Physicochemical Characterization of some Italian rice varieties

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Abstract
The physicochemical, cooking and eating properties of eleven rice cultivars grown in Italy were evaluated. Variations existed in grain dimensions, and the rice grains were classified (according to Italian legislation) as round, medium, long A, long B. The chemical analysis was done to determine the proximate composition as main determinants of cooking quality. The proximate composition results indicated that protein and lipid contents ranged from 6.08 to 9.68 and 0.21 to 0.40 respectively (for milled rice). The gel-time of milled rice from different cultivars varied from 17’15’’ (Carnise) to 24’56” (Ronaldo). CRLB1, Fragrance and Tigre varieties had the highest amylose content, while Cerere and Ronaldo presented the lowest amylose content. The content of amylose is correlated to texture properties, in particular with hardness and stickiness: stickiness is negatively correlated with amylose content with a R² of 0.93, however hardness is positively correlated with R² of 0.94.

The differences in the physicochemical properties could be used to determine the end use of these rice cultivars.

Keywords: rice, amylose content, rice texture, gelatinization time, chalkiness.

Introduction
Rice (Oryza sativa) is a member of Graminaceae family. It is a plant with ancient cultivation, native to South-east Asia. Along with wheat and corn, it is an important source of energy for sustaining the world’s population; rice is the staple food for more than half the world’s population providing more than one fifth (20%) of the total calories consumed worldwide by humans (Ferrero et al., 2008). FAO estimates that nearly 3 billion people share the culture, traditions and potential of rice, in the different parts of the world. To date, Italy is one of the most important producer of rice in Europe (about 1 520 000 tons in the agricultural season 2015/16 – Losi) and Italian rice is considered a high-quality product (1/3 consumed and 2/3 exported).

In Italy there are more than 180 different rice varieties which are submitted to special legislation (Italian National Register of Varieties). All of them should be peculiar in agronomical and/or physicochemical and structural features to be registered as new rice variety.

In order to avoid confusion in consumers, the different rice varieties are classified according to similar characteristics in the annual Decree (DM October 1, 2015) that establishes the rules of marketing by specific denomination. The established
groups are: Comune or Originario, Semifino, Fino and Superfino. Inside them there are some subgroups in which some varieties are identified as reported on the label of rice package. Italian tradition may include typical varieties according to specific preparations: Selenio and Balilla (for soups and puffed rice); S. Andrea, Baldo, Carnaroli, Volano, Arborio, Loto and Roma (for the preparation of risotto); Gladio and Thaibonnet (for salads or to be subjected to parboiling process).

In rice, quality traits encompass physical appearance, cooking and sensory properties, and nutritional value. The value of each trait, like length of the grain, varies according to local cuisine and culture. Predictable expression of these traits across seasons and years gives a cultivar its reputation (Chavez-Murillo et al., 2011).

Rice is commonly consumed as milled or white rice, which is produced by removing the hull and bran layers of the rough rice kernel in dehulling and milling processes, respectively. The rice milling operation involves dehulling (removal of hulls from rough rice kernels) to give brown rice, and milling (removal of bran from brown rice).

There are a few properties that characterize rice kernels: amylose content, biometrics value (length and width of kernel), texture properties (hardness and stickiness) and gelatinization time.

In Italy there is a specific organization for the protection of rice cultivation: Ente Nazionale Risi (ENR). ENR has several Department and structures for many scientific (chemical, agronomical, biotechnological, economical) competences, in particular in Rice Research Centre there is the Chemical Merceological Laboratory (LCM), called “laboratory” or “LCM”. The LCM was made in the 80’s and is accredited since the 2007 by Accredia (the Italian Accreditation Body) for specific analysis on rice.

**Physical characteristics**

**Aromaticity**

An interesting aspect from the point of view of the inclusion in the National (Italian) Register of Varieties is about the presence / absence of aromaticity. The aromatic rices emit in cooking a characteristic scent similar to popcorn related to a pool of chemical compounds including, in particular, the 2-acetyl-pyrroline that some varieties of rice (called “aromatic rice”) are able to synthesize.

