysis and each measurement was done in several repetitions to ensure significant result. The physical analysis was carried out in the Laboratory of Food Technology of Czech University of Life Sciences in Prague – Faculty of Tropical AgriSciences between March, 2015 and February, 2016. In the Figure 9 is showed Kyrgyz city Osh, the sample collection place marked within the area of Kyrgyzstan.



(FAO, 2015)

Figure 9 Map of Kyrgyzstan - place of sample collection

4.2 Physical analysis

4.2.1 Length, width and thickness

The length (L), width (W) and thickness (T) of the rice kernels was determined by use of Vernier calliper with accuracy of 0.01 mm. Rice kernels were randomly selected and each of their dimension was measured and recorded 20 times on each cultivar, similar way as was done in the study by Mir et al. (2013).

4.2.2 Equivalent diameter

Equivalent diameter (D_e) was determined on the base of formula 1 (Mohsenin, 1986), :

$$D_e = \left(L\ \frac{(W+T)^2}{4}\right)^{1/3} \qquad (1)$$

Where, L is length, T is thickness and W is width.

This value express (in mm) potential diameter, if the rice grain was in perfectly round shape. Therefore, this is abstract number displaying potential full diameter of the grain.

4.2.3 Surface area

For calculation of surface area (S) were used previously recorded variables length, width and thickness. The formula for surface area was described by Mohsenin (1986) and Jain and Bal (1997) as following:

$$S = \frac{\pi \text{ x B x L}^2}{(2 \text{ x L-B})} \qquad (2)$$

, while: *B* = $(W\ x\ T)^{1/2}$

Where, L is length and B is function of width and thickness, respectively W and T.

4.2.4 Sphericity

The sphericity (φ) of rice, summarized as *the ratio of the surface area of the sphere having the same volume as that of grain to the surface area of the grain*, was defined by the formula mentioned by Mohsenin (1986):

$$\varphi = \frac{(L\ x\ W\ x\ T)^{1/3}}{L} \quad (3)$$

Where the L is length, W is width and T stands for thickness.

The original values of L, W and T were used and the sphericity data established.

4.2.5 Aspect ratio

The aspect ratio (R_a), expressing ratio of the longer side to the shorter side of the rice kernel, was calculated using formula (Varnamkhasti et al., 2008) :

$$R_a = \frac{W}{L} \quad (4)$$

Where, W is width and L stands for length.

4.2.6 Volume

Volume of grain (V) was calculated by the formula mentioned by Jain and Bal (1997) as following:

$$V = \frac{1}{4}\ x\ [(\pi/6)\ x\ L\ x\ (W + T)^2] \quad (5)$$

Where, L is length, W is width, T is thickness.

4.2.7 Bulk and solid density

Bulk density

The bulk density was calculated according to equation 6 mentioned by Fraser (Fraser et al., 1978) when the 200 ml beaker was filled with the rice up to 100 ml sign and then the mass of rice grains was weighed. The weight of the rice was divided with the volume of the beaker (100 ml). The procedure was repeated five times.

$$\rho_b = \frac{M_g}{V_b} \quad (6)$$

Where M_g is mass of the grain and V_b is volume of the beaker.

Solid density

The solid density is calculated by filling the 100 ml beaker with 50 ml of distilled water and then placing there 3 g sample of rice. The displaced water (volume of the grains) is recorded. The measurement is repeated three times (Shittu et al., 2012).

$$\rho_s = \frac{M_g}{V_{dw}} \tag{7}$$

Where M_g is mass of the grain and V_{dw} is volume of displaced water.

4.2.8 Porosity

Porosity was calculated using results of analysis mentioned above – solid density and bulk density. It determinates free space between the kernels in the mass volume of the grains. The formula was described by Jain and Bal (1997):

$$\varepsilon = 100 \ x \ (1 - \frac{\rho_b}{\rho_s}) \tag{8}$$

Where ρ_b is bulk density, ρ_s is solid density and ε stands for porosity.

4.2.9 Thousand kernel weight

The 1000 kernel weight was measured by random selection of one thousand grains of each cultivar and carefully weighed on digital scale Kern 572-30 (see Figure 10) with accuracy of 0.001 g following by estimation the final weight in grams. The procedure was repeated five times and average values were taken (Varnamkhasti et al., 2008).

Figure 10 Digital scale Kern 572-30

4.2.10 Colour characteristic

Colour of the rice kernels was determined by using the spectro-photometer CM-600d (Konica Minolta Optics, inc.) based on the CIE lab system. Rice was placed in a small plastic bowl in amount ensuring several layers of rice kernels above each other. Than was the colorimeter adjusted on D 65 – simulation of daylight and the angle of observation was 10°. The measurement was repeated five times with each cultivar and the data were downloaded from the device to Excel file. Each measurement was recorded in three dimensions: "L" (lightness), "a" (red/ green ratio) and "b" (yellow/ blue ratio) (Mir et al., 2013).

4.2.11 Optimum cooking time

As was done in the study by Mohapatra and Bal (2006), for the optimum cooking time test was taken a sample of 5 grams from each variety, which was placed in glass Petri dish. The water bath Memmert was filled with water till the marked line. Inside of the water bath was placed 250 ml graduated beaker and filled with 100 ml of distilled water. The water bath was brought to the temperature of 100 °C, when the water starts to boil. When water reach the demanded temperature, rice sample was placed into the cylinder and the time started to be recorded.

After 10 minutes of boiling, 3 grains of rice were removed and pressed between two glass plates, in order to examine the gelatinization of the core. Than every other minute the procedure was repeated, until the rice grains has no more un-cooked centres. Until at least 9 out of 10 grains were properly cooked and then was the rice cooked for another minute to ensure that all the grains are cooked. The optimal cooking time of each cultivar was recorded.

4.2.12 Water uptake ratio

For water uptake ratio test the water bath Memmert was used. From each rice variety 18 samples (2 grams each) were soaked on water with different temperatures and soaking times. The test temperatures were set on 30°, 45° and 60° C and soaking time was set on 30 or 60 minutes. Each measurement was performed in triplicate. The 2g sample was placed in 200 ml beaker which was filled with 100 ml of water and inserted into the water bath of certain temperature and soaked for certain time. After the rice was decanted through colander with dense mesh and dried with paper towel. The sample was reweighted and the new weight was recorded.

The water uptake ratio was calculated by dividing weight of rice after cooking to initial rice sample weight. It was proceed by recording the weight of the initial raw rice sample and the final rice sample on the electronical scale (Kern 572-30 with accuracy of 0.001g) (Shittu et al., 2012).

4.2.13 Hardness of the grain

Grain hardness was measured on Texture analyser MPTest 5.050 from Czech company LaborTech (see Figure 11). The measurement took place at Department of Mechanical Engineering on Technical faculty of Czech University of Life Sciences. The original clearance of probe/ base was set on 8 mm. The upper plate and basis were approaching in the speed of 1 mm/ sec.

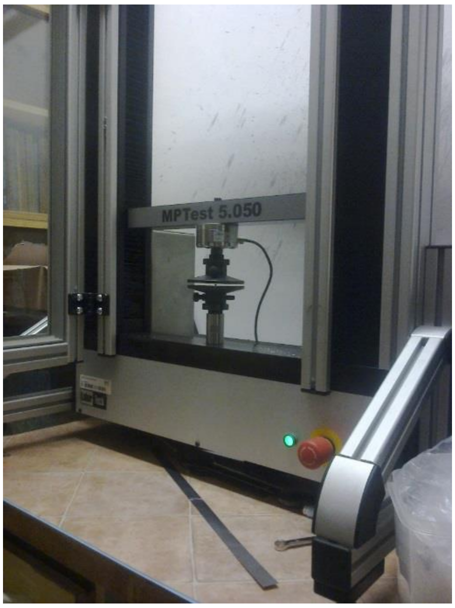


Figure 11 Texture analyser MPTest 5.050

Only good quality grains were used for hardness test. For each cultivar was used 20 grains to perform the measurement. Each grain was placed in the middle of the steel disc along it´s thickness and the test was started. After breaking of the grain with single compress force, the test stopped automatically or was finished manually. The results of each measurement was downloaded from the programme in Excel file and the data was further processed (Mir et al., 2013).

5 Results and Discussion

5.1 Physical characteristics of rice

A summary of the basic physical properties of traditional Kyrgyz rice varieties is shown in Table 2, while the imported varieties are described in Table 3. In the tables are shown results with their standard deviation and with units mentioned next to the physical properties.

Table 2 Physical characteristic of Kyrgyz rice varieties

Property	**Ozgen Champion**	**Batken**	**Ozgen Kakyr**	**Ozgen Uchuk**	**Ozgen Cerza**
Length (mm)	6.99 (0.34)	6.05 (0.30)	6.89 (0.24)	6.96 (0.47)	6.90 (0.48)
Width (mm)	2.94 (0.27)	3.10 (0.17)	2.91 (0.14)	2.86 (0.14)	2.71 (0.14)
Thickness (mm)	1.96 (0.09)	2.13 (0.13)	2.02 (0.15)	2.04 (0.07)	2.01 (0.13)
Equivalent diameter (mm)	3.47 (0.14)	3.43 (0.10)	3.47 (0.07)	3.47 (0.11)	3.37 (0.08)
Surface area (mm^2)	31.78 (2.18)	30.34 (1.80)	31.78 (1.34)	31.90 (2.09)	30.38 (1.45)
Sphericity	0.491 (0.02)	0.559 (0.03)	0.498 (0.02)	0.495 (0.02)	0.487 (0.03)
Aspect ratio	0.42 (0.04)	0.51 (0.04)	0.42 (0.03)	0.41 (0.03)	0.40 (0.04)
Volume (mm^3)	22.02 (2.70)	21.13 (1.91)	21.91 (1.29)	21.84 (2.03)	20.09 (1.32)
Bulk density ($g.cm^{-3}$)	0.80 (0.04)	0.82 (0.03)	0.77 (0.02)	0.78 (0.02)	0.77 (0.01)
Solid density ($g.cm^{-3}$)	1.26 (0.04)	1.17 (0.05)	1.29 (0.04)	1.18 (0.04)	1.21 (0.05)
Porosity (%)	36.54 (3.47)	30.20 (1.06)	39.83 (1.60)	34.05 (3.25)	36.60 (1.84)
Thousand kernel weight (g)	26.60 (0.32)	24.37 (0.38)	26.57 (0.17)	25.39 (0.16)	27.15 (0.07)

Values are expressed as mean (standard deviation). Rice varieties are known by their brand name, since no information on their scientific name had been available.

The values of analysis are grouped according to their origin, since there were some major differences based on that. The values are further discussed and compared in each following chapter accordingly. The textural and cooking characteristics are stated separately due to their format of record.

Table 3 Physical characteristic of imported rice varieties

Property	Elita Krasnodar Russia	Pakistan	Kapchygai Kazachstan
Length (mm)	5.29 (0.23)	6.53 (0.45)	6.00 (0.34)
Width (mm)	2.91 (0.29)	2.52 (0.27)	2.91 (0.19)
Thickness (mm)	1.92 (0.08)	1.88 (0.12)	1.95 (0.15)
Equivalent diameter (mm)	3.14 (0.14)	3.16 (0.17)	3.28 (0.14)
Surface area (mm^2)	25.35 (1.94)	26.74 (2.82)	27.99 (2.29)
Sphericity	0.592 (0.05)	0.480 (0.02)	0.540 (0.03)
Aspect ratio	0.55 (0.07)	0.39 (0.04)	0.49 (0.03)
Volume (mm^3)	16.25 (2.14)	16.63 (2.83)	18.61 (2.37)
Bulk density ($g.cm^{-3}$)	0.87 (0.01)	0.79 (0.03)	0.84 (0.02)
Solid density ($g.cm^{-3}$)	1.41 (0.08)	1.22 (0.03)	1.17 (0.03)
Porosity (%)	38.32 (3.15)	34.84 (2.75)	28.27 (1.84)
Thousand kernel weight (g)	19.67 (0.10)	19.79 (0.28)	21.69 (0.08)

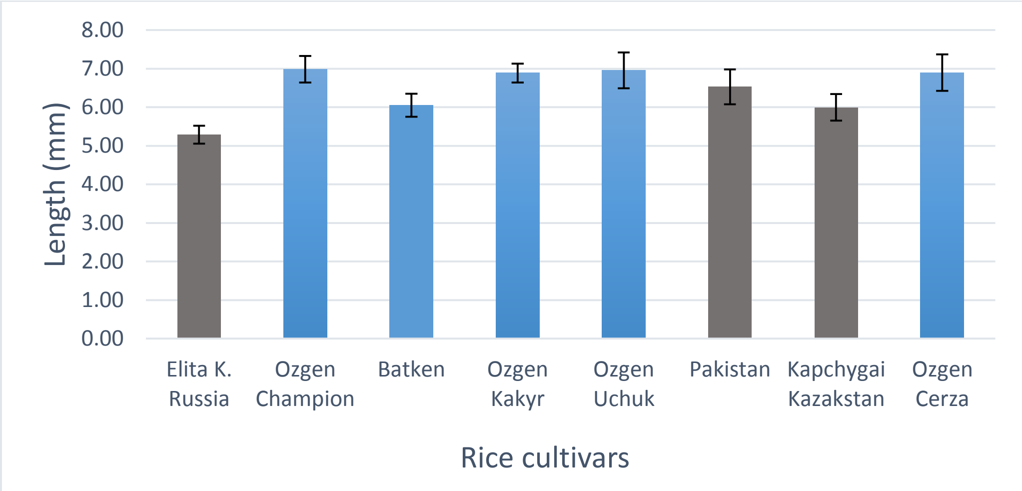
Values are expressed as mean (standard deviation). Rice varieties are known by their brand name, since no information on their scientific name had been available.

5.1.1 Length, Width, Thickness

The average principal dimensions, such as length, width and thickness of Kyrgyz native cultivars were measured and recorded respectively.

