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RICE QUALITY VARIATIONS UNDER MICROWAVE DRYING

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ABSTRACT

Drying is a time-taking and high fuel-consuming process which is accompanied by environment pollution. Microwave technology can be employed as a remarkable approach due to lower cost of energy consumed, ease of application, reduction in time of process, and negligible environmental pollution. Nine different microwave treatments were compared with conventional hot-air oven (control) drying. The results revealed that head rice yield decreased when input power increased. The lowest input power (90 W) which had the least broken rice, showed a 3.66% difference to control treatment. By increasing input power, rice grains whiteness decreased significantly so that the least whiteness (23.13) was associated to input power of 900 W. Also, grain bending strength dropped from 101.8 (control) to 79.97 (the maximum input power). Water absorption of rice samples represented an increase when input power went up whereas gel consistency behaved inversely.

KEYWORDS: Rough Rice, Microwave Drying, Quality, Head Rice Yield

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INTRODUCTION

Microwave drying has acquired an impressive role in drying foodstuff due to high drying rate of materials and ease of utilization. In addition, this process has a significant impact on preventing infection and putrefaction of foodstuff. On the other hand, there won't be environment pollution and production of adverse chemicals (Banik et al., 2003).

Commonly, rough rice drying involves using hot air in which heat transfer through drying air causes moisture transfer to drying fluid. Moisture gradient between hot air and wet grain makes air grab and carry water from kernel. Rate of moisture transfer must be in a range so that grain would not encounter stress; otherwise crack formation would be inevitable which leads to higher broken rice during milling (Pinkrova et al., 2003).

In general, commercial dryers utilize drying air having temperatures of 35–60˚C (Banik et al., 2003). Basically, microwave drying differs from conventional hot air drying. In microwave drying, energy is carried by waves and transferred to material inside a processing chamber. Energy diffuses into rice grains through waves. Meanwhile, polarized molecules of water which are bound intensely start trembling under waves. This makes water – water bonds shatter and water molecules head towards outside of the grain (Banik et al., 2003). To facilitate outward moisture flow from the grain, vacuum creation or air movement around kernels is used.

Microwave drying has advantages such as high rate of drying, low processing time, ease of utilization, and negligible pollution of environment. Studies represented that microwave drying decreased agricultural crops pestered with mites and pests (Wang et al., 2002; Wang et al., 2003; Zhao et al., 2007). It was revealed that using microwave would be a good alternative for fumigants in controlling pests with stored rice.

On the other hand, there have been no losses in microwave drying compared with hot air methods. But, starch formation and its properties changed when high input power of microwave was used (Lewandowicz et al., 2000; Zhou et al., 2002; Banik et al., 2003). It has been also observed changes in protein of some foodstuffs (Verma et al., 2015), physicochemical properties like gelatin solubility (Le et al., 2014) and gelatinization (Jocelyn et al., 2000; Lewandowicz et al., 2000).

One of the microwave applications is in parboiling. In an investigation, a synthetic method of microwave and vacuum was applied so that paddy dried by means of microwave after it was parboiled. The effect of factors like input power, drying time, initial and final moisture content was examined on the rate and quality of drying. Drying rate had a direct relationship to input power while it related inversely to drying time. There was a constant drying rate until

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paddy moisture content reached to 16% and moisture gradient did not affect milling recovery. When moisture content was less than 16%, drying rate influenced head rice yield significantly when microwave was utilized (Wadsworth, 1994).

It was reported that microwave might impact on qualitative characteristics of rice such as cooking, and physicochemical properties (Zhao et al., 2007). It was showed that there was a negative correlation between head rice yield and drying time by microwave. Also, broken rice was correlated positively to drying time. Microwave drying reduced amylose content in varieties characterized with high amylose content. Microwave drying did not alter protein, fat, and ash levels. Also, there was no effect on cooking time of parboiled rice.

Experiments conducted to study the effect of microwave heating on protein solubility and on the functional properties of wheat and red bean (Ashraf et al., 2012). The results revealed that microwave treated samples were affected significantly. Also, it was mentioned that microwave heating of raw materials for a limited time period would be useful in determination of the quality of processed food.

This study aimed to investigate the effect of microwave drying on milling quality of rough rice.