**Dimensional characterization**

Rice grains were classified as medium, long A, long B and round by the application of the Regulation CE 1234/2007 (Annex III, Part 1), as reported below:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Length (L)</th>
<th>Length / Width (L/l) ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>L ≤ 5.2 mm</td>
<td>L/l &lt; 2</td>
</tr>
<tr>
<td>Medium</td>
<td>5.2 mm &lt; L ≤ 6.0 mm</td>
<td>L/l &lt; 3</td>
</tr>
<tr>
<td>Long A</td>
<td>L &gt; 6.0 mm</td>
<td>2 &lt; L/l &lt; 3</td>
</tr>
<tr>
<td>Long B</td>
<td>L &gt; 6.0 mm</td>
<td>L/l ≥ 3</td>
</tr>
</tbody>
</table>

**Chalkiness**

Grain appearance is largely determined by the endosperm opacity. Rice chalkiness appears as a white (opaque) portion of a kernel or can make up the entire kernel (Champagne, 2004). This appearance of grain is commonly classified as the amount of chalkiness. The chalkiness is caused by interruption of final filling of the grain. Chalkiness is able to influence cooking and chewing characteristics of rice’s grain; probably the air spaces present in chalky kernels swell up the starch’s granules during cooking; so
the grain of cooked rice is softer than the crystalline grains. Furthermore the high presence of “chalk” increases the possibility of breakage during milling, thereby downgrading the quality assessment rating of rice (Ferrero et al., 2008).

Chalkiness has been reported to be influenced by both genetics and environment factors. Investigations by electron microscopy showed that the pelleting is mainly due to three factors: a non-uniform deposition of the starch; a less ordered structure among cells of amyloplasts and starch’s granules; the presence of air pockets within the endosperm (Ferrero et al., 2008). Chalk measurements are most commonly made using subjective visualization of kernel placed in a light box (Champagne, 2004).

Rice eating and cooking qualities are highly related to some easily measurable physicochemical properties: apparent amylose content (AM), gelatinization time, rice texture. All of these parameters reflect the starch functionality of the rice grain, but AM is widely recognized as one of the most important determinants for various rice products (J.S. Bao, 2012).

Cooking and eating Characteristics

Gelatinization time
Starch gelatinization phenomena in a hot aqueous medium is influenced by various factors, such as time, temperature and components (moisture, salts, sugar, lipids). Starch gelatinization phenomenon is described as a kind of chemical reaction process in which ungelatinized part of starch is changed to a gelatinized part (Yamamoto, 2004). Physically, starch consists of amorphous and crystallite regions, and the gelatinization initially occurs in the former.

The gelatinization time (or gel-time) is defined as the time necessary for 90% of the kernels to pass from their natural state to the gel state (UNI ISO 14864). The gelatinization is the hydration process which conferring the jelly like state typical of the coagulated colloids, which are named “gels”, on kernels (UNI ISO 14864). The gel state is the condition reached as a consequence of gelatinization, when the kernel is fully transparent and absolutely free from whitish and opaque granules after being squashed between two glass plates (UNI ISO 14864).

The gel-time is correlated with the hydration process of starch when rice is cooked in water at high temperature. This process, first slow and then quick, induce an irreversible change in physical structure of starch. Its crystalline granules became colloidal, losing the characteristic of crystallinity (Tinarelli, 1999). Any Italian variety has a particular gel-time. Usually for rice Italian varieties is observed a gel time in a range of 14 – 24 minutes (Ferrero et al., 2008).

Rice texture
Cooked rice texture has been shown to govern the acceptance of rice by consumers when consumed as the whole grain. Texture has been defined as a multidimensional characteristic that only humans can perceive, define, and measure.

Thus, sensory evaluation is critical although instrumental measurement of textural properties is also common practice (Zhoust Z., 2001).

Although texture is multidimensional, hardness and stickiness are critical and these textural characteristics govern palatability of cooked rice in Italian markets, with hardness being the most important and most commonly measured parameter. Rice texture is affected by factors such as variety, amylose content, gelatinization temperature processing factors and cooking method. For instance, cooked rice with low amylose content is soft and sticky, while rice with high amylose is firm and fluffy (Zhoust Z., 2001).

Chemical characteristics

Proteins
Protein plays an important role in cooked rice texture, because the protein forms a complex with starch that impairs starch granule swelling. Starch granule swelling affects both viscosity intensity and the rate of starch gelatinization. Protein content within the same rice variety varies
by degree of milling. Rice obtained from a higher degree of milling has a comparatively better sensory quality. High protein rice is less sticky and has a harder texture. It was found that rice protein consists mainly of glutelin and oryzenin which forms a complex with starch that decreases rice stickiness (Suwannaporn et al., 2007).

Proteins are most concentrated in the outer layers of the rice kernel, but significant amounts are also present in the endosperm (Champagne, 2004).

Lipids
Lipids can contribute to the quality of rice, influencing the nutritional and sensory characteristics, although not abundant components such as carbohydrates and proteins. The total concentration of fat in the caryopsis of brown rice is between 2 and 4%, while concentration in the milled grain amounts to 0.3 to 0.6% (according to degree of milling). Lipids are present in the form of spherosomes or lipid droplets <1.5 µm in diameter in the aleurone layer, and <0.7 µm in the embryo of rice grain; most of the lipids in the endosperm are associated with protein bodies, but starch granules also have bound lipids. Lipids are generally classified into nonstarch lipids, principally those in the spherosomes or lipid droplets of aleurone layer and embryo, and starch lipids. The first represent a little portion of total lipids, but can play a role in the synthesis of starch; they are the most difficult to extract. The nonstarch lipids are the most abundant and can be found in the aleurone layer and the embryo of brown rice; they’re extracted with petroleum ether (Champagne, 2004).