The length of rice kernel within the Kyrgyz native cultivars was processed and in result the cultivar with longest grain was Ozgen Champion with 6.99 mm (the longest from research sample), and cultivar with shortest grain was Batken with 6.05 mm.

In the case of imported varieties was the longest rice Pakistan with 6.53 mm and the shortest Elita Krasnodar Russia with 5.29 mm, which was also the shortest from the whole research sample. In Figure 12 are shown all the varieties and their length dimension in comparison to each other and as well the imported varieties are marked in grey colour so the differences between local and important could be clearly visible.



*The imported cultivars are marked in grey colour.

Figure 12 Length of rice kernels

From the recorded data we can observe, that the local rice varieties all belong to the category of long rice (Table 4 below) and one of them (Ozgen Champion) is even at the turn to extra-long rice. On the contrary, the imported varieties have lower length dimensions, since one cultivar is in the medium category (Elita K. Russia), and one is at the turn from medium/ long rice.

Further of the width dimensions (see Figure 13) of the local Kyrgyz varieties showed smallest dimension at Ozgen Cerza (2.71 mm) and the longest at Batken (3.10 mm) which is also the largest number from whole research sample and it is only cultivar, standing out of the bold shape category. Batken belongs to slender (long) grain shape.

Table 4 Dimensions and shape classification of the grain

	Lenght	Length (FAO)	Width	Shape (FAO)
Elita K. Russia	5.29 (0.23)	Medium	2.91 (0.31)	Bold
Ozgen Champion	6.99 (0.34)	Long/ extra long	2.94 (0.27)	Bold
Batken	6.05 (0.30)	Long	3.10 (0.17)	Slender (long)
Ozgen Kakyr	6.89 (0.24)	Long	2.91 (0.14)	Bold
Ozgen Uchuk	6.96 (0.47)	Long	2.86 (0.14)	Bold
Pakistan	6.53 (0.45)	Long	2.52 (0.27)	Bold
Kapchygai Kazachstan	6.00 (0.34)	Long/ medium	2.91 (0.19)	Bold
Ozgen Cerza	6.90 (0.48)	Long	2.71 (0.14)	Bold

Kapchygai Kazakstan had large amount of broken grains in the sample, values are expressed as mean (standard deviation) (IRRI, 1980).

From the imported cultivars, the largest proportion had both Elita K. Russia and Kapchygai Kazachstan, with average width dimension of 2.91 mm. The third cultivar, Pakistan, has with 2.52 mm the smallest width of the kernel from the whole sample.

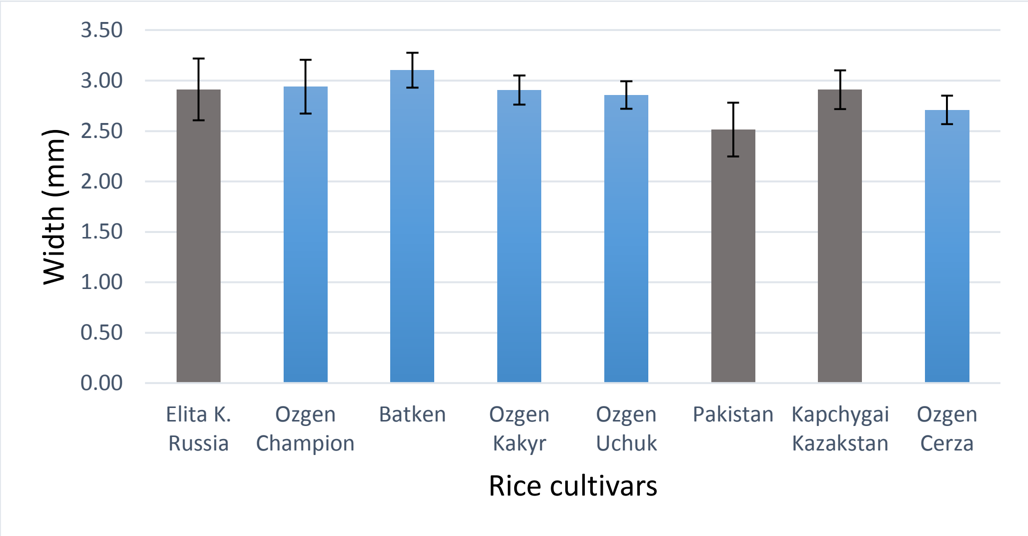


Figure 13 Width dimensions of rice cultivars

The thickness of the local group of cultivars leads Batken with 2.13 mm and concludes Ozgen Champion with 1.96 mm. In the adopted group of cultivars the largest thickness belongs to Kapchygai Kazachstan with 1.95 mm and the lowest hold Pakistan with 1.88 mm. In the terms of the whole research sample, the largest thickness has Batken (2.13 mm) and the lowest Pakistan (1.88 mm) which is shown in Figure 14.

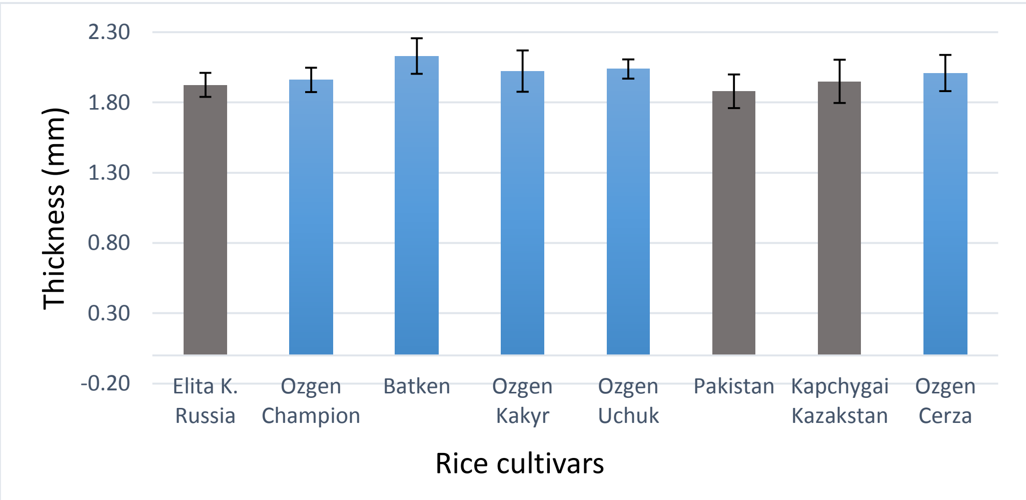


Figure 14 Thickness of the grains

From the analysis of measurement of length, width and thickness categories can be concluded, that Batken rice variety, local to Kyrgyzstan, has one of the largest physical dimensions from the research sample. This has been found out on the grounds of that it has placed twice like a top variety, both in width and thickness category.

Furthermore the imported variety Pakistan has placed twice in the bottom of the sample, therefore can be claimed, that it owns one of the smallest dimensions in the research fragment.

When measuring the physical properties of rice, grain dimensions are the main characteristics that need to be involved (Battacharya, 2011). Most of the authors, while dealing with physical properties of rice establish those basic values (Smanalieva et al., 2015; Oli et al., 2016; Varnamkhasti et al., 2008; Thakur and Gupta, 2006; Díaz et al., 2015; Ravi et al., 2014; Meena et al., 2010 and some others). Measuring the grain dimensions is first step to characterize the rice shape and those values are also further used for several dimensional calculations.

In the article by Smanalieva et al. (2015) had been measured length, width and thickness at Ozgen rice variety, in different storage times. Only the results from longest time of storage was considered, since it is most similar to rice quality in this analysis. The average length of Ozgen rice recorded by Smanalieva was 6.37 mm (± 0.21) which is compared to average results of Kyrgyz varieties 6.76 mm (± 0.36) in this study lower. That could be explained by larger sample of different varieties within the Ozgen family and even other variety Batken, also local to Kyrgyzstan, which make the average result more diverse. The dimensions for width of grain by Smanalieva et al. (2015) were 2.80 mm (±0.10) compared to average width 2.90 mm (± 0.17) from this study, which is significantly similar result, according to circumstances mentioned above. The last dimension, thickness resulted in Smanalieva´s study 1.87 mm (±0.05) which is slightly lower than result 2.03 mm (±0.11) obtained in this study, but since in the average of this study is involved several Ozgen cultivars, is it still relevant result.

In other studies the length, width and thickness of rice varied greatly. Similar results found Fofana et al. (2011) and Díaz et al. (2014) who was also measuring wider spectrum of different varieties. Usually the results were quite comparable in terms of width and thickness but the length of cultivars overlap the values measured in this study often by millimetres. Mir et al. (2013), Shittu et al. (2012). Meena et al. (2010) measured quite similar results however the width values were much lower than the one observed in this study (1.54 - 1.88 mm compared to 2-52 – 3.10 mm).

Fofana et al. (2011) also established the shape characteristic of the rice kernels. The results of size classification were reaching to about 90 % of the varieties to be classified as “long”. According to the kernel shape about 30 % was classified as slender grain shape and the rest was classified as intermediate grain shape. In conformity with the results we can presume that the intermediate designation respond to bold designation used in this study since results recorded by Fofana et al. are similar to the results in this study.

5.1.2 Equivalent diameter

Equivalent diameter is calculation of diameter used for non-circular object. Thus the results respond to approximate diameter of the rice kernel. All the values recorded are shown in Figure 15.

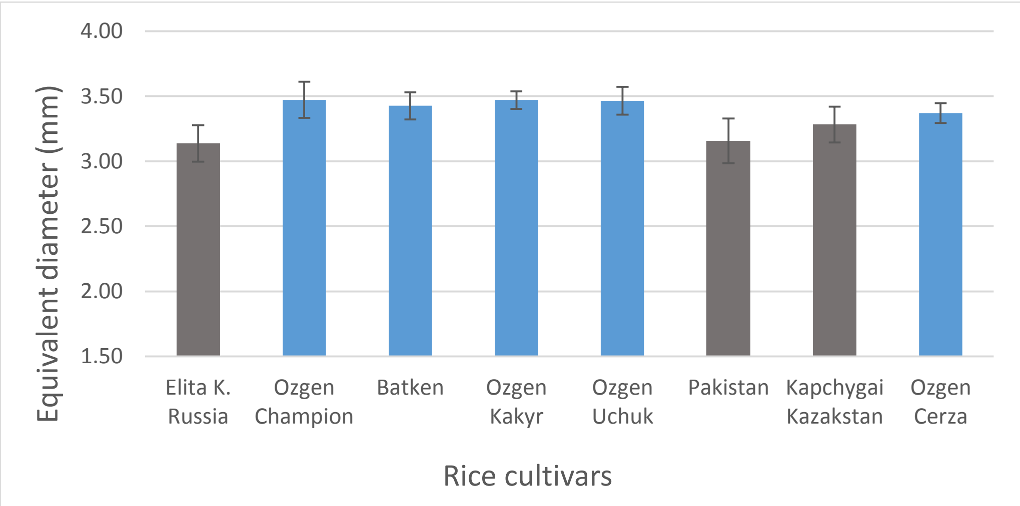


Figure 15 Equivalent diameter of rice cultivars

In the local varieties have the largest D_e at the same time three varieties – Ozgen Champion, Ozgen Kakyr and Ozgen Uchuk, all with 3.47 mm which is also largest D_e in the sample. The lowest eq. diameter has Ozgen Cerza with 3.37 mm.

In the imported varieties has the largest eq. diameter Kapchygai Kazachstan (3.28 mm) and the lowest Elita K. Russia (3.14 mm) which is also lowest diameter in the selection.

The result of equivalent diameter correspond with previous conclusions about rice grain dimensions. The three largest eq. diameters belongs to the group of local varieties, and three lowest represent the non-native cultivar group.

Equivalent diameter is next important variable to establish grain characteristic. Mir et al. (2013) with Indian varieties recorded results in range from 3.60 mm to 3.79 mm, Varnamkhasti et al. (2008) measured 3.30 mm and 3.40 mm on cultivars from Iran and Shittu et al. (2012) had measured it on improved rice varieties from Nigeria nevertheless did not publish the results in the article. In this study the range of equivalent diameter through whole study sample varied from 3.14 mm to 3.47 mm so it could be declared as similar to results of Varnamkhasti et al. (2008) with even wider range of recorded values.

5.1.3 Surface area

Surface area values varied from 25.35 mm² (of Elita K. Russia) to 31.90 mm² of Ozgen Uchuk. The cultivars with the lowest surface area are repeatedly the imported varieties – Elita K. Russia, Pakistan and Kapchygai Kazachstan, in this order. The cultivars with highest surface area are all the Ozgen varieties represented in the research sample.

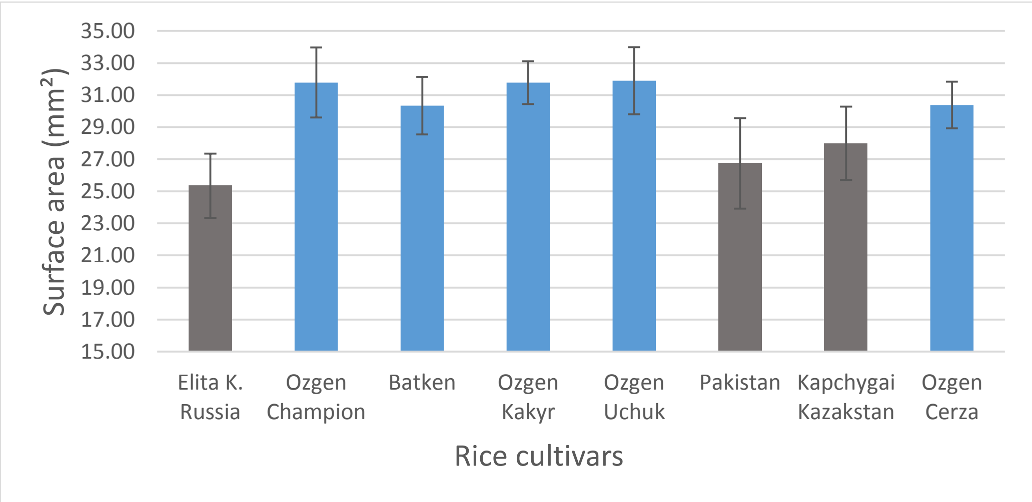


Figure 16 Surface area of the rice cultivars

This result suggest that local varieties (Ozgen cultivars and Batken marked as blue in Figure 16) has overall large kernels than imported varieties from the surrounding countries.

