ORIGINAL ARTICLE

Effect of moisture content of two paddy varieties on the physical and cooked properties of produced rice

Efeito do teor de umidade de duas variedades de arroz sobre as propriedades físicas e de cozimento

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Abstract

Yasemin and Anber are the main rice varieties cultivated in Iraq. Anber is the favorite variety in Iraq because of its unique flavor, and Yasemin is the most cultivated variety. Determining the suitable moisture content of both varieties to produce high extraction rate (lowest rice breakage), good rice whiteness, and the best rice quality in terms of cooked properties was the purpose of this study. Moisture content (MC) (10%, 12%, 14%, 16%) of Yasemin and Anber were used, and targeted whiteness (32, 34, and 36) were obtained by using different milling times. Results showed that the best moisture content was 14% for Yasemin variety and 10% for Anber variety in terms of extraction rate. Process time increasing led to reduction of extraction rate and increased rice whiteness. The highest extraction rate of Yasemin and Anber was 56% and 64% with 32 whiteness, respectively. Kernel breakage had opposite relationship with extraction rate. Yasemin and Anber varieties were classified as short grain rice depending on their length. The maximum elongation was at 16% MC for Yasemin variety and at 10% MC for Anber variety, which increased 60% more than uncooked rice. There was no definite pattern observed for increasing rice volume (width and weight). In conclusion, the extraction rate of Yasemin and Anber varieties was increased at 14% and 10% MC, respectively. For cooked properties, 10% MC of Anber was the best in terms of rice elongation, while 16% MC was the best for Yasemin variety.

Keywords: Rice; Milling process; Moisture content; Extraction rate; Kernel elongation; Kernel breakage.

Resumo

Yasemin e Amber são as principais variedades de arroz cultivadas no Iraque. A variedade Amber é a favorita por causa de seu sabor único, enquanto a Yasemin é a mais cultivada. O objetivo do presente estudo foi determinar o teor de umidade adequado para ambas as variedades, na obtenção da melhor taxa de extração (menor quebra), brancura e qualidade do arroz em termos das propriedades de cozimento. Os teores de umidade (TU) (10%, 12%, 14% e 16%) e a brancura-alvo (32, 34 e 36) foram empregados para as variedades Yasemin e Amber com diferentes tempos de moagem. Os resultados mostraram que o melhor TU, em relação à taxa de extração, foi de 14% para a

variedade Yasemin e de 10% para a variedade Amber. O aumento do tempo do processo levou à redução da taxa de extração e ao aumento da brancura do arroz. As maiores taxas de extração foram de 56% e 64% para as variedades Yasemin e Amber, respectivamente, com 32 de brancura. A quebra do grão teve relação oposta à taxa de extração. As variedades Yasemin e Amber, quanto ao comprimento, foram classificadas como arrozes de grão curto. O alongamento máximo, de 60% com relação ao arroz cru, foi obtido com TU de 16% para variedade Yasemin e de 10% para variedade Amber. Não houve padrão definido para o aumento do volume de arroz (largura e peso). Em conclusão, as taxas de extração das variedades Yasemin e Amber foram maiores em TU de 14% e 10%, respectivamente. Para as propriedades de cozimento, em termos do alongamento do arroz, o TU de 10% para a variedade Amber foi a melhor condição, enquanto para a variedade Yasemin foi de 16%.

Palavras-chave: Arroz; Processo de moagem; Teor de umidade; Taxa de extração; Alongamento do grão; Quebra do grão.