Moisture
Moisture content is the amount of water in the rice grain. In post-harvest handling, grain moisture content is generally expressed as percentage of water contained in the wet grain. Moisture of 14% or less is considered safe for storing grains; paddy should be dried to safe moisture content within 24 hours after harvesting to avoid damage and deterioration. Improper drying and storage practices lead to low grain or seed quality.

Amylose content
The eating quality of rice is strongly influenced by amylose content (Suwannaporn A., 2007).

Amylose content is considered the single most important characteristic for predicting rice cooking and processing behavior. Amylose content is directly related to water absorption, volume expansion, fluffiness, and separability of cooked rice. It is inversely related to cohesiveness, tenderness, and glossiness (Zhou Z., 2001).

Amylose content is positively correlated with hardness and negatively correlated with stickiness (Suwannaporn A., 2007).

On the basis of amylose content, rice starch may be classified as waxy (0% to 2% amylose), very low (5% to 12% amylose), low (12% to 20% amylose), intermediate (20% to 25% amylose), or high (25% to 33% amylose); there are some rice mutants with higher levels of amylose in a range of 35% to 40% (Wani et al., 2012).

The quality characterization of newly developed rice cultivars (from cereal chemistry approach and to find correlation between important properties) is mandatory to study their quality attributes and to compare their different properties with already studied cultivars for further improvement in quality characteristics of under development varieties of rice. The goal of this paper was to study chemical, textural and nutritional characterization of different new rice cultivars grown in Italy.

Materials and methods
Materials
Eleven rough rice samples (Apollo, Carnise, Cerere, CRLB1, Fragrance, Puma, Ronaldo, Sirio CL, Tigre, Ermes, Venere) were obtained from different Seed Companies. Nine of the eleven cultivars are consumed exclusively as milled rice, while Venere and Ermes only as husked rice.

They were recognized at the Italian National
Register of Varieties in the last five/ten years; they include: rice with high amylose content, aromatic rice, pigmented rice, or rice for parboiled market.

Samples of rough rice were dehulled; brown rice was polished with a uniform degree of processing. A dehusked "Universale" were used to remove hull and bran to obtain milled rice. Broken kernels and damaged grains were eliminated by sieving; samples obtained were subjected to analysis.

Physical Characterization

Aromaticity
The analysis is performed according to an internal method developed by LCM (MP23 rev.02, 2011). It is a kind of sensory analysis carried out for comparison between milled rice test and reference materials consisting of aromatic rice variety (Gange) and non-aromatic variety (Gladio), as indicated by CPVO protocol. The samples are cooked in the same test conditions on the stickiness (MP14) and evaluated by a trained panel. The test is aimed to describe the perception of the aroma and its intensity on a predetermined scale.

Length and width
100 grains of brown rice and milled rice kernels (counted by an automatic counter Contador) are measured with the image analyzer WinSEEDLE Pro. The analysis was performed in duplicate by the application of the UNI EN ISO 11746:2012 method. The value of the shape of kernel is given by the ratio between length and width.

1000 Grain Weight
500 grain weight was determined by weighing of a sample’s portion, separation of the whole grains, weight of the residue and counts of whole grains, by the application of UNI EN ISO 520:2011.

Chalkiness
The analytical determination is carried out following an internal method (MP13 rev.03, 2011) that involves the visual evaluation of the single grains and the identification of the pearl, if present (Cormegna et al., 2011).

Cooking and eating Characteristics

Determination of gelatinization time
The UNI ISO 14864:2004 (which is the Italian version of ISO 14864:1998) specifies a method to evaluate the gelatinization time of rice kernels during cooking. It is applied only to milled rice. The principle of the method consist in a determination of the time span between the immersion of the sample of rice into boiling water; kernels becoming fully gelatinized and are evaluated by visual observation (ISO 14864). The method is the international version of the Italian Ranghino test (Ranghino, 1966).

Determination of instrumental textural analysis (hardness and stickiness)
Prepared rice samples were cooked in rice steam cooker (SPL, F.Lli Galli). Cooked rice texture was measured with a Texture Analyzer model TA.XT plus (Stable Micro Systems) using the compression test according to UNI EN ISO 11747:2012 method (resistance to extrusion: hardness) and an internal method (MP14 rev.07) for stickiness.