The surface area was measured in the range from 25.35 mm² to 31.90 mm² in the whole test sample but it is important to mention quite large values of standard deviation in the sample. Another authors stated results of 34.32 mm² till 43.78 mm² for paddy rice from India (Mir et al., 2013), 39.63 mm² till 49.69 mm² on the new Nigerian rice (Shittu et al., 2012), 13.998 mm² on Indian paddy long-grain varieties (Thakur and Gupta, 2006) and 25.62 mm² to 38.46 mm² on rice which was studied by Varnamkhasti et al., 2008. According to results of surface area, this thesis have once more similar results with study of Varnamkhasti et al., (2008). Varnamkhasti however recorded higher top values in his measurement, thus in his test samples are present varieties with higher surface area than in this study. Nevertheless the overall values of this test can be considered as similar.

Mohapatra and Bal (2006) mentioned, that surface area and thickness of grain are very important for decision about diffusion water during cooking process. Also Juliano (1993) confirm this statement with the finding which concludes that optimal cooking time for rice is depend on thickness and surface area of the grain.

5.1.4 Sphericity

Sphericity of the each cultivar was determined and compared within the sample (see Figure 17). In the local cultivars of Ozgen and Batken, the largest sphericity was founded at Batken with value of 0.559 and the smallest at Ozgen Cerza with value of 0.487.

At the others rice varieties the largest sphericity was recorded at Elita Krasnodar Russia with 0.592 which was as well the largest sphericity from the research sample. The lowest was recorded at Pakistan with 0.480 which was at the same time the smallest sphericity of the sample.

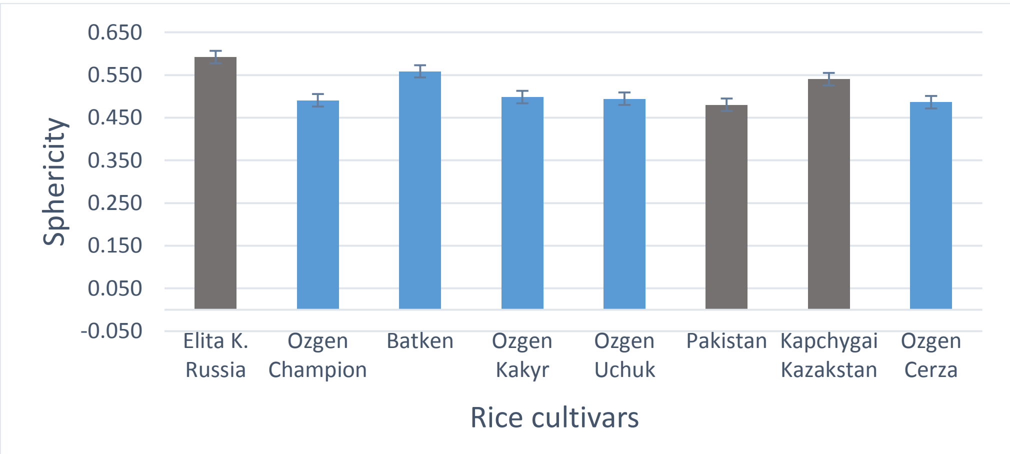


Figure 17 Sphericity of the rice

Hence the conclusion of this measurement cannot be that clear, since both peak values are included in the non-native cultivar group. Therefore it does not show the clear formula of diverse sphericity among certain group of cultivars.

According to Mohsenin (1986) the sphericity values of rough rice (and majority of agricultural products) should vary in the range of 0.32 – 1. In the context of this statement, the results of this analysis move in the interval and are consistent with Mohsenin´s hypothesis. Some other authors stated their sphericity results as well, prospectively: Mir et al. (2013) stated that the paddy Indian rice from test sample had its sphericity in range of 0.32 – 0.53, Shittu et al. (2012) measured that improved paddy rice grown in Nigeria has sphericity from 0.39 – 0.44, Díaz et al. (2015) who observed Japanese rough rice (Japonica, Indica and NERICA) sphericity vary from 0.38 – 0.55, Thakur and Gupta (2006) find sphericity of Indian paddy rice in value 0.38 and Varnamkhasti et al. (2008) study showed sphericity of Iranian rice in range 0.37 – 0.46.

There was not found result similar to one measured in this study, however the upper line of values was comparable to several studies (Mir et al., 2013; Díaz et al, 2015) while the bottom values were in all cases lower than the one measured. The explanation could be that in terms of sphericity is the study sample more unified than the test samples of the articles mentioned. Therefore the result values in this study have lower span than the studies mentioned above.

5.1.5 Aspect ratio

Aspect ratio is essential formula dividing width and length of the rice kernel. The result shows important information about classification of the grains and resolve the extent of off-size in retail standardization (Mir et al., 2013).

The aspect ratio was found to be highest in Elita Krasnodar Russia (0.55) while lowest in Pakistan (0.39), both belonging to the imported varieties group. That suggest that there are difference not only between local and imported varieties, but likewise within the non-native varieties, which originate from various countries and therefore can have significant divergence within the imported-rice sample.

The highest aspect ratio of variety of Kyrgyz origin had Batken with 0.51 and the lowest of Kyrgyz group had Ozgen Cerza with 0.40. The remaining data can be found in Table 2 and Table 3.

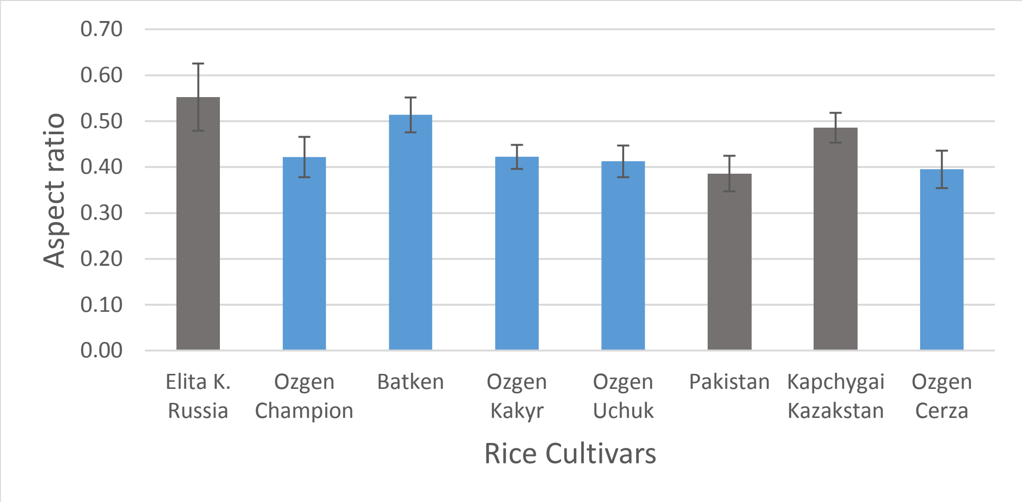


Figure 18 Aspect ratio of rice

As was mentioned by Varnamkhasti et al. (2008) the determination of values of aspect ratio is important due to classification of grain dimensions and the extent of off-size in market ranking. Their measurement showed values of 0.28 – 0.29 while for the same variable measured Mir et al. (2013) for different cultivars of rice aspect ratio of 0.19 – 0.43. In comparison with those measurement results of this study range in upper level and even show higher aspect ratio than was mentioned before (0.39 - 0.55).

Several authors were instead of aspect ratio measuring length/width ratio. However those two measurements cannot be compared since the formula of comparison width and length differ to one used in this study.

5.1.6 Volume

The volume of the seed in Kyrgyz varieties fluctuated from 20.09 mm³ in Ozgen Cerza to 22.02 mm³ in Ozgen Champion. Champion had also the largest volume of the grain from all cultivars.

In the section of newly introduced varieties of rice, the most voluminous in its grain was Kapchygai Kazachstan with 18.61 mm³ and the one with lowest volume was Elita K. Russia with 16.25 mm³. As seen in Figure 19, Elita and another imported rice Pakistan hold the bottom two lines in this measurement, when the Kapchygai was third with lowest volume.

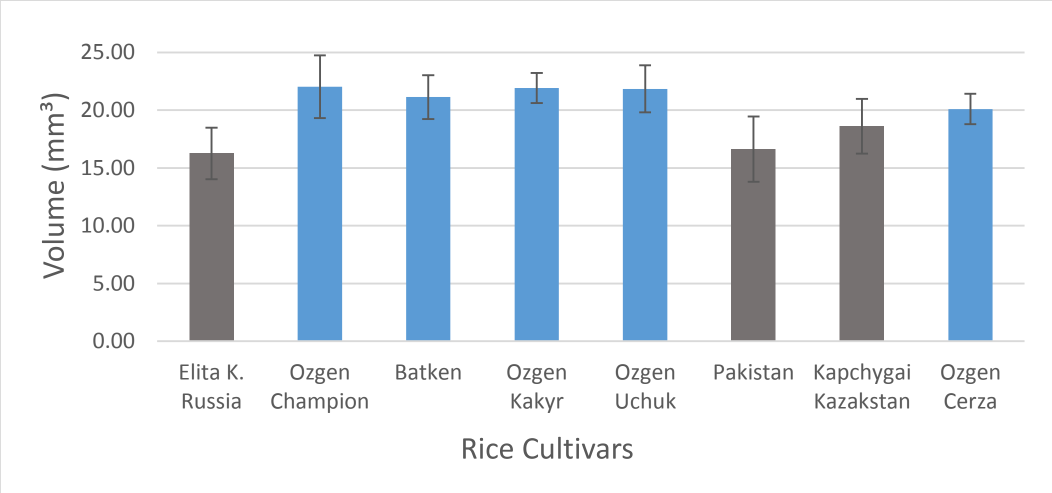


Figure 19 Volume of rice kernels

This results display connection between imported group of rice and lower volume of the kernel. The three imported rice varieties represent the lowest values of the rice volume in the research sample, therefore we can consider them as the rice varieties with smallest kernels, in the volume perspective.

Varnamkhasti et al. (2008) result of volume of Iranian rice was in range from 13.94 mm^3 to 26.75 mm^3. He also mentioned that the volume determination is important for its use for modelling of grain aeration and consequently all the drying, heating and cooling devices. Díaz et al. (2015) find out in their study that the value of volume range from 21.1 mm^3 to 36.4 mm^3 and Shittu et al. (2012) measured 27.99 mm^3 to 39.77 mm^3 as volume values. Mir et al. got volumes of paddy rice in span of 24.46 mm^3 to 28.45 mm^3. Compared to the results of different authors the volume values from this measurement are significantly lower. The reason could be generally lower grain dimensions (mainly the length as mentioned in chapter 5.1.1) and based on those values the final volume is lower. The only author, whose range of results is quite similar to one from this study is Varnamkhasti et al. (2008). Although his results start on lower bottom line and overcome the upper line compared to our results, they comprise values measured in this study (18.61 – 22.02 mm^3) in their range.

5.1.7 Bulk and solid density

Bulk density

Both bulk and solid density display properties of the kernel in the spatial dependence. They both estimate how the kernels will behave in larger quantities in the space and how much of it they will occupy.

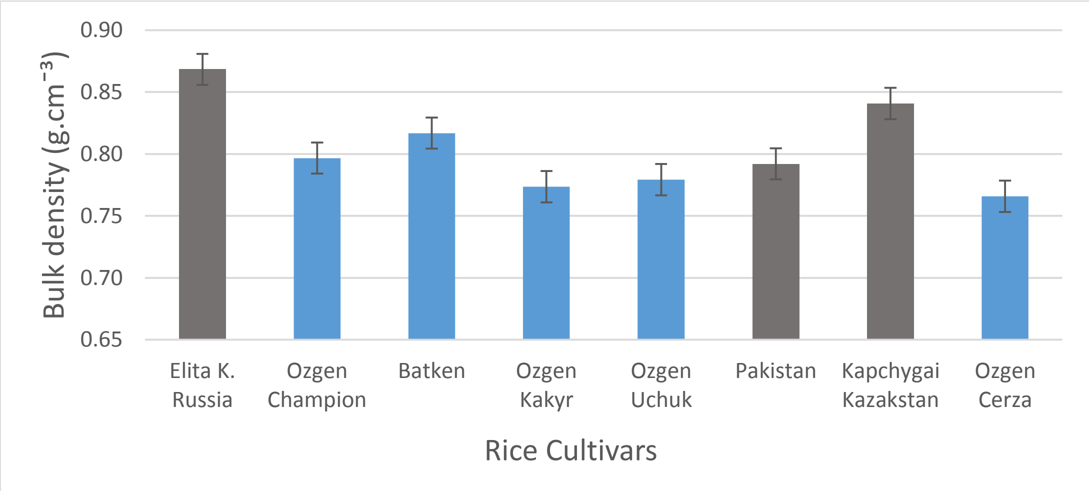


Figure 20 Bulk density values

Bulk density describes grain behaviour in the dry mass meanwhile the solid density is more focused on particular volume the grains take in space, when measured by water test.

In this measurement was founded, that from the Kyrgyz native group was the variety with largest bulk density Batken (0.82 $g.cm^{-3}$) while the lowest bulk density has both Ozgen Cerza and Ozgen Kakyr (0.77 $g.cm^{-3}$) which was the bottom value of the whole sample.

In the imported varieties and also overall was leading cultivar Elita K. Russia (0.87 $g.cm^{-3}$) and the cultivar with lowest number was Pakistan with 0.79 $g.cm^{-3}$.