1 Introduction

Rice (*Oryza sativa* L.) is one of the most important crops beside wheat and maize (Shewry et al., 2002). Rice is the main food for more than half of the world population. Approximately 90% of the rice production occurs in tropical/sub-tropical Asia where 60% of the world population lives (Sridevi & Chellamuthu, 2015). Iraq government via Grain Board of Iraq (GBI) imported 696.000, 366.000, and 217.000 ton (Alhendi & Mohammed, 2018) in addition to domestic paddy rice 200.000, 43.000, and 100.000 ton during 2015, 2016, and 2017, respectively, to distribute a monthly ration to Iraqi people (Data from GBI). Ghadge & Prasad (2012) mentioned that 75% of the daily taken calories of Asian people were from rice. The properties of the produced rice are different depending on rice variety, cultivation methods, paddy processing, and cooking conditions (Roy et al., 2011). The marketing value of rice depends on its physical quality. The percentage of the whole rice (head rice) is considered the most important feature of the produced rice (Ghadge & Prasad, 2012). The market value of the broken rice is half the value of the head rice (75% to 100% of the whole kernel) (Corrêa et al., 2007). Kernel breakage of rice during milling is one of the main problems in rice industry due to the cooking quality of the produced rice and consequently the market value of the rice (Alizadeh et al., 2011). Most breakage in rice occurs because of the grains fissuring before milling, which is caused because of readsorption of moisture by low-moisture grains. Harvesting paddy with high moisture content and controlling drying process play an important role of fissured paddy and consequentially breakage of rice (Kunze, 2008). Most kernel breakage occurs at the beginning of paddy processing; however, some authors mentioned that extending the milling process leads to a high temperature that rises the rice breakage (Buggenhout et al., 2013). For cooking properties, greater length elongation, less volume extension, and less water absorption have been related to high rice quality (Ge et al., 2005).

Anber is the best rice variety cultivated in Iraq because of its unique flavor, while Yasemin is the most commonly cultivated variety in Iraq, which present 97%, 99%, and 78% of cultivated rice in Iraq during 2015, 2016, and 2017 respectively (Data from GBI). Therefore, the current study considered these two varieties to determine the optimum moisture content of paddy to produce the best rice quality in terms of high extraction rate, rice breakage reduction, rice whiteness increasing, and cooking quality enhancement. These are the main parameters in terms of good milling quality (Furahisha et al., 2016), and milling quality improvement is a continuing goal for the rice specialists in the country.

2 Material and methods

2.1 Paddy preparation for milling

Two paddy varieties namely Anber and Yasemin were obtained from Al-Najaf and Babel (two Iraqi provinces) silos during 2017 harvesting season. They have been cleaned from impurities by using a sieve with 2.58 mm diameter. Samples were stored at ambient temperature with the initial moisture content of 16%. Four levels of moisture content (16.0%, 14.0%, 12.0%, and 10.0% w.b.) of the two varieties were reached either by dropping moisture naturally (waiting for moisture reduction) or by natural (sun) drying . Moisture content (MC) of the rice paddy was determined by using a moisture tester (Seedburo Equipment Company, Des Plaines, IL, USA) following AACC method (American Association of Cereal Chemists, 2000).

2.2 Milling

The cleaned paddy rice (with specific MC) was milled by using two huller machines. The first huller (SATAKE Corporation, Bangkok, Japan) removed rice husk, and the process was repeated twice to reduce the whole rice proportion in the produced rice. Dehulled rice (100 g) obtained from the first huller machines was placed in the second huller machine (Mitsubishi Electric Automation, Thailand) for 33 s to 48 s depending on the rice MC and the paddy variety to obtain the required whitening, which was set to be 32, 34, and 36. The lowest whiteness permissible limit according to the rules and regulations for the paddy rice manufacturing in public and private milling for the season 2016/2017 was 32 (Data from GBI). The second huller was cleaned after every two runs to obtain a suitable friction that gives a constant whiteness with the same process properties.

2.3 Physical properties of the produced rice

2.3.1 Rice whiteness

Rice whiteness was determined by using a rice whiteness tester (Rice whiteness Tester C-600, Kett Electric Laboratory, Tokyo, Japan) after calibration with a whiteness standard plate at 84.9 whiteness.

2.3.2 Extraction rate

The extraction rate of each treatment was calculated by weighing the produced head rice to the amount of the origin paddy used. The Equation 1 below expresses the calculation.

$$Extraction\ rate\ = \frac{Head\ rice\ g}{paddy\ g} \times 100 \tag{1}$$

2.3.3 Breakage of rice kernels

Broken rice was separated by placing a specific amount of the processed rice in the rice grader (Satake Testing Rice Grader, Satake Australia, Penrith, NSW, 2750, Australia) to separate the whole rice from the broken rice. Then the broken percentage was calculated by dividing the broken weight by the whole sample weight multiplying by 100.