As reported in Table 2, X g of rice kernels in Y ml of distilled water are cooked for 30 minutes (20’ with the steam cooker on and 10’ off). Portions of Z g are analyzed in the texture analyzer; the result is the mean of K data and the determination is made in duplicate.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>20 g</td>
<td>38 ml</td>
<td>17 g</td>
<td>6</td>
</tr>
<tr>
<td>Stickiness</td>
<td>8 g</td>
<td>12 ml</td>
<td>2 g</td>
<td>8</td>
</tr>
</tbody>
</table>
Chemical Characterization

Determination of the nitrogen content and calculation of the crude protein content.

Protein content was calculated from nitrogen content assessed by the Kjeldahl method using a 5.95 conversion factor. A test portion of milled rice (1 g) is digested by sulfuric acid 18 mol/l (20 ml) in the presence of a catalyst. The reaction products are made alkaline then distilled. The liberated ammonia is collected in a boric acid solution, which is titrated with a sulfuric acid solution, to determine the nitrogen content and calculate the crude protein content according to ISO 20483:2006.

Determination of crude fat

For crude fat, the Soxhlet extraction method with petroleum ether as solvent was used, according to AACC Method 30-25.01. 5 g of dried (in a vacuum oven: 100 mm Hg; 5 hours) grinded rice are extracted with 100 ml of petroleum ether (30-60°C) for 2 hours.

Moisture Content

Moisture content of brown and milled rice was determined by using the standard methods of analysis ISO 712:2009. 5 g of grinded rice are dried in a Memmert UFE 400 oven for 2 hours at 130-133°C.

Amylose Content

Rice is ground to a very fine flour to break up the endosperm structure in order to aid complete dispersion and gelatinization; the flour is then defatted. A test portion is dispersed in a sodium hydroxide solution, to an aliquot portion of which an iodine solution is added. The absorbance, at 720 nm, of the colour complex formed is then determined using a UV-VIS spectrophotometer (Lambda 25, Perkin Elmer). The amylose mass fraction of the sample is then read from a calibration graph, which is prepared using mixtures of potato amylose and amylopectin to make allowance for the effect of amylopectin on the color of the amylose–iodine complex of the test solution (UNI EN ISO 6647-1:2007).

Statistical Analysis

Replicate determination data were submitted to Shapiro-Wilk and Huber tests by a specific UNI-CHIM software.

Comparison of means was performed by one-way analysis of variance (ANOVA) followed by Turkey’s method; least significant differences were computed at P < 0.05.

In Table 3, 4 and 5 all data are a mean of values. Standard deviation of the mean is in parenthesis. Different letters within the same column indicate significant difference using Turkey’s method.

Table 3 – Physical characteristics and grain type of nine new Italian rice varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Lenght (mm)</th>
<th>Width (mm)</th>
<th>Grain Type</th>
<th>Mass 1000 grains (g)</th>
<th>Chalkiness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 10)</td>
<td>(n = 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apollo</td>
<td>7.33 (0.04)</td>
<td>2.20 (0.00)</td>
<td>Long B</td>
<td>22.64 (0.20)</td>
<td>Pearled (nd)</td>
</tr>
<tr>
<td>Carnise</td>
<td>6.90 (0.01)</td>
<td>3.20 (0.01)</td>
<td>Long A</td>
<td>31.67 (0.28)</td>
<td>Pearled (ve)</td>
</tr>
<tr>
<td>Cerere</td>
<td>4.83 (0.01)</td>
<td>2.92 (0.01)</td>
<td>Round</td>
<td>20.25 (0.63)</td>
<td>Pearled (le)</td>
</tr>
<tr>
<td>CRLB1</td>
<td>7.08 (0.02)</td>
<td>2.02 (0.01)</td>
<td>Long B</td>
<td>19.08 (0.10)</td>
<td>Vitreus</td>
</tr>
<tr>
<td>Fragrance</td>
<td>6.87 (0.06)</td>
<td>2.30 (0.01)</td>
<td>Long B</td>
<td>22.63 (0.18)</td>
<td>Vitreus</td>
</tr>
<tr>
<td>Puma</td>
<td>6.23 (0.04)</td>
<td>2.59 (0.02)</td>
<td>Long B</td>
<td>22.92 (0.17)</td>
<td>Vitreus</td>
</tr>
<tr>
<td>Ronaldo</td>
<td>6.43 (0.04)</td>
<td>2.68 (0.00)</td>
<td>Long A</td>
<td>25.30 (0.16)</td>
<td>Pearled (le)</td>
</tr>
<tr>
<td>Sirio CL</td>
<td>6.54 (0.07)</td>
<td>2.04 (0.01)</td>
<td>Long B</td>
<td>17.57 (0.08)</td>
<td>Vitreus</td>
</tr>
<tr>
<td>Tigre</td>
<td>6.78 (0.08)</td>
<td>2.00 (0.01)</td>
<td>Long B</td>
<td>17.40 (0.09)</td>
<td>Vitreus</td>
</tr>
<tr>
<td>Ermes</td>
<td>8.01 (0.03)</td>
<td>2.12 (0.01)</td>
<td>-</td>
<td>23.41 (0.14)</td>
<td>nd</td>
</tr>
<tr>
<td>Venere</td>
<td>5.92 (0.04)</td>
<td>2.59 (0.01)</td>
<td>-</td>
<td>20.36 (0.21)</td>
<td>nd</td>
</tr>
</tbody>
</table>