As could be seen in the Figure 20, the local varieties of Ozgen are visibly lower in bulk density values than imported varieties, such as Elita K. Russia or Kapchygai Kazachstan. This could be simply illustrated in the way, that the local varieties have longer and less regular shape of the kernel (as shown in previous measurement, the Kyrgyz varieties had lead many categories about the grain size and shape, volume, sphericity etc.) thus they take up larger space and are more problematic to sufficiently infill complimentary space between them.

The result of this analysis were comparable to results of Singh et al. (2005) who measured solid density in range of 0.77 g/ml – 0.87 g/ml and to results of Meena et al. (2010) who got results of Indian rice in range of 0.76 g/ml - 0.89 g/ml (the units are equal to $g.cm^{-3}$). Singh et al. mentioned that bulk density is factor influencing cooking time as well.

Lower values measured Mir et al. (2013) with values of bulk density ranging from 0.50 g/ml to 0.60 g/ml, Shittu et al. (2012) with values of 0.55 g/ml – 0.69 g/ml, Díaz et al. (2015) with results moving from 0.60 g/ml to 0.63 g/ml and Varnamkhasti et al. (2008) who got results in range from 0.47 g/ml to 0.55 g/ml while he stated that bulk density analysis is *useful for the design of silos and hoppers for handling and storage of rice.*

With higher values of bulk density the rice requires lower packing space, therefore in this study the imported varieties are the one who would generally need smaller package for the same amount of rice as the local varieties (Thakur and Gupta, 2006).

Solid density

The solid density was more balanced within the varieties than bulk density, however several deflections could be spotted (see Figure 21). In the local sample the largest solid density had Ozgen Kakyr with 1.29 $g.cm^{-3}$ and the lowest Batken, which had along with Kapchygai Kazachstan from imported group lowest value (1.17 $g.cm^{-3}$).

The biggest solid density was in imported sample represented by Elita K. Russia, which has with 1.41 $g.cm^{-3}$ the upper value from whole research sample.

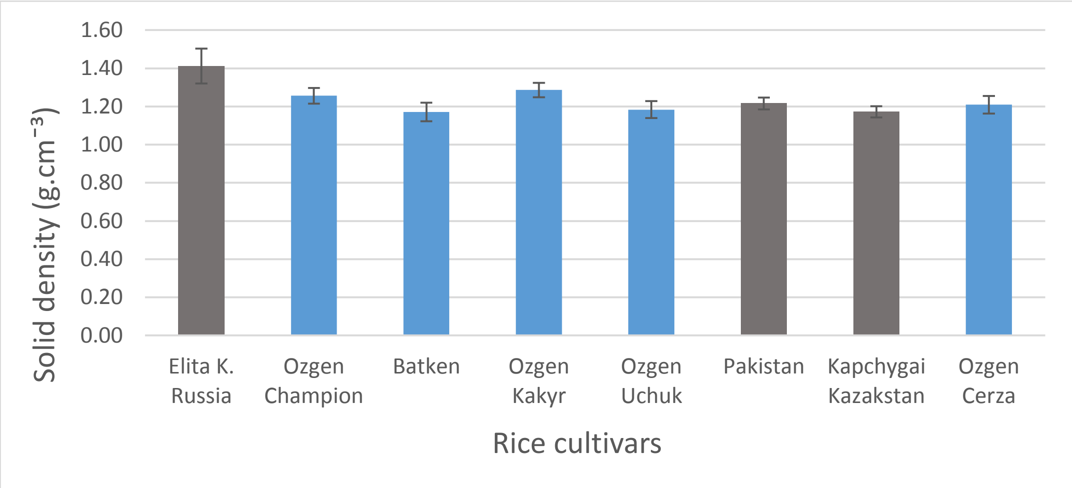


Figure 21 Solid density values

The preeminent variety is in both cases Elita K. Russia, which defines its space properties as very good (in terms of taking up the space in storage). The second variety, which follows Elita is Ozgen Kakyr, thus local variety. The remaining rice varieties are not very significantly different from each other, in order to formulate clear hypothesis.

Although bulk density is very common analysis done in the physical properties evaluation, the solid density is rather rare. From the authors who include solid density to their analysis Shittu et al. (2012) measured 1.06 and 1.28 (however he calls it *true density* in his study, the measurement is similar to the one performed in this study). Also Varnamkhasti et al. (2008) was recording solid density of the rice grains, but he used Toluene displacement method, therefore it cannot be fully compared with our result. His recoded values were 1.19 g.cm^{-3} and 1.27 g.cm^{-3}. To conclude similar results have not been founded in the according literature sources.

5.1.8 Porosity

Porosity, defined as the ratio of intergranular free space volume and the bulk grain volume. Hence porosity express percentage of volume of void spaces in the sample (Jain and Bal, 1997).

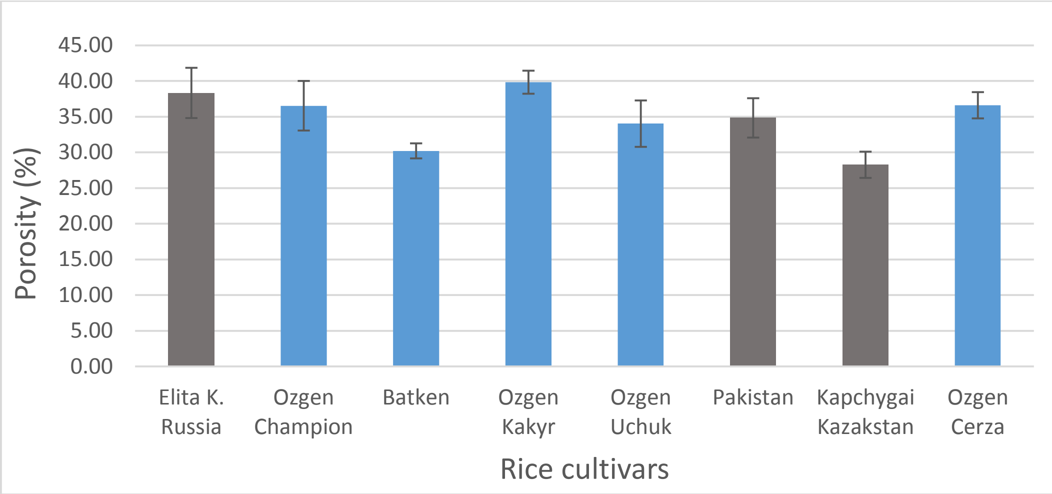


Figure 22 Porosity of rice

As the outcome of this measurement occurred results with quite large variability. In the local sample the largest porosity was represented by Ozgen Kakyr with 39.83 % that has been also the highest porosity from the research sample. The bottom value was represented by Batken variety with 30.20 %.

In non-local sample the upper value represented Elita K. Russia with 38.32 % porosity and the bottom value Kapchygai Kazachstan with 28.27 % porosity – as well the lowest value of the whole sample (see Figure 22).

Considering there is not very clear pattern within the research sample in terms of porosity, it could be only concluded that the distribution of porosity among the local and imported varieties is equally intermittent.

From the authors who involved porosity in their physical characteristic analysis were found none with values close to this study. All the results of other authors have been significantly higher, than porosity measured at Kyrgyz-grown rice varieties. Mir et al. (2013) found porosity in values from 52.70 % to 59.45 %, Shittu et al. (2012) measured porosity at two samples with values 45.30 % and 57.01 %, Thakur and Gupta (2006) found result of their measurement as 48.06 % for their paddy rice and Varnamkhasti et al. (2008) found out as the results of porosity test values in range of 53.07 % - 63.33 %. All these values exceed results of this study, where average porosity of all samples showed 34.83 % (closest value 45.30 % was measured by Shittu et al., 2012).

According to Varnamkhasti et al. (2008) the low percentage of porosity like is present at our test sample can cause difficulties in active drying process of the rice. In case of convective drying with forced draft the low porosity means that the resistance towards air combustion product is low resulting is slower drying than in case of rice with high porosity.

5.1.9 Thousand Kernel Weight

This analysis displayed the mass weight equivalent of one thousand rice grains, from each cultivar respectively. It could be used as factor of the rice weight and compared with other analysis results likewise.

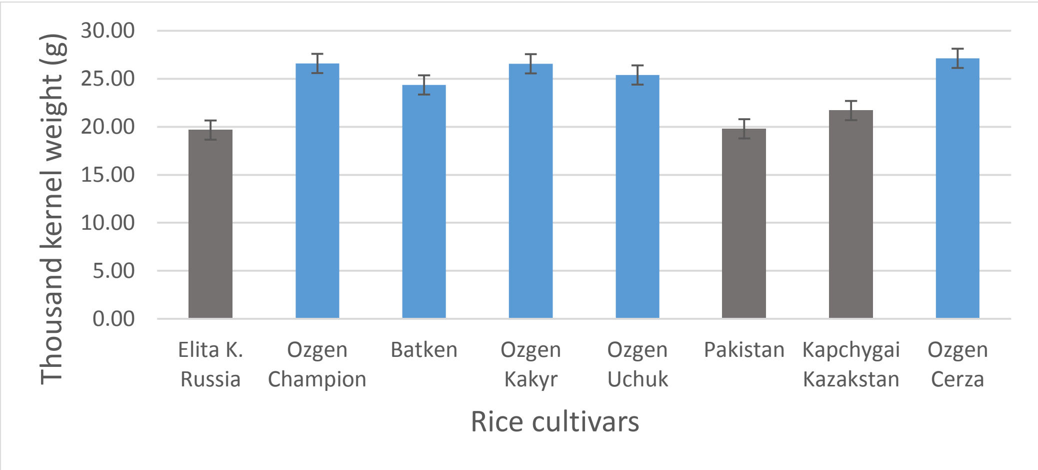


Figure 23 Thousand kernel weight of rice

The local Kyrgyz varieties have altogether relatively high thousand kernel weight, varying from 24.37 g per thousand grains of Batken till 27.15 g of TKW for Ozgen Cerza. They all occupy the upper area of the graph (Figure 23).

The imported varieties are visibly lower in their thousand kernel weight. Their values diverge from 19.67 g for Elita K. Russia (as the lowest TKW of the sample) till 21.69 g of Kapchygai Kazachstan.

As a consequence, the imported varieties could be considered as lighter in weight in comparison with Kyrgyz varieties, since their TKW is visibly lower in all cases. This pattern validate previous results about smaller grain dimensions and volume, therefore apparently the weight of grain is lower as well.

According to Smanalieva et al. (2015), the Ozgen varieties varied in their TKW from 23.63 to 24.94 g and she stated that this value is decreasing with increasing storage time. From that we can assume, that rice used in this thesis (stored for over a year in constant conditions) had its inner moisture declined concluding in lower TKW than in the measurement by Smanalieva. Overall her values are in the range of results of this thesis as well as of several others authors: Mir et al. (2013) measured TKW in range from 22.23 g to 28.63 g which only slightly exceed results of this study and Díaz et al. (2014) measured quite similar results only with lower bottom line of values (15.3 g – 24.1 g). Also Ravi et al. (2014) measured comparable values in range from 20.6 g to 24.5 g of TKW. According to the article written by Ravi et al. (2014) is the thousand kernel weight also useful parameter to measure the “milling outturn”. It determinate the relative amount of foreign matter in a given volume of paddy rice.

Lower results showed Singh et al. (2005) who recorded thousand kernel weight in scale from 14.00 g to 19.9 g, therefore almost under the values of this study.

5.2 Textural characteristics, mechanical characteristics and cooking properties

Additionally to physical properties observed in the rice varieties other characteristics were also studied. The category of textural characteristic contain colour analysis and for mechanical characteristic was performed grain hardness measurement. Also group of cooking properties was investigated which involved test of optimal cooking time and water uptake ratio. Those result supported and verified the previous results of physical characteristics analysis and assembles all important information in order to properly evaluate varieties from research sample.

5.2.1 Colour characteristics

Colour characteristic of all rice varieties was examined with spectro-photometer CM-600d working in the CIE system. Therefore the values for L* (lightness), a* and b* were examined respectively. CIE diagram reflect where in the spectre the certain colour situated in perspective of *L (measure of brightness from black (0) to white (100)), a** *indicates the degree of redness (+a*) to greenness (-a*) and b* is the measure of yellowness (+b*) to blueness (-b*)* (Oli et al., 2016). All the colour values were noted in Table 5 (see below).

Table 5 Colour characteristics in CIElab system

Rice cultivars	No. of measurements	L*	a*	b*
Elita K. Russia	5	69.80 (3.14)	- 0.22 (0.16)	12.24 (0.34)
Ozgen Champion	5	45.74 (1.80)	9.63 (0.20)	10.13 (0.71)
Batken	5	67.49 (1.52)	3.37 (0.23)	16.95 (0.55)
Ozgen Kakyr	5	37.58 (3.27)	9.98 (1.19)	11.11 (1.87)
Ozgen Uchuk	5	56.28 (3.53)	10.17 (0.82)	18.00 (0.97)
Pakistan	5	56.69 (1.51)	1.61 (0.46)	21.12 (1.04)
Kapchygai Kazachstan	5	72.19 (1.64)	1.94 (0.25)	12.66 (0.87)
Ozgen Cerza	5	41.79 (1.61)	9.74 (0.46)	9.65 (0.79)

The values in brackets are expression of standard deviation.

The whitest of all cultivars was measured to be Kapchygai Kazachstan with value 72.19 in the L* parameter, while it was followed by Elita Krasnodar Russia with value of L* equal to 69.80 and by Batken (like a whitest local rice) with L* 67.49. The darkest in light (but not specifically in colour) was Ozgen Kakyr with L* corresponding to 37.58. For summary, as the lightest Kyrgyz variety was found Batken and as the darkest Ozgen Kakyr (37.58), while in the group of imported varieties the lightest was Kapchygai Kazachstan and the darkest Pakistan with value 56.59.

In the parameter a* stands for scale limited with redness and greenness. In the context of research sample, the highest a* value reached Ozgen Uchuk (10.17) which puts it on the scale closest to “greenish” colour, however the value is in context still very small. The lowest a* value, therefore closest to “reddish” colour was Elita K Russia with - 0.22. All three imported cultivars has placed in the lowest a* values, thus closest to the “reddish” colour from whole sample.