Materials and methods

The experiments were carried out at the department of agricultural engineering research, Rice Research Institute of Iran (RRII), Rasht, Iran in the cropping season of 2015. A locally grown cultivar, Hashemi (long grain) was selected for tests. A field with proper maturity level was chosen and then paddy was harvested manually. To reduce paddy moisture content, harvested crop was left over across the field by a day. Later, crop was gathered and threshed by a tractor driven thresher. All impurities and grits were removed from paddy by hand. Clean paddy was placed in sealed plastic bags for upcoming tests. Initial rough rice moisture content was determined by a grain moisture meter (GMK-303 RS, Korea) which was 14.5% (w.b.) on average.

A microwave oven (SolarDom CP – 3493SCR/34L, LG, Korea) was used for drying samples. Also, as a control treatment, a conventional hot air oven (Memmert UE600, Germany) was employed for drying. In each run, 150 g of rough rice was spread onto a tray and placed inside oven. While moisture gradient was examined by grain moisture meter, drying process continued until they reached to 8.5±0.5% (w.b.). Microwave input power setups selected to be 90, 180, 360, 600, and 900 W. Initial tests represented that intermittent method should be used for input power of 90 W. Afterwards, dried samples were placed in fully sealed plastic bags. All treatments applied in the tests are given in Table 1.

Dried samples, then, were husked by a testing rubber roll husker (THU35B, SATAKE Corporation, Japan). The husked paddy milled by a laboratory friction type whitener (Baldor, McGill Miller No. 2, USA). Milled rice (broken and head rice) and bran were obtained in this step. A testing rice grader (TRG05B, SATAKE Corporation, Japan) which had an indented cylinder provided with precise separating of broken kernels from head ones.

The following traits were tested:

Brightness degree (BD)

The level of light which milled rice kernels reflected was recorded by a milling meter (MM1C, SATAKE Corporation, Japan). The digit which the device displays indicates the amount of whiteness or removed bran from kernel.

Head rice yield (HRY)

100 g of milled rice was graded by the testing rice grader. By definition, a grain having at least 75% of a whole grain length is considered as head rice. HRY is calculated by the following formula (Allameh and Alizadeh, 2013):

$$HRY = \frac{head\ rice\ weight}{rough\ rice\ weight} \times 100 \quad (1)$$

Milling recovery (MR)

Milling recovery depends on the type of variety and genetic characteristics and differs for various varieties. It is computed as follows (Allameh and Alizadeh, 2013):

$$MR = \frac{total\ milled\ rice\ weight}{rough\ rice\ weight} \times 100 \quad (2)$$

Grain bending strength (GBS)

From each treatment, ten kernels were selected and husked manually. Then, grain bending strength was recorded by a testing force gauge (FG-20 kg-232, Korea). Every single kernel was placed on a special stand and force was applied on the middle of the kernel. The amount of force at yield point was grain bending strength which was displayed by force gauge.

Gel consistency (GC)

Samples were initially kept in a room for two days to have their moisture contents balanced. Then, 100 mg flour from head rice kernels was provided while 0.2 ml Ethyl Alcohol containing Thymol blue 0.025% had been added to it. Next, 2 ml of potassium Hydroxide (0.2 mol.l-1) was added and contents were blended well by a shaker (Vortex Mixer, Stuart Sa8, UK). Afterwards, samples were placed in a hot water bath for 8 minutes. They were then cooled at room temperature for 5 minutes and placed in a cold water bath for 20 minutes. Later on, gel movement on a calibrated paper was recorded after one hour (Anderson and Guraya, 2006).

Water absorption capacity (WA)

In order to procure the amount of water absorbed by rice kernels during cooking, 40 ml distilled water was poured into a pot and then 5 g rice kernel was placed inside a mesh container and enclosed in the boiling pot. After cooking the sample, they were removed from mesh container and weighted. The amount of water absorbed and ratio of cooked rice to raw one were calculated by the following formulas (Takhur and Gupta, 2006):

$$cooked\ rice\ to\ raw\ rice\ ratio = \frac{weight\ of\ cooked\ rice}{weight\ of\ sample} \quad (3)$$

$$absorbed\ water = weight\ of\ cooked\ rice - weight\ of\ sample \quad (4)$$

Statistical analyses

The experiments conducted in a factorial arrangement laid out in an unbalanced design with three replications. Two main factors were as input power (at five levels of 90, 180, 360, 600, and 900 W) and drying manner (at two levels of intermittent and continuous). Dependent variables included HRY, MR, BD, GBS, GC, and WA. Means comparison performed using Duncan's multiple range tests. Data analysis took place through SAS 9 (2004, SAS Institute, US).