ve = very extended; le = little extended
Results and discussion
Physical characteristics of rice grain
The mentioned physical characteristics of the milled grain rice were classified as medium, long A, long B and round (Regulation CE 1234/2007, Annex III, Part 1), respectively, where six of the nine cultivars analyzed were long B grain type, two were long A, one was round and none medium (Table 3).

All varieties of milled rice, even if in the same merceological group, are characterized by different length and width. Fragrance and Puma presented similar mass of 1000 grains such as Sirio CL and Tigre too.

For Ermes and Venere the length, width and mass of 1000 grains are measured on husked rice. Their biometric values are peculiar and mass of 1000 grains too.

Amylose content and Texture properties of milled rice
Rice was classified by its amylose content into three groups: low amylose content (less than 19 g/100g, such as Cerere, Puma and Ronaldo); medium amylose content (20-24 g/100g: Apollo, Carnise and Sirio CL); and high amylose content (over 24 g/100g: CRLB1, Fragrance and Tigre), as reported in Table 4. As written above, the content of amylose is correlated to texture properties, in particular with hardness and stickiness.

Ronaldo and Cerere have similar hardness, but different stickiness; the opposite of CRLB1 and Fragrance.

Apollo and Carnise have similar textural value of analysis of both characteristics (stickiness and hardness).

There are no significant differences between the three rice high amylose varieties (CRLB1, Fragrance and Tigre). Apollo and Sirio CL have similar content of amylose, not similar to Carnise.

Amylose content of Puma and Cerere are different and Cerere content is similar to Ronaldo.

These determination are not made on Ermes and Venere because these varieties are consumed as husked rice and not as milled rice.

Table 4 – Amylose content and texture properties of nine new Italian rice varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Hardness (kg/cm²) (n = 10)</th>
<th>Stickiness (g.cm) (n = 3)</th>
<th>Amylose (AM) (g/100g) (n = 2)</th>
<th>AM classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo</td>
<td>1.03 (0.02)</td>
<td>1.55 (0.25)</td>
<td>24.26 (0.40)</td>
<td>Medium AM</td>
</tr>
<tr>
<td>Carnise</td>
<td>1.02 (0.05)</td>
<td>1.63 (0.18)</td>
<td>22.91 (0.33)</td>
<td>Medium AM</td>
</tr>
<tr>
<td>Cerere</td>
<td>0.71 (0.04)</td>
<td>4.98 (0.43)</td>
<td>16.34 (0.13)</td>
<td>Low AM</td>
</tr>
<tr>
<td>CRLB1</td>
<td>1.26 (0.03)</td>
<td>0.53 (0.21)</td>
<td>26.08 (0.20)</td>
<td>High AM</td>
</tr>
<tr>
<td>Fragrance</td>
<td>1.20 (0.04)</td>
<td>0.48 (0.04)</td>
<td>26.83 (0.06)</td>
<td>High AM</td>
</tr>
<tr>
<td>Puma</td>
<td>0.79 (0.01)</td>
<td>3.35 (0.27)</td>
<td>17.97 (0.06)</td>
<td>Low AM</td>
</tr>
<tr>
<td>Ronaldo</td>
<td>0.71 (0.03)</td>
<td>5.75 (0.22)</td>
<td>15.87 (0.40)</td>
<td>Low AM</td>
</tr>
<tr>
<td>Sirio CL</td>
<td>1.04 (0.06)</td>
<td>1.09 (0.22)</td>
<td>23.94 (0.19)</td>
<td>Medium AM</td>
</tr>
<tr>
<td>Tigre</td>
<td>1.12 (0.02)</td>
<td>1.00 (0.10)</td>
<td>26.97 (0.13)</td>
<td>High AM</td>
</tr>
</tbody>
</table>

Proximate Analysis
Table 5 depicts the chemical properties of different rice cultivars.

The moisture content of different rice varieties found to range from 12.64 to 14.21 g/100g (the analysis of this parameter was performed in single).