According to the parameter b*, the highest value thus yellowness had rice variety Pakistan with 21.12 followed by Ozgen Uchuk with 18.00 and Batken with 16.95. On the other hand, the lowest values of parameter b* was measured by Ozgen Cerza (9.65) and Ozgen Champion (10.13).

In summary, the highest value from Kyrgyz sample of cultivars had Ozgen Uchuk and the lowest Ozgen Cerza. In non-native fragment the highest number obtained Pakistan and the lowest Elita K. Russia (12.24).

From the previous results can be concluded several observations. Firstly, it is obvious that most of the varieties (precisely 6 out of 8) have had values of lightness over 50 points, therefore we can call most of the rice “light” in colour. Also two lightest variates comes from foreign country, thus those are probably lighter than local species.

Regarding parameter a*, stand out overall result, when half of the sample group tends to be coloured more reddish and other half (4 out of 8) is pursuant to greenish colour. Consequently the final result sound that the distribution of colour (green or red tones) among all cultivars is equally divided between those two. Also, since all the imported cultivars had low values of a* parameter it could be stated, that they are in major more coloured in red tones than the local varieties, which tend more to green colour shades.

In relation to parameter b*, the results were most indistinct from all three parameters of colour determination. There was not discovered any direct influence or connection between different groups of cultivars in order to grains yellow or blue shades. Hence as the result of this parameter has been discovered that there is no direct and significant divergence amid final values of rice cultivars.

From the examined varieties three are coloured brown-reddish, respectively Ozgen Champion, Ozgen Kakyr and Ozgen Cerza, while the rest of varieties is coloured in white shades.

Several authors followed up colour characteristic of the rice – from them Deepa et al. (2007) described the colour of cultivars only verbally and Ravi et al. (2014) measured the colours in percentage. The others add also values in the CIElab system which could be compared with the results of this study.

Oli et al. (2015) was describing three varieties of milled rice grown in Australia. The colour values were (L*, a* and b* values respectively) 74.66, -0.17 and 16.63 for Reiziq variety and 74.82, -0.33 and 17.31 as the average colour characteristic from both low and high head rice yield of Sherpa variety. Also Lambert et al. (2007) was measuring various de-husking states of rice and its effect on rice colour, while the milled rice had colour values approximately (L*, a* and b* respectively) 58.7, 5.1 ad 24.3.

Smanalieva et al. (2015) measured the colour during the analysis of Ozgen rice in her study. Her results (L* - 66.04, a* - 10.76, b* - 20.09) are similar to values of Ozgen Uchuk in this study, therefore possibly it could be one of the cultivars included by Smanalieva.

The CIE lab values measured on brown rice by Mir et al. (2013) differ from the one we measured. The reason could be clearly the difference between milled and brown rice which is mainly in colour spectre. According to L* values were the results quite similar, except the Ozgen varieties Champion, Kakyr and Cerza. However in the other two values – a* and b* did not meet any similarity with varieties from this study.

Shittu et al. (2012) also measured colour characteristics of brown rice though the values were different from the one recorded in this study. Only exception made Kapchygai Kazakstan which had similar CIE lab values with rice cultivar WAB 189 from Shittu´s study.

The colour of rice is an important sensory parameter. Generally, the whiter the milled rice, the more value it has in the market place (Marshal and Wadsworth, 1994). However as the literature review of this thesis found out, in Kyrgyzstan are actually more valued coloured varieties of Ozgen rice for its supposedly better taste.

5.2.2 Grain hardness

Rice hardness is one of the most important quality parameters, which define storage quality, cooking behaviour and also customer preference. Harness of grain has been measured, while all data was recorded and later on analysed.

As could be seen in Figure 24, results of this measurement are relatively divergent. The extreme values in this analysis are fluctuating from 63.47 N (Batken, average value from twenty repetition) to 155.50 N at Ozgen Cerza, which means the difference between bottom value and upper value shows almost 245 % increase in hardness. That is quite unusual considering that large heterogeneity was recorded even within the groups of local and imported varieties.

Regarding Kyrgyz varieties, the top value of hardness was recorded at Ozgen Cerza (155.50 N) and the lowest at Batken (63.47 N). As is shown in Figure 19 and has been mentioned above, those varieties are as well the extremes in the research sample.

In the imported rice cultivars reached the highest hardness Pakistan with 130.28 N and the lowest hardness got Elita Krasnodar Russia with 66.85 N.

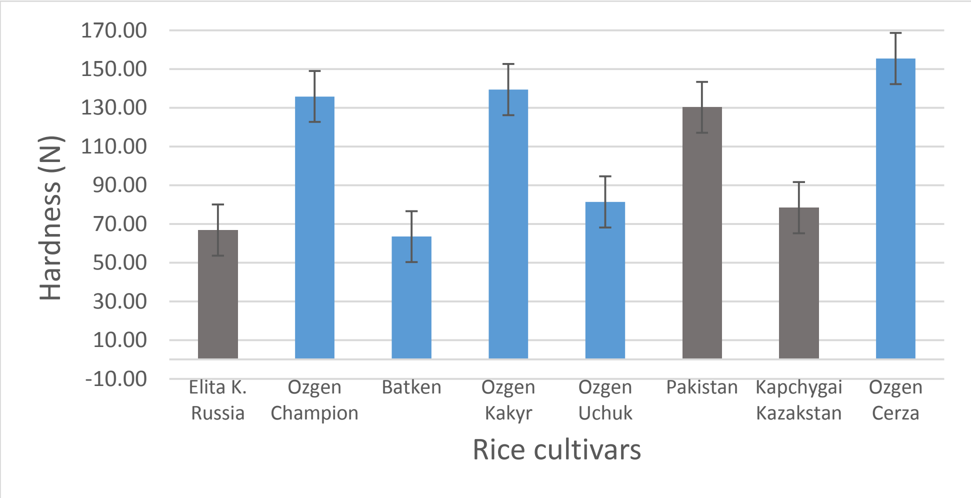


Figure 24 Grain hardness

The overall result of the hardness measurement showed that there is no direct linkage between hardness and origin of eight milled rice cultivars present in the research sample. In Kyrgyz segment, relatively similar hardness shared three Ozgen varieties (Ozgen Champion, Ozgen Kakyr and Ozgen Cerza) while the last Ozgen (Ozgen Uchuk) and Batken cultivar kept its values sizable lower.

In the imported varieties were two cultivars (Elita K. Russia and Kapchygai Kazachstan) shifting around proximately 66 – 78 N while the last cultivar Pakistan overcame them largely with 130.28 N.

Similar results recorded Fofana et al. (2011) with rice hardness range from 59 N to 122 N and Mir et al. (2013) with range from 72.99 N to 133.48 N. In both cases the range of results was lower than in this study but as well both are covered by the range recorded in this study. Another authors mentioned rice hardness however they were measuring hardness of already cooked rice, thus the values cannot be compared.

Also the hardness recorded by this study was quite diverse thus it is difficult to compare such a large range of values with no clear pattern. The variation in the hardness could be caused by different compact arrangement of the starch granules in the centre of the kernel. The hardness values are also important for classification of the rice varieties and the yield protection against degradation during milling, transportation or due to pests and insects (Mir et al., 2013).

In terms of the classification we can claim that the Ozgen cultivars, popular by local people, have the top hardness from the examined varieties while also Pakistan variety reach high values (with exception of Ozgen Uchuk which hardness compared to other Ozgen cultivars is rather low).

5.2.3 Optimum cooking time

Determination of cooking time of the rice varieties is one of two cooking characteristics examined during this study. Cooking time is very important information in relation to consumer preferences and also certain types of rice cultivars and their utilization.

Figure 25 shows bellow summary of optimal cooking times of all cultivars. The outer borders of this measurement results belong to Ozgen Uchuk (with 33 minutes) and to Batken (with 19.33 minutes) which makes the difference between the extremes over 13 minutes.

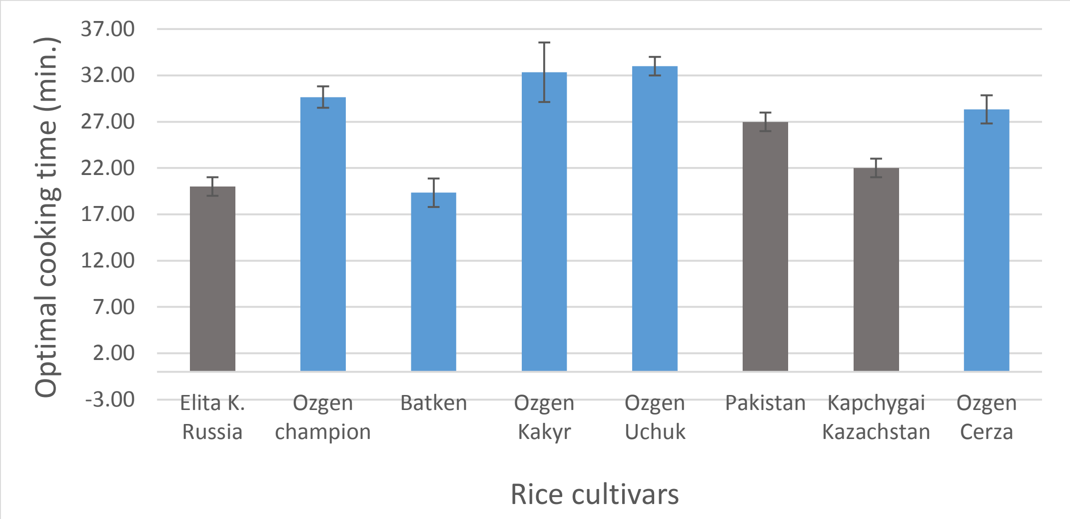


Figure 25 Optimal cooking time

In the Kyrgyz traditional varieties group keeps the average cooking time around 30 minutes with one exception of Batken cultivar, which has the shortest cooking time both from local and imported cultivars (19.33 min.). The longest optimal cooking time holds Ozgen Uchuk with 33 min. Therefore both end values are from the traditional cultivars.

Imported varieties are generally shorter in optimal cooking time, when shortest cooking demands Elita Krasnodar Russia (20 min.) and the longest Pakistan (27.00 min.).

In general, the local Kyrgyz varieties of rice tends to have longer optimal cooking time compared to three imported varieties. This resemble with their larger grain dimension, which cause fuller body of the rice and thus longer cooking time as well. Cooking time is although dependent on other parameters (chemical composition, structure of kernel etc.).

According to Yadav and Jindal (2007) the cooking process is an important operation done in order to provide softness and accessibility of the rice kernels for direct eating. The length of cooking and final texture of the rice kernels is crucial for customers to select the optimal variety for their consumption. Therefore the optimal cooking time results can sort varieties from sample of this study into several categories according to the time of cooking. As was stated in the article by Singh et al. (2005), the main factors affecting variations in cooking quality of rice are genetic and environmental.

Since the differences between imported and local Kyrgyz varieties are significant, the results will be compared respectively to this frame. Similar results to optimal cooking time of Kyrgyz varieties (with exception of Batken) measured Deepa et al. (2007) who got results in range of 30 to 38 minutes. Also Jinorose et al. (2014) measured average cooking time of rice around 30 minutes, which agree with results of this study. Quite similar results as imported varieties grown in Kyrgyzstan found Fofana et al. (2011) with range of cooking time from 17 to 26 minutes (compared to 20 – 27 minutes of imported varieties of this study).

The other authors measured slightly lower cooking times, which can be dependent on smaller dimensions of the rice grains and also on different inner structure and chemical composition. Mohapatra and Bal (2006) measured range of 14 till 24 minutes for cooking the rice, Singh et al. (2005) had even lower bottom line of values with 13.3 minutes till 24 minutes, Meena et al. (2010) recorded optimal cooking time of 15 – 20 minutes and Ravi et al (2014) measured optimal average cooking time about 21.5 minutes.

5.2.4 Water uptake ratio

Water uptake measurement was involved in the set of analysis, since it pictures other textural characteristic according to rice rather than simply cooking. While in many nations, including Kyrgyz one, rice is traditionally soaked in water for several minutes to hours in order to improve its cooking and sensory quality and behaviour.

The water uptake ratio was registered for three temperatures – 30 °C, 45 °C and 60 °C, all in two time segments – 30 minutes and 60 minutes. The summary of the results is shown in Figure 26 (for 30 minutes soaking) and in Figure 27 (60 minutes soaking).

The results of this measurement were quite unexpected. In the first part, where rice was soaked for 30 minutes at different temperatures could be observed significant difference between behaviour of Pakistan rice and all the other varieties. In the conditions of rising temperatures and stable time of soaking, the Pakistan and Ozgen Kakyr was the only cultivar which reacted with steadily increasing amount of water uptake (Figure 26). The increase in the WUR at Pakistan showed high coefficient of determination (see Annex 6). On the contrary the rest of cultivars behaved considerably different, when they all (with exception of Ozgen Kakyr) decreased in water uptake ratio at 45 °C and again rise (with exception of Ozgen Champion) at 60 °C but only to the level of 30 °C values or slightly above that. In this measurement the local as well the imported varieties behaved quite similar with exemption of Pakistan, which greatly stand out from the test sample with its absorption characteristics.