2.3.4 Cooked rice

Cooked rice properties were detected according to Tian et al. (2005) study. Ten intact uncooked rice kernels were selected randomly from each process line and measured for weight, length (kernels were placed

as one line), and width (kernels were placed side by side). Then, the selected kernels were soaked into distilled water for 30 min and placed between two wet filter papers in a petri dish above boiling water for 20 min. The cooked rice was transferred to a dry filter paper inside a dry petri dish, placed in a desiccator for about 15 min to remove the adhered water. The desiccated cooked rice kernels were measured for length, width and weight similarly to before cooking.

2.4 Statistical analysis

Statistical analysis was performed using two-way analysis of variance (ANOVA) (Two-Factors with Replication) with SAS version 9.0 (SAS Institute INC., SAS Campus Drive, Cary, NC, USA) and Least Significant Difference (LSD) for comparison of means. Differences were considered significant at α=0.05. All experiments were conducted in duplicate.

3 Results

3.1 Physical properties of produced rice

Table 1 shows the required time of each variety with different moisture content to produce different rice whiteness. The higher the moisture content, the higher the process time required to obtain a specific rice whiteness. Yasemin variety (10% MC) required the lowest treatment time to obtain the required whiteness, which was 32, 34, and 36 compared to Yasemin variety with different MC. Table 2 explains the extraction rate of produced rice with different moisture contents and with different whiteness. The extraction rate of Yasemin was between 48% and 56% for 32 rice whiteness and between 44% and 54% for 36 rice whiteness. While the extraction rate of Anber was higher than Yasemin, which was between 53% and 64% for 32 rice whiteness and between 49% and 60% for 36 rice whiteness. Extraction rate generally reduces with high rice whiteness. For Yasemin, the highest extraction rate was for paddy with 14% MC followed by 12% MC for the rice whiteness 32 and 34. The lowest extraction rate was at 10% MC for Yasemin. The opposite was for Anber, which had the highest extraction rate with 10% MC for all rice whiteness followed by 14% MC. Table 3 presents kernel breakage of produced rice with different rice whiteness and different moisture content. Kernel breakage increased with high rice whiteness; however, for some treatments breakage values were almost stable such as for Anber variety with 12% and 16% MC. The highest kernel breakage percentage was with 10% MC of Yasemin and 14% MC of Anber. The lowest kernel breakage was with 14% MC of Yasemin and 10% MC of Anber, which were the highest extraction rate treatments.

Table 1. Required time for each treatment to obtain 32, 34, and 36 whiteness of Yasemin and Anber varieties with different MC.

| Time (s) | Yasemin | | | | Anber | | | |
| | Moisture content (%) | | | | Moisture content (%) | | | |
	10	12	14	16	10	12	14	16
33	32.3 ± 0.2	–	–	–	–	–	–	–
36	–	32.0 ± 0.0	31.9 ± 0.1	–	32.0 ± 1.0	31.9 ± 0.1	32.2 ± 0.5	–
39	33.8 ± 0.3	–	–	–	–	–	–	31.75 ± 0.4
42	–	33.8 ± 0.3	34.1 ± 0.6	31.9 ± 0.4	34.6 ±0.2	33.8 ± 0.4	33.9 ± 0.4	34.0 ± 0.1
45	36.3 ±0.6	–	–	33.5 ± 0.5	36.5 ± 0.6	36.6 ± 0.1	–	–
48	–	36.3 ± 0.4	36.0 ± 0.1	36.2 ± 0.5	–	–	36.5 ± 0.1	36.0 ± 0.0

Table 2. Extraction rate of produced rice with different MC and different whiteness of Yasemin and Anber varieties.

Whitens	Yasemin				Anber			
	Moisture content (%)				Moisture content (%)			
	10	12	14	16	10	12	14	16
32	48.0 ± 1.1Aa	53.9 ± 7.8Aa	56.1 ± 2.9Aa	44.4 ± 0.2Aa	63.8 ± 0.7Aa	53.0 ± 3.3Aab	56.1 ± 2.9Aab	49.8 ± 0.7Ab
34	48.8 ± 0.6Aa	54.6 ± 7.9Aa	54.1 ± 1.6Aa	48.9 ± 0.3Aa	62.8 ± 0.7Aa	51.2 ± 3.9Ab	54.1 ± 1.6Aab	50.8 ± 0.4Ab
36	45.7 ± 0.8Aa	44.7 ± 1.7Aa	53.8 ± 1.0Aa	51.4 ± 3.4Aa	60.4 ± 1.7Aa	49.3 ± 2.1Ab	53.8 ± 1.0Aab	53.2 ± 1.9Aab

Values expressed as a mean ± S.D. Means with a different capital letter within the same column are significantly different, and with different small letters within the same row and same variety are significantly different at $p < 0.05$.