The protein contents and lipid contents ranged from 6.08 to 9.68 and 0.21 to 0.40 respectively (for milled rice). For husked rice (Ermes and Venere) the protein content is quite similar to milled rice, but, obviously, the lipid content is higher than milled.
Table 5 – Amylose content, Lipid, Protein and Moisture of nine new Italian rice varieties

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Amylose (g/100g) (n = 2)</th>
<th>Lipid (g/100g) (n = 6)</th>
<th>Protein (g/100g) (n = 10)</th>
<th>Moisture (g/100g) (n = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo</td>
<td>24.26 (0.40)b</td>
<td>0.31 (0.01)h</td>
<td>7.21 (0.05)d</td>
<td>13.99</td>
</tr>
<tr>
<td>Carnise</td>
<td>22.91 (0.33)c</td>
<td>0.29 (0.02)c</td>
<td>7.39 (0.05)c</td>
<td>14.21</td>
</tr>
<tr>
<td>Cerere</td>
<td>16.34 (0.13)c</td>
<td>0.40 (0.02)c</td>
<td>6.08 (0.08)c</td>
<td>13.44</td>
</tr>
<tr>
<td>CRLB1</td>
<td>26.08 (0.20)c</td>
<td>0.21 (0.03)c</td>
<td>9.15 (0.03)c</td>
<td>12.64</td>
</tr>
<tr>
<td>Fragrance</td>
<td>26.83 (0.06)c</td>
<td>0.30 (0.02)c</td>
<td>6.97 (0.07)c</td>
<td>13.47</td>
</tr>
<tr>
<td>Puma</td>
<td>17.97 (0.06)d</td>
<td>0.29 (0.03)c</td>
<td>9.68 (0.07)c</td>
<td>12.71</td>
</tr>
<tr>
<td>Ronaldo</td>
<td>15.87 (0.40)c</td>
<td>0.28 (0.02)c</td>
<td>6.40 (0.03)c</td>
<td>13.45</td>
</tr>
<tr>
<td>Sirio CL</td>
<td>23.94 (0.19)b</td>
<td>0.34 (0.03)c</td>
<td>7.59 (0.31)c</td>
<td>13.62</td>
</tr>
<tr>
<td>Tigre</td>
<td>26.97 (0.13)c</td>
<td>0.27 (0.01)c</td>
<td>8.55 (0.19)c</td>
<td>13.00</td>
</tr>
<tr>
<td>Ermes</td>
<td>nd</td>
<td>2.44 (0.03)</td>
<td>8.06 (0.06)</td>
<td>13.50</td>
</tr>
<tr>
<td>Venere</td>
<td>nd</td>
<td>2.61 (0.08)</td>
<td>7.26 (0.05)</td>
<td>13.75</td>
</tr>
</tbody>
</table>

Cooking properties of milled rice

The cooking characteristics of the different new Italian varieties of rice, are presented in Table 6. The gel-time of milled rice from different cultivars varied from 17’15” (Carnise) to 24’56” (Ronaldo).

There are some consideration on biometrics increase values. Varieties long B increase more width than length (except Puma which gives the same kind of increase in length and width).

Solid losses of all varieties varied from 11.10% (Puma) to 14.93% (Apollo).

Correlation Analysis: Amylose content and texture properties

Stickiness and Hardness analytical data are reported in Fig.1 and it is possible to view the inversely correlated between the two properties. In particular: high amylose varieties (Tigre, Fragrance and CRLB1) are characterized by high hardness and low stickiness; low amylose varieties (Ronaldo, Cerere and Puma) have low hardness and high stickiness values. Apollo, Carnise and Sirio CL (medium amylose content varieties) are collocate between the other varieties for the texture properties.

In Fig. 2 hardness (with its standard deviation) is plotted in function to amylose content and the positive correlation between the properties is noted. The coefficient of correlation (R²) is 0.94. Stickiness is negatively correlated with amylose content (Fig. 3) with a R² of 0.93.