RESULTS AND DISCUSSION

The drying rate

The best characteristics of microwave technology are expedition in operation and lower waste of energy. In Figure 1 which shows the drying curve of Hashemi cultivar in all treatments, rough rice drying was performed very rapidly in this approach. There was a significant relationship between drying duration and moisture reduction for input power. In other word, having higher input power led to drying in a shorter duration. The shortest time for rough rice to be dried from 14.5% to 8.5% was associated to treatment 10 (900 W) whilst it took one hour for intermittent drying that employed input power of 90 W (treatment 2).

Head rice yield (HRY)

As table of ANOVA represents, there is significant difference among treatments in terms of HRY at 1% level (Table 2). Means comparison of treatments (Table 3) indicated that grain breakage raised dramatically when energy level and drying rate went up so that the least HRY (2.63%) obtained in T10 (900 W). Although, using intermittent drying treatments lowered the broken percentage in comparison with control treatment but, applied treatment differed significantly from control (3.66%).

Studies have shown that an increase in input power would raise broken percentage (Zhao et al., 2007; Le et al., 2014). The reason could be attributed to the effect of beam and rise of molecular movement on starch structure of a grain as well as water content which was extracted from a grain during drying process. Trembling molecules made starch molecules fracture. In this case, rice treated by input power of 900 W had a quite different odor so that it was tended to smolder.

Milling recovery (MR)

In Table 2, ANOVA for milling recovery displays that significant differences exist between treatments at 1% level. Means comparison for milling recovery (MR) did not display significant difference (Table 3). Milling recovery ranged between 70.03-73.70%.

Brightness degree (BD)

ANOVA for variations of brightness degree is shown in Table 2. There are significant differences between treatments at 1% level. Table 3 indicated that transparency of rice grains decreased when input power increased and rice appeared more dingy so that rice grains were quite bleary and scorched in T10. According to Zhao et al. (2007) and Verma et al. (2015), the reason was that starch molecular structure was affected by microwave input power. Kinetic energy of wave has been able to affect starch molecular structure and through rapid moisture removal, peculiarly colored reactions have occurred in treatments characterized with high input power. In moderate and low input power (90 W), rice grains were explicitly brighter.

Grain bending strength (GBS)

ANOVA for grain bending strength variations is represented in Table 2. Significant differences exist among treatments at 1% level. Means comparison for grain bending strength revealed that by increasing input power, strength of grains decreased so that GBS ranged 87.93 - 95.73 in input power of 90 W but it fell to 79.97 in input power of 900 W. Starch molecular bonds would lose their strength due to bearing microwave energy. The more input power, the less endurable grain against tension, and there would be a reverse correlation between input power and grain bending strength. In fact, energy radiated to grain has marred starchy texture of rice grain and its strength in consequence (Lewandowicz et al., 2000).

Water absorption capacity (WA)

ANOVA for water absorption variations is brought in Table 2. It shows clearly that there are significant differences between treatments at 1% level.

Means comparison for water absorption capacity was an indicative how samples absorbed more water when input power increased. However, the least water absorption was observed for control treatment. It could be stated that by raising input power, starch molecules encountered intermolecular fractures and starch chains shortened. Hereby, free starch chains became more unbound and because of high possibility of hydrogen bonds formation, samples attracted more water. This fact indicates breakdown of starch molecules chain or blocks (Pinkrova et al., 2003).

Gel consistency (GC)

In Table 2, ANOVA for gel consistency variations is represented. There are significant differences amid treatments at 1% level. Increasing input power led to reduction in gel consistency, i.e. the more input power raised, the less gel consistency obtained. Lowering gel consistency is a consequence of shortened starch chains as a result of molecules fractures which, in turn, comes from rise of input power (Anderson and Guraya, 2006; Zhao et al., 2007; Le et al., 2014; Verma et al., 2015;).

CONCLUSION

In general, increasing input power in microwave drying of rough rice revealed that because of rapid moisture removal from rice grain in a short time, starch molecules breakdown raised considerably. Ultimately, this caused an increase in broken rice, blear colored grains, more water absorption capacity, and reduction in gel consistency. These changes occurred as a result of intermolecular and starch chains fractures that could affect quantitative and qualitative properties of rice.