Table 3. Kernel breakage percentage of produced rice with different MC and different whiteness for Yasemin and Anber varieties.

Whitens	Yasemin				Anber			
	Moisture content (%)				Moisture content (%)			
	10	12	14	16	10	12	14	16
32	22.9 ± 1.1ABa	17.0 ± 7.8Bb	14.9 ± 2.9Ab	17.4 ± 0.2Ab	14.5 ± 0.7Bc	17.5 ± 3.3Ab	22.5 ± 2.9Ba	17.3 ± 0.7Ab
34	21.3 ± 0.6Ba	15.5 ± 7.9Bb	16.0 ± 1.6Ab	18.3 ± 0.3Aab	15.5 ± 0.7Bc	17.9 ± 3.9Ab	22.0 ± 1.6Ba	18.3 ± 0.4Ab
36	26.0 ± 0.8Aa	23.9 ± 1.7Aab	16.0 ± 1.0Ac	21.4 ± 3.4Ab	18.0 ± 1.7Ab	19.0 ± 2.1Ab	26.5 ± 1.0Aa	18.5 ± 1.9Ab

Values expressed as a mean ± S.D. Means with a different capital letter within the same column are significantly different, and with different small letters within the same row and same variety are significantly different at $p < 0.05$.

3.2 Cooking properties of produced rice

Figure 1 demonstrates kernel length of rice grains before cooking and the length increment after cooking. There were no significant differences between kernel length before cooking of each variety with different whiteness and different moisture content. Yasemin and Anber have approximately the same length, around 6 mm. Length increment of Yasemin varied; however, the highest increment occurred with high moisture content. For Anber, the highest increment occurred with 10% MC followed by 16% MC. Figure 2 expresses rice width of 10 rice kernels; rice width was between 2.2 mm and 2.6 mm for Yasemin variety and between 2.0 and 2.6 mm for Anber variety. The increment in rice width was between 11% and 47% for Yasemin variety and between 2% and 40% for Anber variety. There were significant differences between rice width before cooking and for the increment after cooking for both varieties (Figure 2). Figure 3 shows 10 rice kernels weight before cooking and increment after cooking. The weight increment generally varied; however, the lowest increment of Yasemin variety was with 10% MC, while the highest increment was with 16% MC and some with 14% MC. For Anber variety, the highest increment mostly occurred with 10% MC followed by 16% MC.