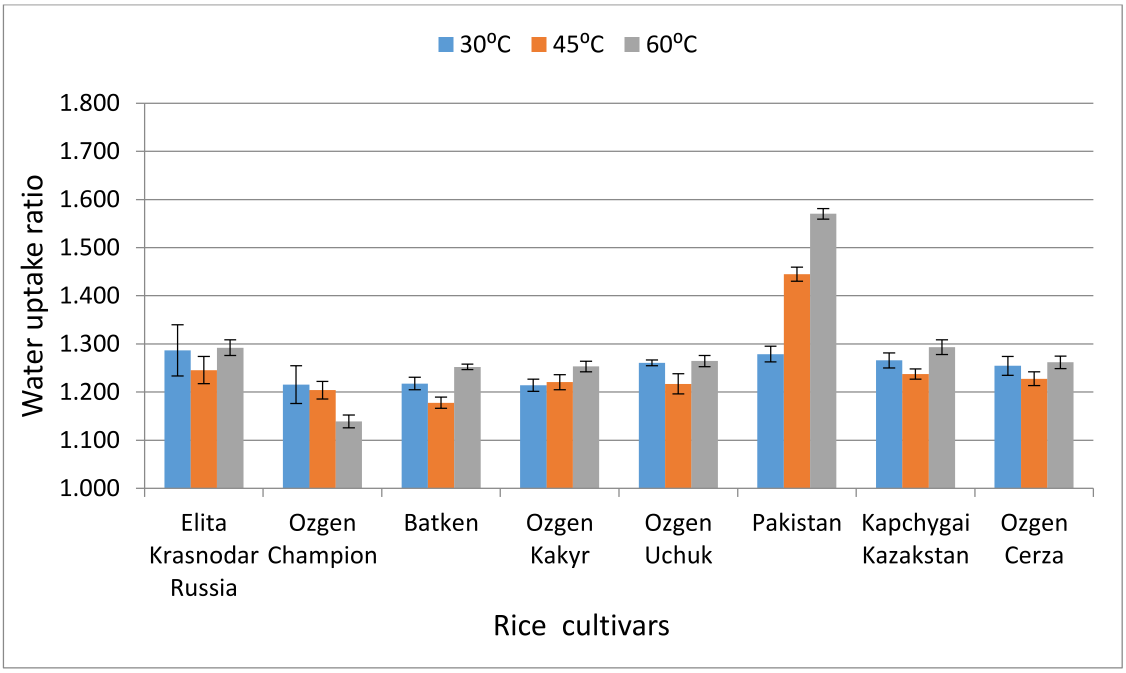


Figure 26 Water uptake ratio (30 minutes)

The summary of results from this measurement is that the varieties except Pakistan do not uptake significantly more water with increasing temperature at levels 30 °C – 45 °C – 60 °C and contrary they decrease in soaking at 45 °C. The exception made Pakistan imported variety, which up took steady amount of water with increasing temperature and some divergence showed also Ozgen Kakyr (local variety) which also up took steadily increasing amount of water with high coefficient of determination (see Annex 4), and Ozgen Champion (local variety) which conversely up took gradually less and less water with increasing temperature with also high coefficient of determination (see Annex 2).

In the measurement with longer time period of soaking, 60 minutes, the results were actually similar, with slightly larger water uptake ratio values (Figure 27). Again the Pakistan was the cultivar with highest reaction to water soaking and also with the highest WUR, which was equally increasing with coefficient of determination almost equal to 1 (see Annex 6). Ozgen Kakyr, from the Kyrgyz cultivars, also soaked the water in equally increasing way, thus in much smaller volume than Pakistan. In this measurement Ozgen Champion showed large increase on 45 °C level, therefore was not anymore equally decreasing like in measurement of 30 minutes soaking. The other cultivars, local and non-local behaved similar to performance in Water uptake ratio – 30 minutes (Figure 26) only with slightly higher values of WUR.

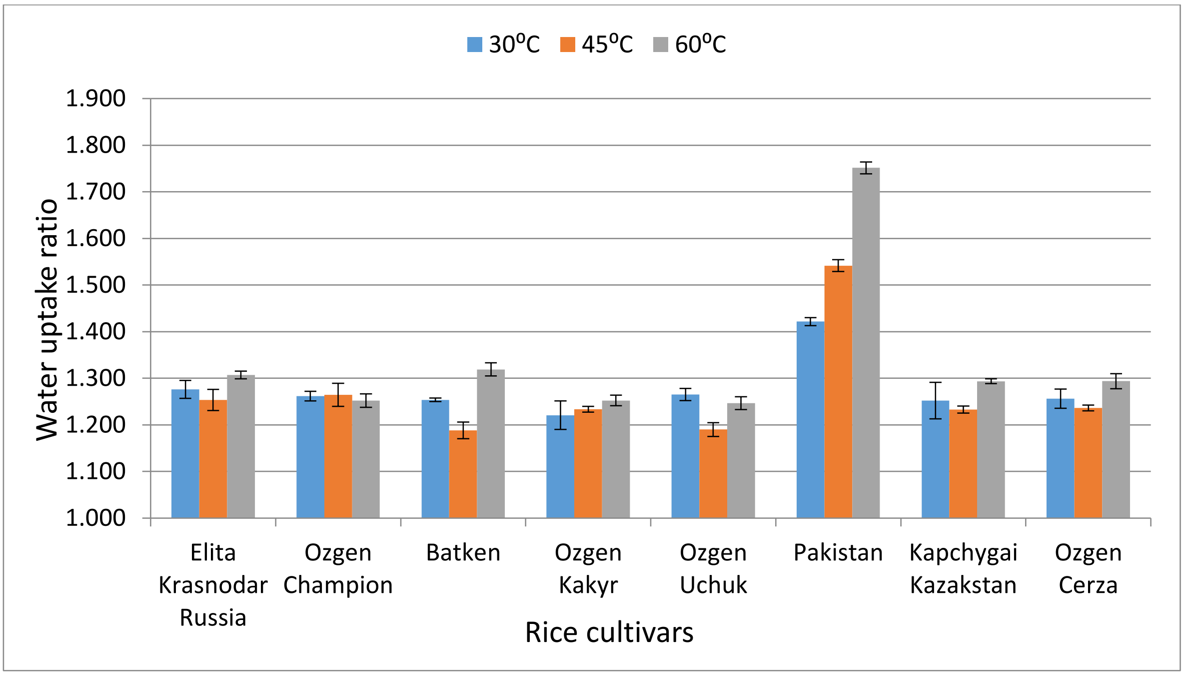


Figure 27 Water uptake ratio (60 minutes)

Water uptake ratio was measured by several authors (Fofana et al., 2011; Mohapatra and Bal, 2006; Singh et al., 2005; Mizuma et al., 2008; Yadav and Jindal, 2007; Meena et al., 2010 and Thakur and Gupta, 2006) however many of them performed the measurement with different methodology from this thesis. Many authors (Mohapatra and Bal, 2006; Singh et al., 2005; Yadav and Jindal, 2007; Fofana et al., 2011 and Meena et al., 2010) established water uptake ratio at 100 °C and just the time was various.

Only Shittu et al. (2012) used also similar temperatures (30 °C, 45 °C and 60 °C) for his water uptake ratio measurement. The collective also measured unusual behaviour of rice at 45 °C which they attribute to *some microstructure details that are yet to be studied for the different rice varieties.* Nevertheless the results of their study showed gradually increasing values with increasing temperature unlike this study. Yet Shittu et al. recorded some non-typical behaviour of rice as well. *Unusual reduction in hydration* *rate was observed with paddy rice of ITA 150, ITA 301, and WAB 450 as soaking temperature was increased from 45°C to 60°C. The reduction in hydration rate may be partly due to slight swelling of the grains which could have led to decrease in porosity of the material and consequently, reduction in water absorption rate.*

The water uptake in this study didn't showed large increase between 30 minutes and 60 minutes therefore we can assume that the main factor influencing water uptake is temperature rather than time. Also the temperature levels used in this study (30 °C, 45 °C and 60 °C) were probably sufficient to model the pre-cooking rice soaking, however with an emphasis to the results of this measurement those temperatures are too low to show significant increase in water uptake ratio.

The information about the texture of final product is also one of the outcomes of WUR measurement. According to Mohapatra and Bal (2006) *rice with higher water binding capacity normally yields soft textured cooked product,* opposite to the lower binding where the grains remains more firms and structured. As the result we can claim, that the Kyrgyz rice is after cooking staying more firm and therefore probably more suitable for the local traditional dish Plov compared to imported variety of Pakistan, which end up in soft textured product with different use in the national cuisine.

Since the rice for completed water uptake after cooking absorb approximately 2.5 times its initial weight (Battacharya, 2011), we can observe that the measurement of WUR where the weight of initial sample of rice increased approximately up in 0.25 value of the initial weight. Thus we can conclude that the temperature and time were not sufficient in in terms of complete water uptake process.

6 Conclusions

This study represents extensive collection of information on physical properties of rice cultivars grown and consumed in Kyrgyzstan, Central Asia. The research had shown that the physical properties, texture characteristics and cooking characteristics among all cultivars differ significantly. The broad variation applied to grain length and shape (from medium to long and from bold to slender) which is particularly important information for designing milling machinery and all kinds of optimization in the post-harvest operations (handling, processing and packaging) while avoiding any loses and damage. According to grain dimensions and physical characteristics (equivalent diameter, surface area and volume) had been proven that varieties with non-native origin differ greatly from the traditional Kyrgyz varieties and in all those parameters they showed significantly lower values.

The sphericity, aspect ratio, solid density and porosity showed results with wide range of values however in comparison between local and imported group of cultivars could not been declared any assumptions since the values showed non consistent patterns.

The imported varieties had significantly higher values in measurement of bulk density which confirmed the lower values of grain dimensions. At the same time the thousand kernel weight resulted in clear pattern where local cultivars reached upper level in weight of their kernels. Colour of the grain was estimated based on CIE lab system and the hardness established showed wide range of recorded values (63.47 – 155.50 N) however neither one of the cultivar sections was dominant in the test. Those information are useful for discovering the suitable use for each cultivar.

Optimal cooking time showed that imported varieties needed lower interval for full grain cooking compared to the local Kyrgyz varieties. Water uptake ratio came up with results strictly separating the soaking characteristics of Pakistan rice from the rest of varieties.

The rice grain characteristics obtained by this study are important for the producers and consumers in Kyrgyzstan and will provide a guidance in terms of breeding, processing and retail of those rice varieties.

7 References

Akramov KT, Omuraliev N. 2009. Institutional Change, Rural Services and Agricultural Performance in Kyrgyzstan. Washington DC: IFPRI. 1-29.

Battacharya KR. 2011. Rice Quality: A Guide to Rice Properties and Analysis. Woodhead Publishing Limited, UK. 431-526.

Calpe C. 2006. Rice International Commodity Profile. Food and Agriculture Organization of the United Nations, Markets and Trade Division. 2-23.

De Datta SK. 1981. Principles and Practices of Rice Production. Los Baños, Philippines: The International Rice Research Institute, 1-4.

De Martino L, Carlsson A, Rampolla G, Kadyrzhanova I, Svedberg P, Denisov N, Novikov V, Rekacewicz P, Simonett O, Fernandez SJ, del Pietro D, Rizzolio D, Palosaari M. 2005. Environment and Security - Transforming Risks into Cooperation: Central Asia Ferghana/Osh/Khujand area. Nairobi, New York, Vienna and Brussels: UNEP, UNDP, OSCE and NATO. 1 -56.

Deepa G, Singh V, Naidu KA. 2008. Nutrient composition and physicochemical properties of Indian medicinal rice – Njavara. Food Chemistry 106: 165–171.

Devkota KP. 2011. Resource utilization and sustainability of conservation-based rice-wheat cropping systems in Central Asia. The University of Bonn, the Faculty of Agriculture. Dissertation thesis: 1-26.

Díaz EO, Kawamura S, Koseki S. 2015. Physical properties of rough and brown rice of Japonica, Indica and NERICA types. Agricultural Engineering International: CIGR Journal, Special issue 2015 - 18th World Congress of CIGR: 274-285.

Dzunusova M, Mammadov A, Apasov R. 2008. Country Report on the state of plant genetic resources for food and agriculture – Kyrgyzstan. FAO, Bishkek: 4-48.

Ezilon Maps. Not dated [online]. Available at http://www.ezilon.com/maps/asia/kyrgyzstan-maps.html (accessed on 12 March, 2016).

FAO. Not dated [online]. Available at http://www.fao.org/countryprofiles/index/en/ (accessed on 15 January, 2016)

FAOSTAT. Not dated [online]. Available at http://www.faostat3.fao.org (accessed on 6 February, 2016).

Fernando B. 2013. Rice as a source of fibre. Journal of Rice Research 1 (2): 1-4.

Fitzgerald MA, McCouch SR, Hall RD. 2008. Not just a grain of rice: the quest for quality. Trends in Plant Science Vol.14 No.3.: 133-139.

Fitzherbert A.R. 2000. Country Pasture and Forage Resources Profiles, [online]. FAO, Available at http://www.fao.org/ag/AGP/AGPC/doc/Counprof/kyrgi.htm (accessed on 2 March, 2016).

Fofana M, Futakuchi K, Manful JT, Bokossa Yaou I, Dossou J, Bleoussi RTM. 2011. Rice grain quality: A comparison of imported varieties, local varieties with new varieties adopted in Benin. Food Control 22: 1821-1825.

Fraser BM, Verma SS, Muir WE. 1978. Some physical properties of fababeans. Journal of Agricultural Engineering Research 23: 53-57.

Gepts P. 2004. Crop domestication as a long-term selection experiment. Plant Breeding Reviews. 24: 1–44.

GRiSP (Global Rice Science Partnership). 2013. Rice almanac, 4th edition. Los Baños (Philippines): International Rice Research Institute: 22-103.

Haard NF, Odunfa SA, Lee C, Quintero-Ramirez R, Lorence-Quinones A, et al. 1999. Fermented Cereals: A global perspective. Food and Agriculture Organisation of the United Nations. Agricultural Services Bulletin 130: 1-25.

IRRI (International Rice Research Institute). Not dated [online]. Available at http://www.irri.org (accessed on 10 January 2016).

Jain RK, Bal S. 1997. Properties of Pearl Millet. Journal of Agricultural Engineering Research 66: 85 – 91.

Jinorose M, Prachayawarakorn S, Soponronnarit S. 2014. A novel image-analysis based approach to evaluate some physicochemical and cooking properties of rice kernels. Journal of Food Engineering 124: 184–190.

Juliano BO. 1993. Rice in Human Nutrition. Food and Agriculture Organization of the United Nation, International Rice Research Institute, Rome: 1-101.