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Treatment	Input power (W)	Process duration (min)	Drying manner	Drying condition till final moisture content
1(control)	2400	1440	Conventional hot air oven	Hot air temperature of 42 ˚C
2	90	60	Intermittent	1 min. drying, 4 min. tempering
3	90	45	Intermittent	1 min. drying, 3 min. tempering
4	90	30	Intermittent	1 min. drying, 2 min. tempering
5	90	25	Intermittent	1 min. drying, 1 min. tempering
6	90	25	Continuous	Until final moisture content
7	180	16	Continuous	Until final moisture content
8	360	10	Continuous	Until final moisture content
9	600	7	Continuous	Until final moisture content
10	900	5	Continuous	Until final moisture content

Table 1: Experimental treatments used for tests

Source	df	Sum of Squares	f	p
HRY	9	12907.86	2495.72	0.0001**
error	20	11.49		
total	29	12919.36		cv=2.26%
MR	9	32.47	6.10	0.0004**
error	20	11.83		
total	29	44.31		cv=1.07%
BD	9	959.55	134.39	0.0001**
error	20	15.87		
total	29	975.41		cv=2.37%
GBS	9	1069.42	4.56	0.0023**
Error	20	521.60		
Total	29	1591.03		cv=5.70%
WA	9	113.17	322.42	0.0001**
Error	20	0.78		
Total	29	113.95		cv=0.44%
GC	9	287.08	159.49	0.0001**
Error	20	4.00		
Total	29	291.08		cv=0.88%

*: significant at 5%, **: significant at 1%, ns: not significant

Table 2: ANOVA for all traits variations under treatments in the tests

Treatment	Drying manner	HRY%	MR%	BD	GBS	WA	GC
Control	Hot air	57.40^{a}	71.83^{bc}	37.4^{d}	101.80^{a}	41.73^{g}	54.50^{a}
T2	1 min. drying, 4 min. tempering	53.77^{b}	70.53^{c}	42.33^{a}	91.23^{bc}	43.00^{f}	52.66^{b}
T3	1 min. drying, 3 min. tempering	52.10^{c}	71.47^{c}	41.10a^{bc}	95.73^{ab}	43.57^{e}	52.50^{bc}
T4	1 min. drying, 2 min. tempering	51.53^{c}	70.87^{c}	41.73^{ab}	87.93b^{cd}	43.57^{e}	52.00^{bcd}
T5	1 min. drying, 1 min. tempering	41.77^{d}	71.63^{bc}	40.73^{bc}	91.47^{bc}	43.43^{e}	51.83^{cd}
T6	Till final moisture content	41.26^{d}	71.30^{c}	41.73^{ab}	91.47^{bc}	43.30^{ef}	51.67^{d}
T7	Till final moisture content	20.33^{e}	73.70^{a}	39.93^{c}	86.80^{cd}	44.26^{d}	50.33^{e}
T8	Till final moisture content	10.13^{f}	73.43^{a}	34.63^{e}	84.80^{cd}	45.23^{c}	47.67^{f}
T9	Till final moisture content	4.37^{g}	72.87^{bc}	33.40^{e}	83.77^{cd}	47.30^{b}	45.83^{g}
T10	Till final moisture content	2.63^{h}	70.03^{d}	23.13^{f}	79.97^{d}	48.40^{d}	44.50^{h}

In each column, figures having the same letter are not significant at 5% level

Table 3: Means comparison for traits tested in different treatments

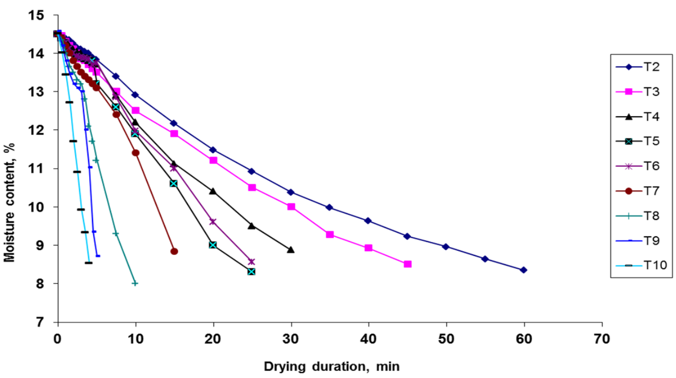

Figure 1: Drying curve for all treatments used in tests