4 Discussions

4.1 Physical properties

In some countries, rice whiteness is one of the main characteristics of produced rice, while for other countries this is not considered like that. In Iraq, rice whiteness is an important trait as well as in Iran (Alizadeh, 2011).
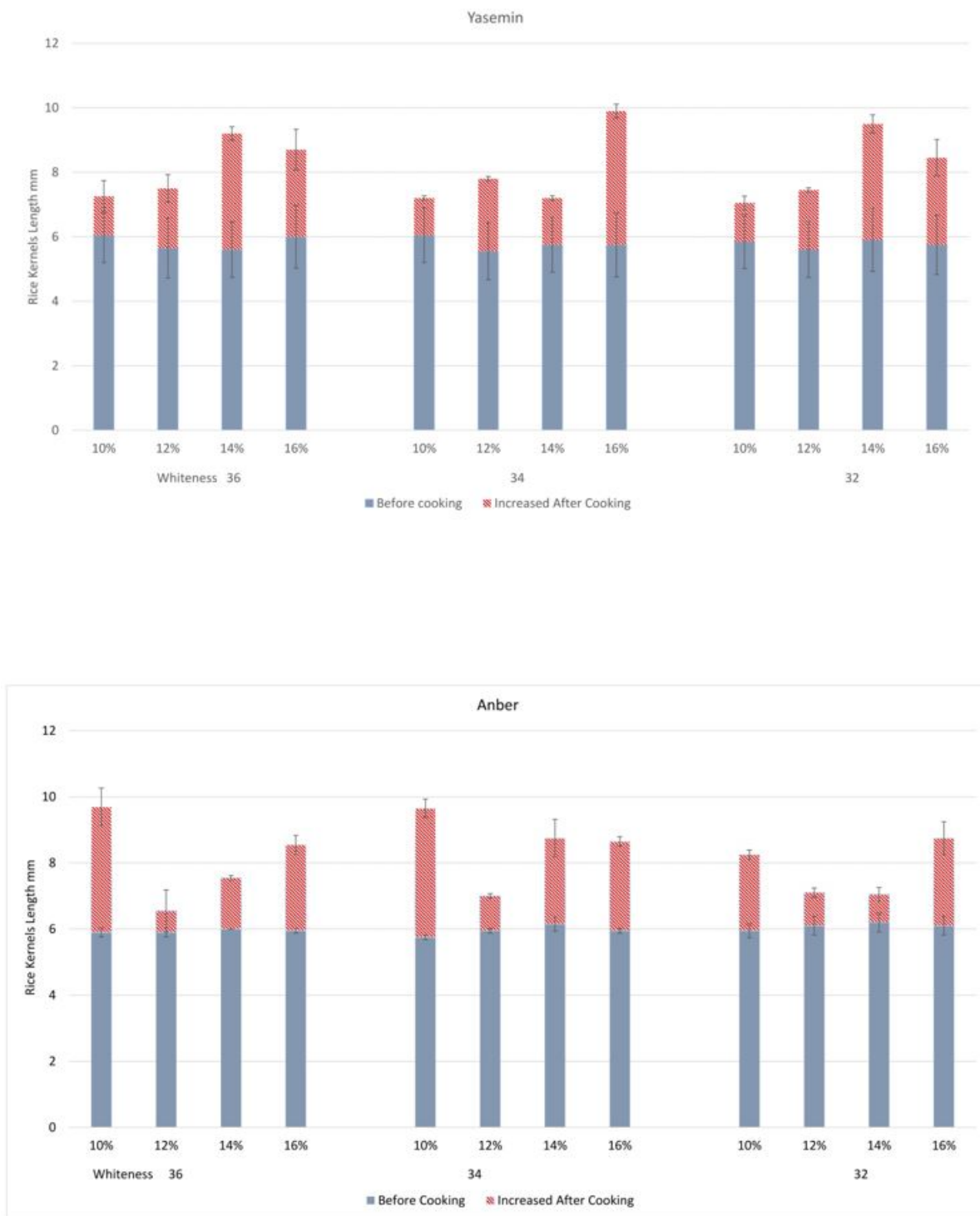
Figure 1. Kernels length (mm) of produced rice before cooking and length increment after cooking for Yasemin and Anber varieties with different MC and different whiteness.