Table 6 – Cooking properties of milled rice

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Gel-time (min sec) (n = 1)</th>
<th>Length increase (%) (n = 3)</th>
<th>Width increase (%) (n = 3)</th>
<th>Solid loss (%) (n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apollo</td>
<td>21’24”</td>
<td>32.10 (2.18)</td>
<td>70.97 (0.81)</td>
<td>14.93 (0.99)</td>
</tr>
<tr>
<td>Carnise</td>
<td>17’15”</td>
<td>50.43 (3.25)</td>
<td>21.77 (2.16)</td>
<td>13.23 (0.75)</td>
</tr>
<tr>
<td>Cerere</td>
<td>18’52”</td>
<td>80.27 (1.12)</td>
<td>25.25 (1.83)</td>
<td>13.33 (0.06)</td>
</tr>
<tr>
<td>CRLB1</td>
<td>21’47”</td>
<td>38.20 (1.31)</td>
<td>77.67 (3.25)</td>
<td>12.53 (1.60)</td>
</tr>
<tr>
<td>Fragrance</td>
<td>20’58”</td>
<td>43.50 (1.47)</td>
<td>79.97 (2.33)</td>
<td>12.53 (0.15)</td>
</tr>
<tr>
<td>Puma</td>
<td>23’48”</td>
<td>45.23 (1.03)</td>
<td>44.30 (2.82)</td>
<td>11.10 (1.74)</td>
</tr>
<tr>
<td>Ronaldo</td>
<td>24’56”</td>
<td>39.23 (0.59)</td>
<td>44.80 (2.95)</td>
<td>14.87 (0.31)</td>
</tr>
<tr>
<td>Sirio CL</td>
<td>19’10”</td>
<td>37.17 (1.36)</td>
<td>66.30 (1.73)</td>
<td>13.07 (1.10)</td>
</tr>
<tr>
<td>Tigre</td>
<td>18’32”</td>
<td>48.30 (3.20)</td>
<td>68.90 (6.93)</td>
<td>13.03 (0.21)</td>
</tr>
</tbody>
</table>
Physicochemical Characterization of some Italian rice varieties

C. Simonelli, A. Abbiati, M. Cormegna

Figure 1 – Stickiness vs hardness in milled rice (new Italian varieties)

Figure 2 – Regression between hardness (HD) and amylose content (AM) in milled rice (new Italian varieties)

\[
y = 0.044x + 0.0012 \\
R^2 = 0.94073
\]
Correlations among various physico-chemical and cooking properties

Pearson correlation coefficient for relationships among various physico-chemical and cooking properties of the new Italian varieties of rice are reported in Table 7.

In the event that there is no correlation between the properties, the coefficient values will oscillate around zero and will sometimes be positive or negative. If, however, the correlation between

Table 7 – Pearson correlation between various physico-chemical and cooking properties of new Italian rice varieties

<table>
<thead>
<tr>
<th></th>
<th>L/W ratio</th>
<th>Mass 1000 grains</th>
<th>Hardness</th>
<th>Stickiness</th>
<th>Amylose</th>
<th>Gel-time</th>
<th>Solid loss</th>
<th>Length increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass 1000 grains</td>
<td>-0.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>0.79</td>
<td>-0.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stickiness</td>
<td>-0.76</td>
<td>0.23</td>
<td>-0.96</td>
<td>-0.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amylose</td>
<td>0.81</td>
<td>-0.28</td>
<td>0.97</td>
<td>-0.97</td>
<td>-0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gel-time</td>
<td>0.05</td>
<td>0.01</td>
<td>-0.34</td>
<td>0.43</td>
<td>-0.42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid loss</td>
<td>0.02</td>
<td>0.18</td>
<td>-0.20</td>
<td>0.29</td>
<td>-0.13</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length increase</td>
<td>-0.75</td>
<td>0.00</td>
<td>-0.46</td>
<td>0.46</td>
<td>-0.45</td>
<td>-0.42</td>
<td>-0.16</td>
<td></td>
</tr>
<tr>
<td>Width increase</td>
<td>0.92</td>
<td>-0.59</td>
<td>0.73</td>
<td>-0.67</td>
<td>0.74</td>
<td>0.19</td>
<td>-0.04</td>
<td>-0.65</td>
</tr>
</tbody>
</table>
the variables is strong, the coefficient will assume values close to +1 or -1, as in the following cases:

- Stickiness is inversely proportional to hardness (-0.96);
- The amylose content is directly proportional to hardness (0.97) and inversely to stickiness (-0.97);
- There is a direct correlation between the length increase in cooking and the length/width ratio (0.92);
- The amylose content and the length/width ratio give a fairly good direct correlation (0.81).

### Discussion

As reported in Table 3, the new varieties of rice are characterized in according to the Reg. CE 1234/2007. These physical properties, together with amylose content, are primary quality factors in the breeding, drying, cleaning, marketing, and processing of end-use products. As described by Adair et al. (1973), and remarked by Tinarelli (1999), rice grain may be classified into grain-type categories based upon three physical quantities: length, shape and weight. Usually the grain weight (size) is determined by the analysis of the mass of 1000 grains.

To predict the cooking quality of rice, it’s essential to understand the structure of the starch that composes it. As previously mentioned, there are two types of starch in rice grain: amylose and amylopectin. The first one has a huge impact in the cooking quality of rice and it’s the linear form of the starch. Actually the determination of the amylose is made by the UNI EN ISO 6647-1:2007 method which involves the determination of apparent amylose (amylose and the long linear chain of amylopectin). INQR (International Network for Quality Rice) has developed a new method for the determination of amylose content using the technology SEC (Standard Exclusion Chromatography) for the preparation of standards for the calibration curve (Fitzgerald et al., 2009). Last year, the ISO 6647 has been revised in this way and is therefore now available for analyzing the amylose content new ISO 6647:2015.