Kalb T.J., Mavlyanova R.F. 2005. Vegetable production in Central Asia: status and perspectives. Proceedings of the workshop, 13–14 June 2003, Almaty, Kazakhstan, 89–93.

Khush GS. 1997. Origin, dispersal, cultivation and variation of rice. Plant Molecular Biology 35: 25–34.

Kochkunov A. 2010. The Ritual of Hospitality in Traditional and Modern Kyrgyz Culture. Anthropology of the Middle East, Vol. 5, No. 2: 36–58.

Kolov O. 1998. Ecological Characteristics of the Walnut-Fruit Forests of Southern Kyrgyzstan. Blaser J, Carter J, Gilmour D editors. Biodiversity and Sustainable Use of Kyrgyzstan's Walnut-Fruit Forests. English Version. IUCN, Intercooperation Gland, Cambridge, Bern: 59–61.

Kovach MJ, Sweeney MT, McCouch SR. 2007. New insights into the history of rice domestication. TRENDS in Genetics 23 (11): 579-587.

Kwarteng EA, Ellis WO, Oduro I, Manful JT. 2003. Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. Food Control 14: 507–514.

Lamberts L, De Bie E, Vandeputte GE, Veraverbeke WS, Derycke V, De Man W, Delcour JA. Effect of milling on colour and nutritional properties of rice. Food Chemistry 100: 1496–1503.

Mamatov NE, Cusupov MK, Raimcanov B. 2007. Water resources problems in Kyrgyzstan. International Congress on River Basin Management: Practices on River Basin Management: 171-179.

Marshall WE, Wadsworth JI. 1994. Rice: Science and technology. New York: Marcel Dekker, Inc.: 125 – 176.

Meena SK, Vijayalakshmi D, Ravindra U. 2010. Physical and cooking characteristics of selected aromatic rice varieties. Journal of dairying, foods & home sciences, 29 (3/4): 227 – 231.

Mir SA, Bosco SJD, Sunooj KV. 2013. Evaluation of physical properties of rice cultivars grown in the temperate region of India. International Food Research Journal 20(4): 1521-1527.

Mitchell L. 2015. Kyrgyzstan. The Globe Pequot Press Inc., USA: 9-48.

Mizuma T, Kiyokawa Y, Wakai Y. 2008. Water Absorption Characteristics and Structural Properties of Rice for Sake Brewing. Journal of Bioscience and Bioengineering Vol. 106, (3): 258–262.

Mohaparta D, Bal S. 2006. Cooking quality and instrumental textural attributes of cooked rice for different milling fractions. Journal of Food Engineering 73: 253–259.

Mohsenin NN. 1986. Physical properties of plant and animal materials (2^{nd} edition). New York: Gordon and Breach: 22-127.

Oli P, Ward R, Adhikari B, Torley P. 2016. Colour change in rice during hydration: Effect of hull and bran layers. Journal of Food Engineering 173: 49-58.

Pelkmans M. 2007. ‘Culture’ as a tool and an obstacle: missionary encounters in post-Soviet Kyrgyzstan. Journal of the Royal Anthropological Institute 13: 881-899.

Ravi U, Menon L, Madhavan R, Priyadharshini S, Dhivya ME. 2014. Determination of quality characteristics of indigenous organic Asian Indian rice variety - *Neelam samba* Agricultural Science Digest 34 (3) : 177 – 182.

Ricipedia. Not dated [online]. Available at http://www.ricepedia.org (accessed on 15 February 2016).

Se CH, Khor BH, Karupaiah T. 2015. *Prospects in development of quality rice for human nutrition.* Malaysian Applied Biology, 44 (2): 1-31.

Shittu TA, Olaniyi MB, Oyekanmi AA, Okeleye KA. 2012. Physical and Water Absorption Characteristics of Some Improved Rice Varieties. Food Bioprocess Technol 5: 298–309.

Shobana S, Kokila A, Lakhsmipryia N, Subhashini NS, Ramya Bay M,Mohan V, Malleshi NG, Anjana RM, Henry CJK, Sudha V. 2012. Glycaemic index of three Indian rice varieties. International Journal of Food Sciences and Nutrition, 63(2): 178–183.

Singh N, Kaur L, Sodhi NS, Sekhon KS. 2005. Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. Food Chemistry 89: 253–259.

Smanalieva J, Salieva K, Borkoev B, Windhab EJ, Fischer P. 2015. Investigation of changes in chemical composition and rheological properties of Kyrgyz rice cultivars (Ozgon rice) depending on long term stack-storage after harvesting. LWT – Food Science and Technology, 63: 626-632.

Thakur AK, Gupta AK. 2006. Water absorption characteristics of paddy, brown rice and husk during soaking. Journal of Food Engineering 75: 252–257.

United Nations. 2016. UN Data: Kyrgyzstan. Available at http://data.un.org/CountryProfile.aspx?crName=Kyrgyzstan: Accessed: 2016-01-03.

Varnamkhasti MG, Mobli H, Jafari A, Keyhani AR, Soltanabadi MH, Rafiee S, Kheiralipour K. 2008. Some physical properties of rough rice (Oryza Sativa L.) grain. Journal of Cereal Science 47: 496–501.

Vlkova M, Verner V, Kandakov A, Polesny Z, Karabaev N, Pawera L, Nadvornikova I, Banout J. 2015. Edible plants sold on marginal rural markets in Fergana valley, southern Kyrgyzstan. Bulgarian Journal of Agricultural Science, 21 (No 2): 243–250.

World Bank. 2016. Data: Kyrgyz Republic. Available at http://data.worldbank.org/country/kyrgyz-republic: Accessed 2016-02-10.

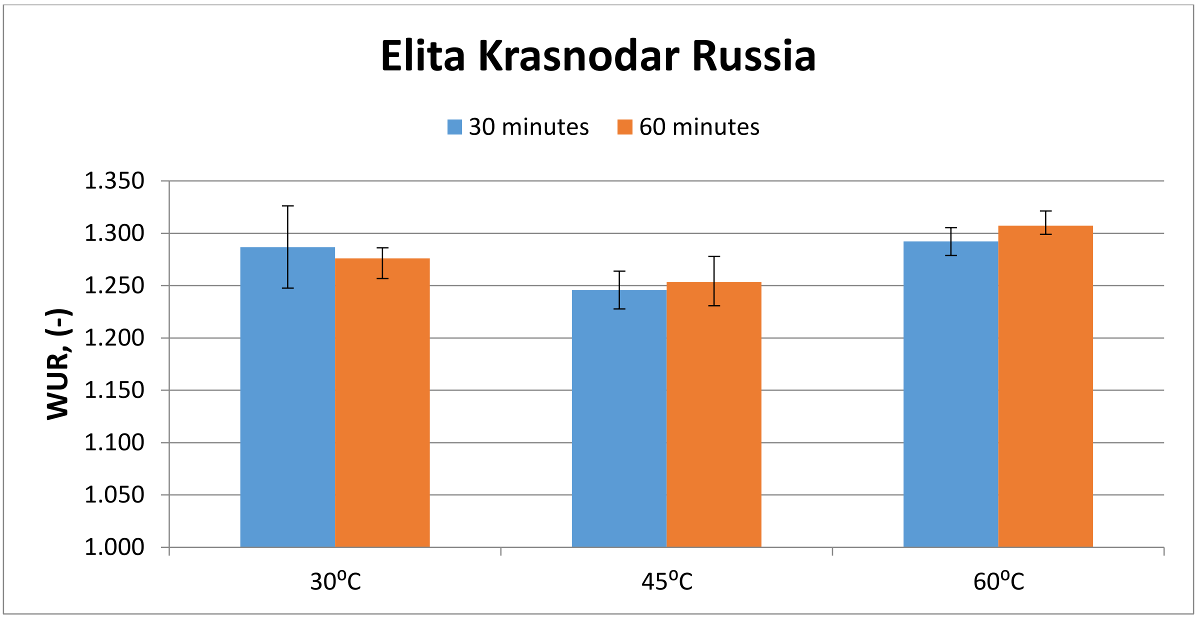
Yadav BK, Jindal VK. 2007. Water uptake and solid loss during cooking of milled rice (Oryza sativa L.) in relation to its physicochemical properties. Journal of Food Engineering 80: 46–54.

Zanca R. 2003. Take! Take! Take! Host-Guest Relations and All that Food: Uzbek Hospitality Past and Present. Anthropology of East Europe Review: 8-16.

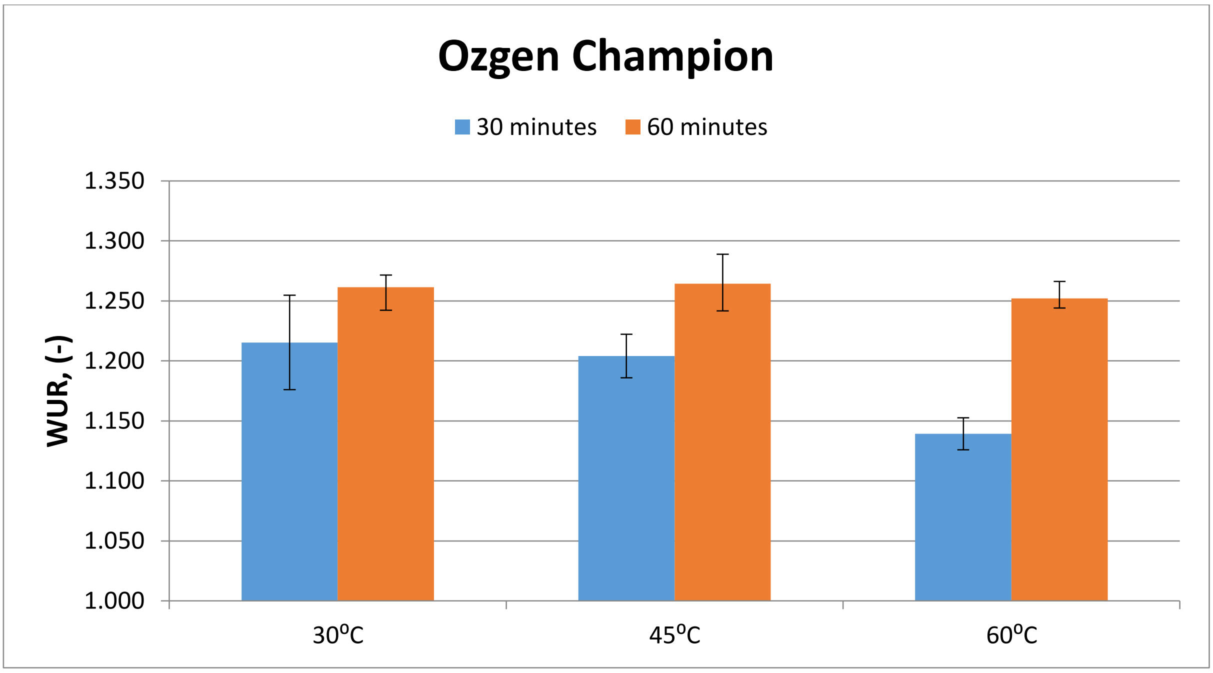
Zhang G, Malik VS, Pan A, Kumar S, Holmes MD, Spiegelman D, Lin X, Hu FB. 2010. Substituting Brown Rice for White Rice to Lower Diabetes Risk: A Focus-Group Study in Chinese Adults. Journal of the American Dietetic Association 110: 1216-1221.

List of Annexes

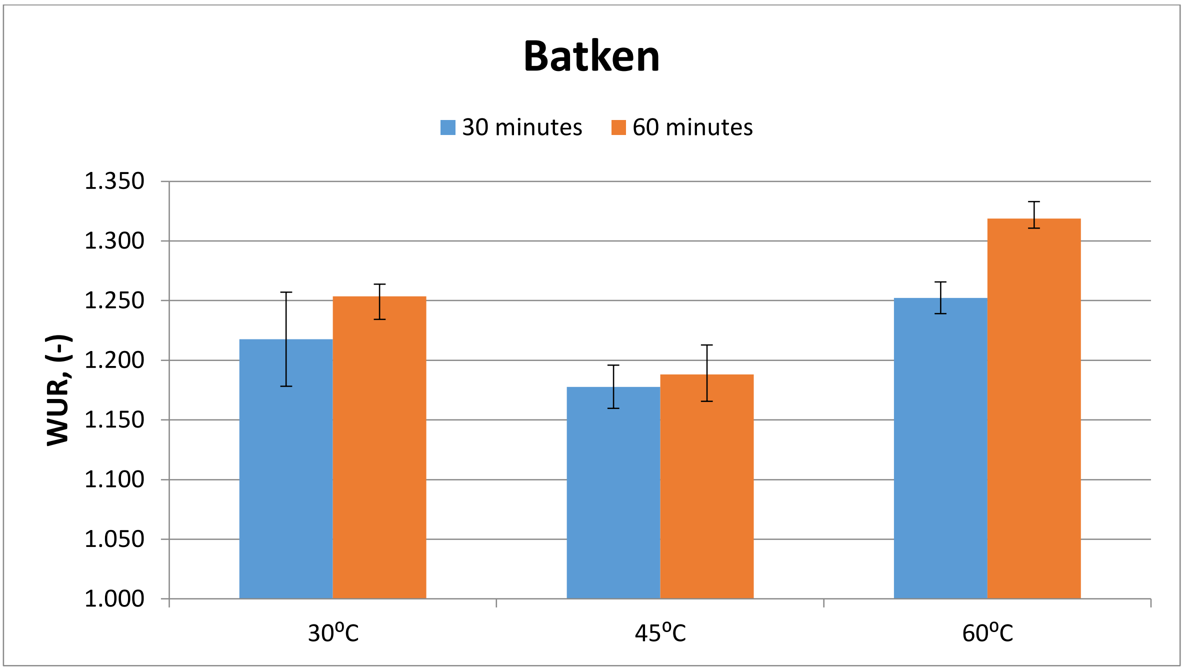
Water uptake ratio graphs of each variety