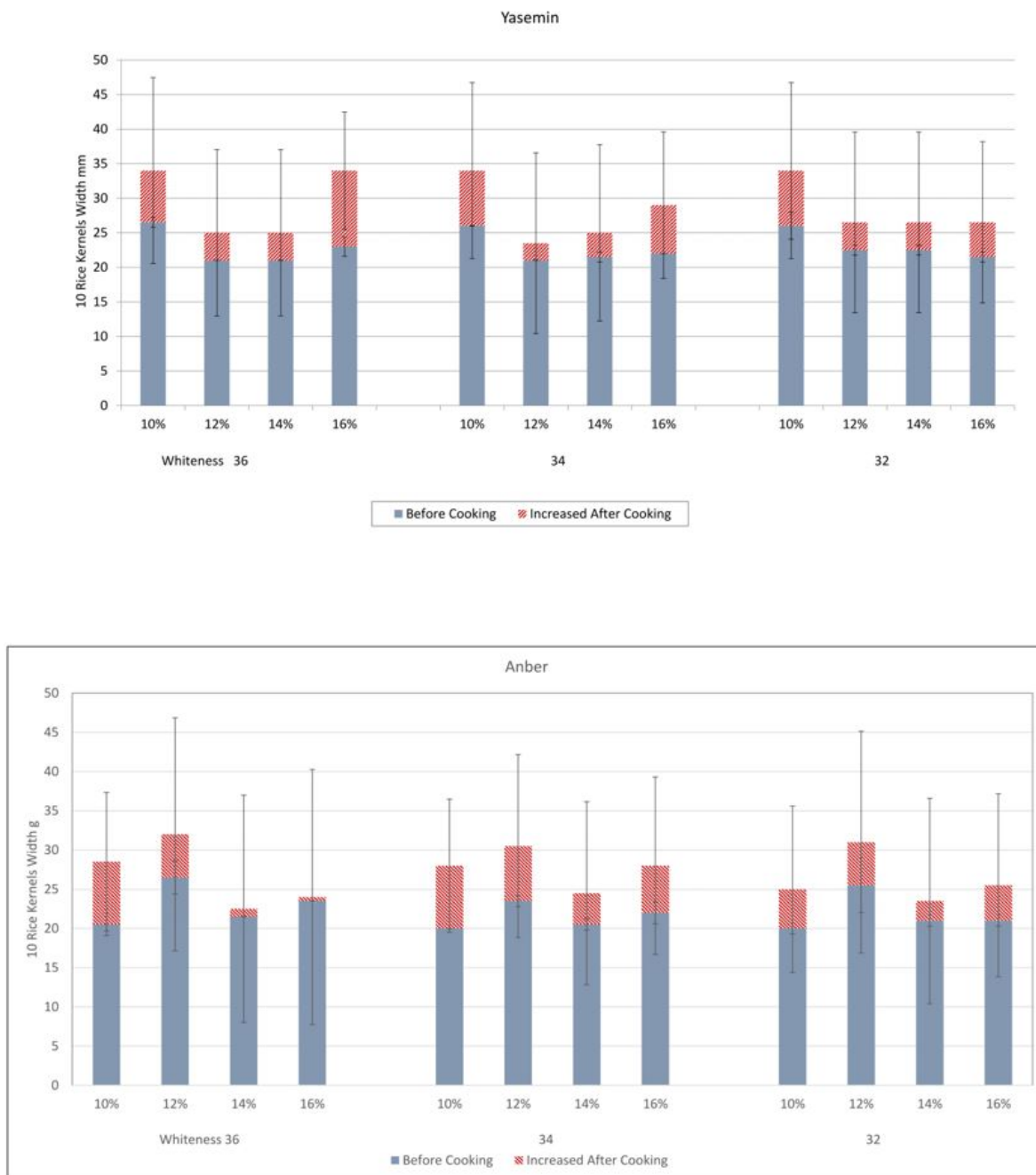
Figure 2. 10 kernels width (mm) of produced rice before cooking and the increment of width after cooking for Yasemin and Anber varieties with different MC and different whiteness.
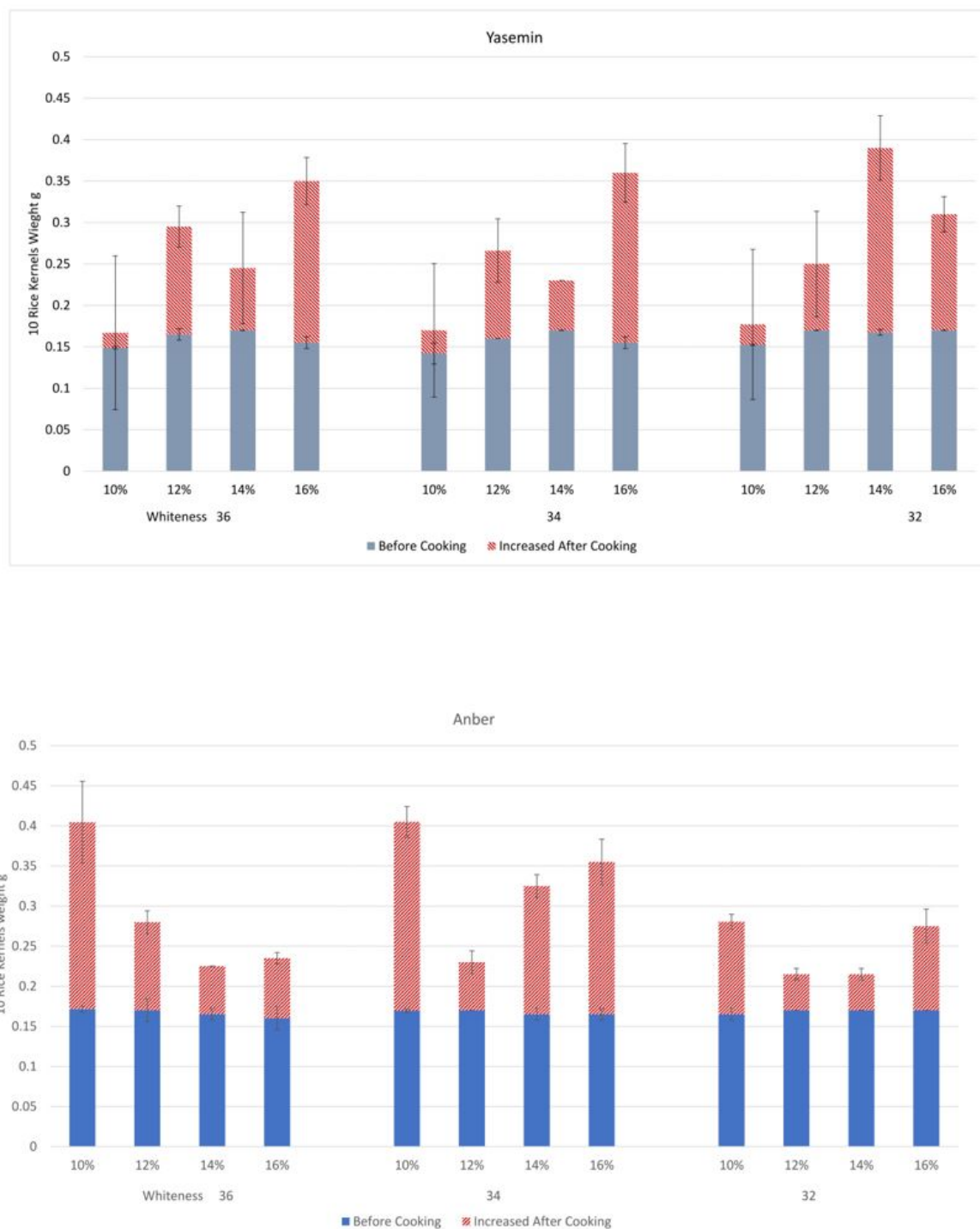
Figure 3. 10 kernels weight (g) of produced rice before cooking and the increment of weight after cooking for Yasemin and Anber varieties with different MC and different whiteness.