The differences in textural properties among the various rice cultivars may be attributed mainly to differences in the amylose content (Singh et al., 2005).

The higher value of hardness in rice cultivars may also be attributed to differences in their granular structure. A higher hardness has been reported for rice cultivars having smaller size starch granules (Singh et al., 2003).

As noted in several studies, even on Italian varieties (Sicheri and Martinotti), it appeared that the husked rice grains (Venere and Ermes) have a higher nutrient content than milled rice.

As reported in other studies (Kadan et al., 1997; Singh et al., 2005) there is a strong correlation between the amylose content and the hardness (Pearson index: 0.97).

In the literature, in addition to the correlation between stickiness and hardness with the amylose content, can be found interesting data, relating to the correlation between sensory factors (from the panel test) and the protein content (Lyon et al., 1999).

The factors relating to the characterization of stickiness (manual and visual adhesiveness, stickiness to lip, initial starchy coating, surface slickness, roughness, self-adhesiveness, cohesiveness, hardness, cohesiveness of mass) identified through a panel test, give a coefficient of correlation $r = 0.32$ with amylose and $r = -0.67$ with the protein content (Lyon et al., 1999).

With the work submitted in this context, it was possible to directly determine the stickiness as an individual parameter and identify distinct correlation coefficients with amylose ($r = -0.96$) and with the protein content ($r = -0.47$).

As regards the sensorial properties by panel tests that describe the hardness (chewiness and roughness), the coefficients of correlation with amylose and protein content, in the literature appear to be respectively $r = -0.27$ and $r = 0.05$ (Lyon et al., 1999).
From the data shown in Table 5 it is possible to determine the correlation coefficients of hardness and stickiness respectively with amylose and protein content (Table 8 and Fig. 4, 5).

Certainly both for hardness and for stickiness there are significant correlations with amylose content, confirmed by the excellent values of $r$ and $R^2$; the correlation between the protein content and the parameters of hardness and stickiness was also evaluated and appeared to be not particularly significant.

Conclusions

Taking into consideration the varieties grouped as defined in the EC Regulation 1234/2007, is possible to analyze the long A group (Carnise, Puma and Ronaldo). There are two pearled varieties (Carnise and Ronaldo) and a crystalline one (Puma), respectively, in medium (Carnise) and low amylose (Ronaldo and Puma); characteristics of texture (hardness and stickiness) resulting therefrom accordingly. Also the gelatinization time (and subsequent cooking times) are very different from each other as well as the behavior of the grain during cooking (Table 6), in particular for the Carnise, as shown in Figure 4.

The Carnise is commercialized in the group of Carnaroli (DM October 1, 2015) such as Superfine rice and is therefore referred as a “risotto” rice. The Ronaldo is a variety mainly used for parboiling analogous to Puma; this latter, unlike Ronaldo, is a so-called “early variety” from the agronomic point of view.

Within the group of the long B, there are three aromatic varieties (Apollo, Fragrance and Tiger); they have different aspect of the grain (the first pearled, the other two crystalline), amylose content (respectively a medium and two high amylose) and peculiar value of texture (hardness and stickiness).

It is possible to note that, while maintaining the same conformation in the radar chart, the three long B varieties have different behaviors. Apollo, Fragrance and Tiger are within the same product group in the Superfine rices, all aromatics.

The other two long B (CRLB1, and Sirius CL) do not exhibit aromaticity, are crystalline at different amylose content (high and medium respectively), with not comparable texture properties (in particular the hardness) and different cooking behaviors (gel-time). The Puma, in the normative of the Internal Market, is in the “Fino” group. CRLB1 and Sirio CL are in the same product group (Superfine), together with more historical Italian varieties as Gladio and Thai bonnet.
Moreover there is a single variety, among those studied, classified as a “round”: the Cerere. Its radar chart is shown in Figure 7 and it is also possible to note from its conformation which is unique compared to all other varieties. In the normative of the Internal Italian Market belongs to “Comune” or “Originario”.

The study carried out showed that the varieties taken in consideration, even within to the same product group, have peculiarities that are reflected in the different chemical and physical characteristics and behaviors in cooking.

In addition to the usual correlations between amylose and textural properties, it was examined if there might be links among other physico-chemical properties. The study of the Pearson coefficient shows that rice that have a high length / width ratio (as long B) tend to have high values of increase in width in cooking and are characterized by high levels of amylose.

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