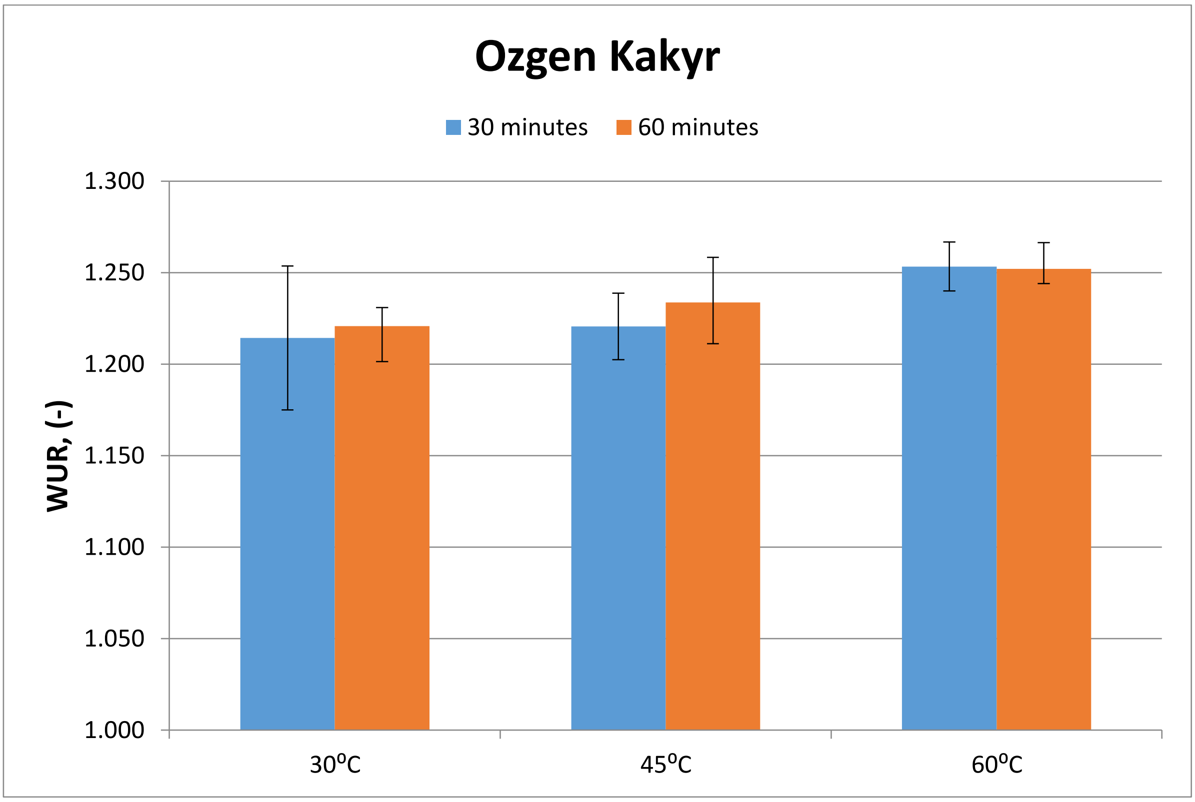
Annex 1 WUR of Elita Krasnodar Russia



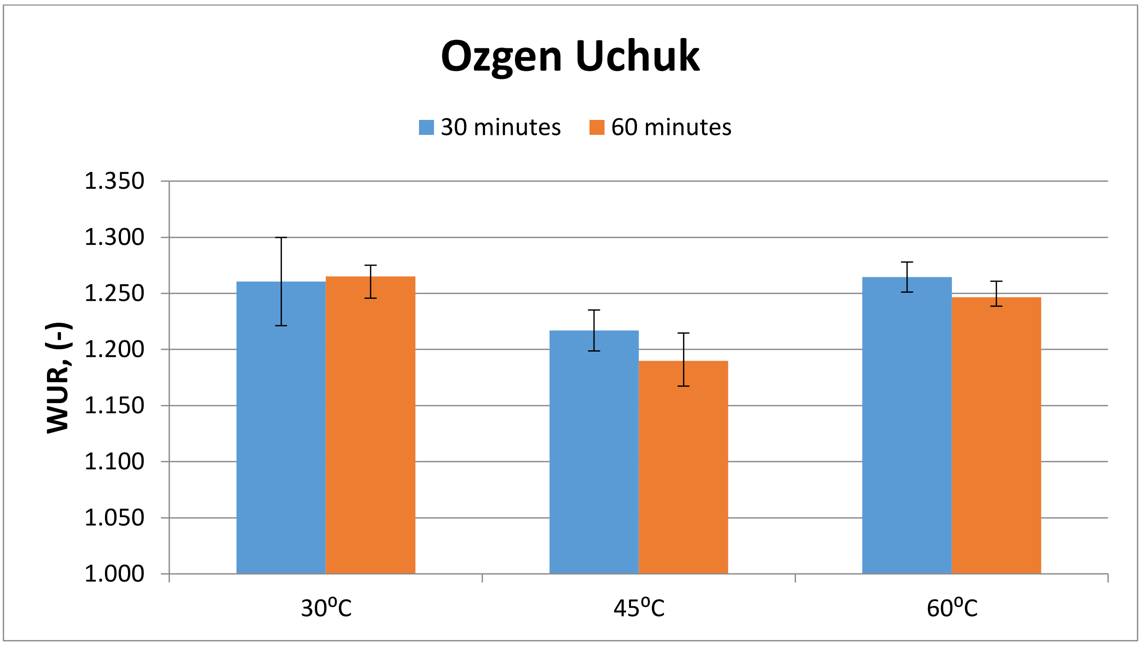
Annex 2 WUR of Ozgen Champion



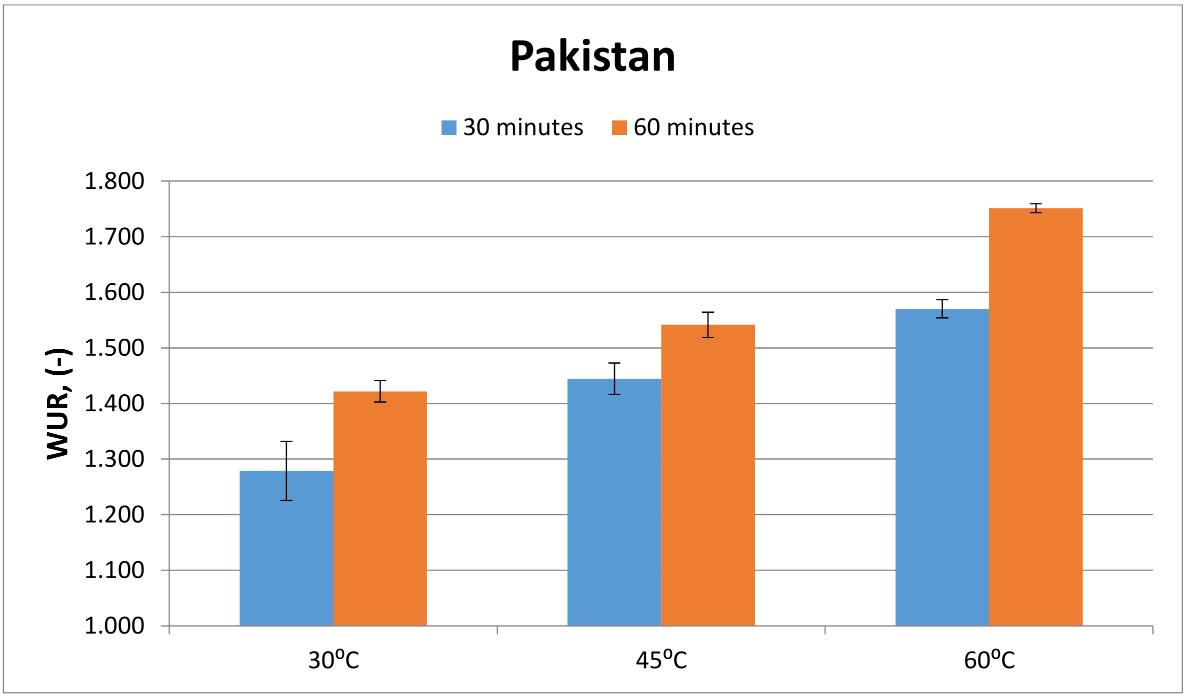
Annex 3 WUR of Batken



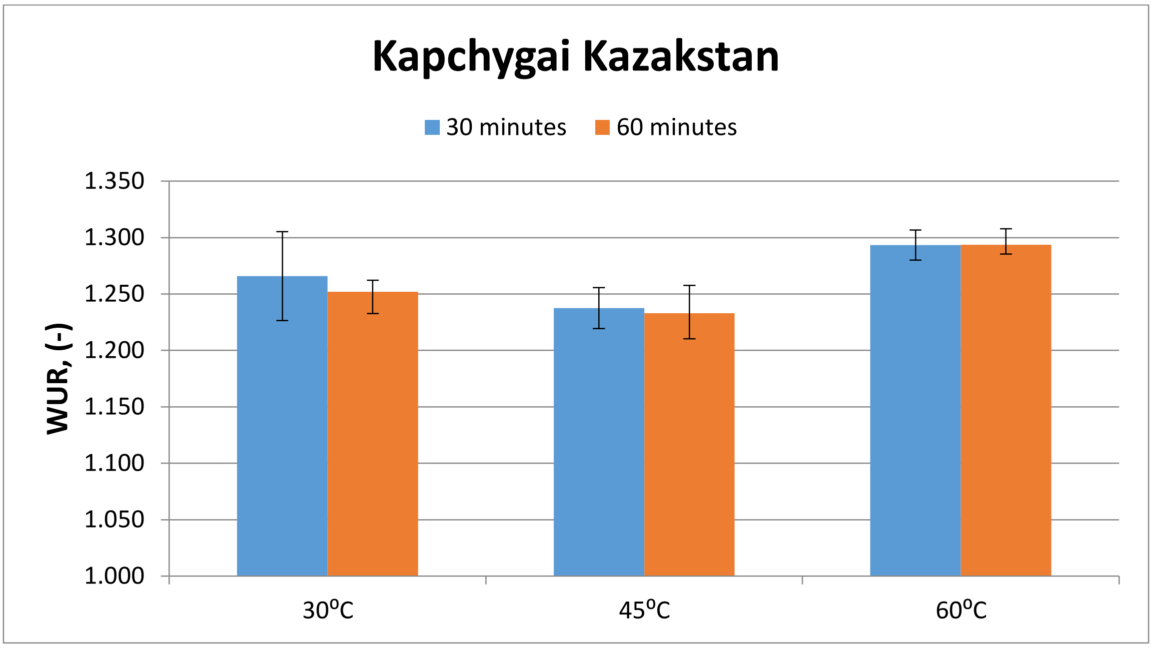
Annex 4 WUR of Ozgen Kakyr



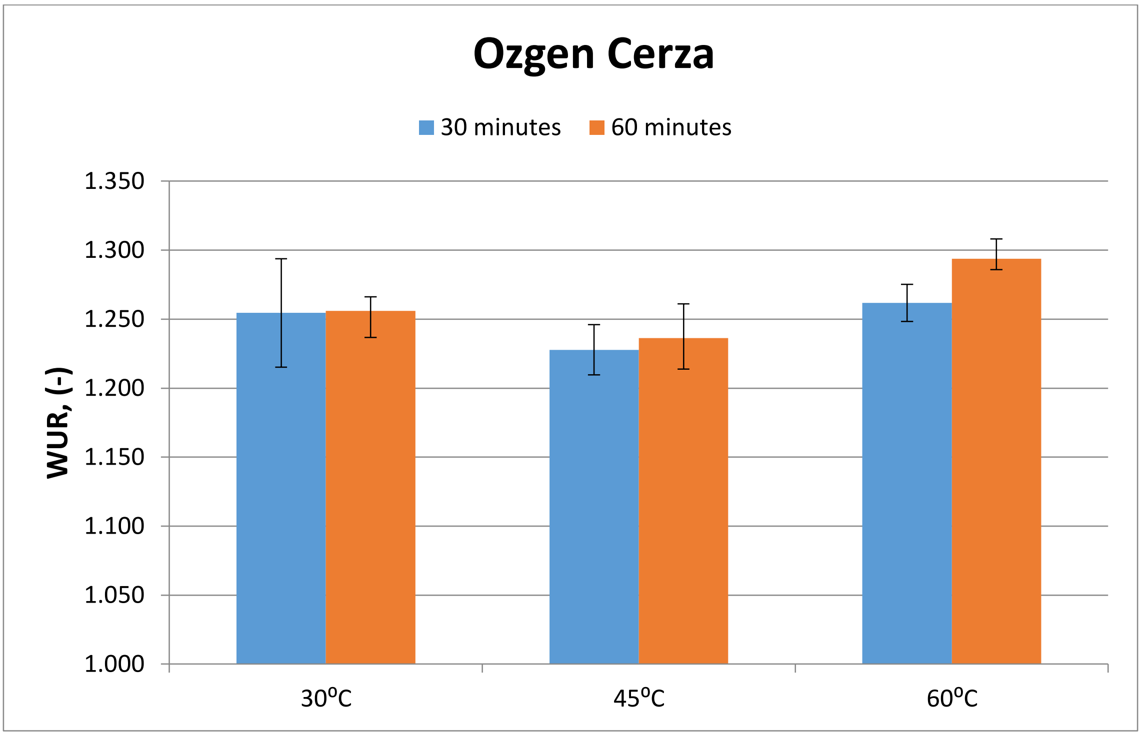
Annex 5 WUR of Ozgen Uchuk



Annex 6 WUR of Pakistan



Annex 7 WUR of Kapchygai Kazakstan



Annex 8 WUR of Ozgen Cerza

Annex 9. Pictures of cultivars

Elita Krasnodar Russia

Ozgen Champion

Batken

Ozgen Kakyr

Ozgen Uchuk

Pakistan

Kapchygai Kazakstan

Ozgen Cerza