Rice whiteness increases with extending the degree of milling (DOM), which depends on rice variety (Billiris et al., 2012). Yasemin variety required less time to produce whiteness compared to Anber. Rice whiteness depends on some parameters such as chalkiness, size, and shape. Furahisha et al. (2016) mentioned that the whiteness index varied among cultivars due to unique chemical and physical properties, which affects milling features. The lowest acceptable whiteness in the rice industry in Iraq is 32 (GBI); however, higher rice whiteness is preferred by Middle East people (Lyon et al., 1999). Champagne et al. (1999) mentioned that 40 ± 2 was the target whiteness considered as typical of regular milled rice. Paddy with lower moisture

content needed less process time to obtain the exact whiteness compared with high moisture content (Table 1) and that is probably because the higher moisture content, the less friction occurred, which leads to increase the required time to obtain exact whiteness. Process time increasing leads to process cost increasing, which is higher with high MC of process paddy. Buggenhout et al. (2013) mentioned that process time increasing causes a high percent of rice breakage due to high temperature, but this does not agree with the result of this study for Yasemin variety, in which kernel breakage was higher with the lowest treatment time (lowest MC, 10%).

Extraction rate increasing of whole rice (head rice) is a fundamental aim in rice industry (Banasek & Siebenmorgen, 1990). Producing high whiteness rice causes extraction rate lowering because of more bran layers removal. In addition, high whiteness needs more process time, leading to kernel breakage increasing, which reduces the extraction rate. The extraction rate had a negative correlation with the percent of kernel breakage (Table 2 and 3); the higher extraction rates, the lesser kernel breakage detected. The extraction rate range of the two varieties with different moisture content was between 44% and 63%, and it was higher than the extraction rate mentioned by Sanusi et al. (2017), which was between 13% and 48% for four different varieties. While in the Rather et al. (2016) study the head rice percentage was between 66% and 68%. The highest extraction rate of Yasemin was with 14% MC (Table 2) and the lowest kernel breakage was with 14% MC (Table 3). However, Perdon et al. (2000) reported that moisture content of harvested paddy must be reduced to about 12% for safe storage purposes. While the highest extraction rate and lowest kernel breakage of Anber variety were with 10%. Furahisha et al. (2016) reported that 12% MC was to achieve the highest total rice yield. Moisture content causes differential stress inside the rice kernel that causes significant kernel fissure (Cnossen & Siebenmorgen, 2000). Rice breakage usually occurs due to harvesting, drying, dehulling, and milling when the applied forces exceed the grain strength. Therefore, the process intensity controls the broken rice percentage in addition to fissures, chalkiness, immaturity, and rice kernel dimensions (Buggenhout et al., 2013).

4.2 Cooking properties

People from different areas of the world prefer different sensory properties of rice. For example, in Middle East people prefer long, firm and non-sticky cooked rice; U.S. consumers prefer medium and long grain rice, while Japanese people prefer short and sticky rice (Lyon et al., 1999). Rice variety is one of the main features that affect the quality of produced rice due to the fundamental characteristics of each variety. One of the rice classifications depends on the length of the kernel. Long grain rice should be equal or more than 6.6 mm, medium grain rice should be equal or more than 6.2 mm, and less than 6.2 mm is considered short grain rice (Food and Agriculture Organization of the United Nations, 1995). Depending on this classification, Yasemin and Ander varieties are short grain rice. The longest grain was 6.2 mm of Anber variety, obtained from 14% MC with 32 whiteness. For Yasemin variety, the longest grain was 6.05 mm. Rice length increasing after cooking is also considered a quality parameter of the produced rice (Ge et al., 2005). Basmati 370, a famous variety, has more than 100% increase in length with a little increase in width after cooking (Tian et al., 2005). The elongation of produced rice was variable; the highest elongation was about 60% and that mostly occurs with 14% MC and 16% MC of Yasemin variety and 10% MC of Anber variety. These results agreed with the Rather et al. (2016) study, in which the rice elongation of three studied varieties was between 60% and 70%. The 14% and 10% MC treatment of Yasemin and Anber respectively were the best treatments in terms of high extraction rate and lower percent of broken kernel. The lowest elongation was 20% or less that occurred with 10% MC and 12% MC of Yasemin and Anber respectively. Tian et al. (2005) mentioned that elongation of different rice varieties was between <30% and >130%. The elongation of Yasemin and Anber is within the middle and lower percentage of the Tian et al. (2005) study.

Weng et al. (2008) reported that rice width of 46 rice cultivars was between 2.4 mm and 3.5 mm depending on the cultivars genetic. The rice width of Yasemin and Anber varieties were mostly lower than 2.4 mm;

however, the largest width was 2.6 mm for both varieties. High extension of rice volume after cooking is one of an unwanted features of a good quality rice (Ge et al., 2005). The increment of Anber variety was less than Yasemin variety and, in both varieties, the highest width extension was less than 50% of the original width (Figure 2). The highest increment occurred with 10% and 12% MC of Anber variety and with 10% MC of Yasemin variety in addition to some 16% MC treatments.

Increasing of rice weight after cooking refers to water absorption. The lesser the water absorption of cooked rice, the higher the rice quality (Ge et al., 2005). The weight range increasing mentioned by Perdon et al. (1997) was between about 50% and 210% of the initial rice weight depending on the moisture content of raw rice, rice storage period, and temperature of rice during storage. This range of weight increment of Yasemin was between 12% and 123% and for Anber was between 26% and 138% (Figure 3). The maximum weight increment of Yasemin variety was mostly with high MC (14% and 16%) of raw rice, while for Anber variety was with low MC (10%). Perdon et al. (1997) mentioned that the highest weight increment was with 8.8% MC and 13.6% MC at 30 °C.

5 Conclusion

According to their length, Yasemin and Anber varieties were classified as short grain rice. Extraction rate and kernel breakage of Yasemin and Anber varieties could be improved by using an appropriate moisture content during rice processing. 14% MC and 10% MC of Yasemin and Anber respectively were the best MC in terms of producing high extraction rate, lower kernel breakage, and high rice elongation. Increasing the required rice whiteness reduces the extraction rate. The initial moisture content of paddy had an effect on the cooking properties of the produced rice.

Acknowledgements

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