EFFECT OF HEATING ON BROWN RICE COMPOSITION AND QUALITY[1]

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ABSTRACT

The effects of heating temperature, of moisture content of rice to be heated, and of heating time on many properties of rice were studied in three experiments. Enzyme activity, reducing sugar content, and acidity of water-extract changed during heating, and were good indicators for judging changes in quality of rice. Enzyme activities went down, reducing sugars increased, and acidity of water-extract decreased. Viability of rice (14.3% moisture) was well preserved even after heating at 60°C. for 1 hr., but was destroyed by heating at 70°C. for 1 hr. Cooking quality tests of heated rices confirmed that heating has an effect similar to that of aging on rice texture, but no effect on fat acidity or on gelatinization temperature of rice flour. High-moisture rices showed less resistance to heating than low-moisture rices. Heating temperature was a greater factor than heating time, and only the increase in reducing sugars was much influenced by heating time.

Several studies to determine food quality of rice during storage have sought a sensitive means for measuring decrease in its quality. Changes in fat acidity, nonreducing sugars (1), and enzyme activity, especially that of catalase (2), are sensitive indicators under ordinary storage conditions, according to reports.

However, when rice is heated, as in drying, the mechanism of deterioration may differ and the usual indicators may not be useful. McFarlane *et al.* (3) reported the effect of heating on percentage germination. But germination percentage is not necessarily a sensitive indicator of small changes in food quality of rice, and may be maintained after other properties have changed appreciably (1,2,4). For instance, rice heated for 1 hr. at 60°C. retains its germination percentage but is considered by many rice eaters as having poor food quality.

The present study of changes in a number of properties of rice when it is heated was made to determine the most sensitive indicators for judging accompanying changes in food quality. These indicators not only may be useful in practical drying and processing, but also may provide information on the mechanisms that produce the changes.

Materials and Methods

Separate experiments were planned, investigating several variables, one at a time, to clarify the complicated interconnected factors. Individual experiments examined the effects on composition and quality of variation in tempera-

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ture at constant moisture, of moisture variation at a single temperature, and of time of heating at fixed moisture and temperature.

The rice varieties studied were Mihonishiki, Norin No. 22, and Norin No. 29, all short-grain rices produced in Japan.

Brown-rice samples were prepared from rough rice with rubber-roll shellers to minimize bran damage. The samples were stored in a cold room until examined. Portions were milled to white rices for examination of cooking quality, and portions of the white rice were ground to 60-mesh for amylograph measurement and determination of water-soluble substance. Moisture adjustment of rices used in experiment II was made by the procedure of Milner and Geddes (5).

Properties measured were: moisture content, germination percentage, acidity of water-extract, fat acidity, peroxide content, reducing sugar content, catalase activity, alpha-amylase activity, beta-amylase activity, water-soluble substance, cooking qualities, and specific amylogram values. All these properties were determined in experiment I, and those showing important differences among samples were also determined in experiments II and III.

Moisture content was determined in an oven for 5 hr. at 105°C.; acidity of water-extract by the AOAC method (6); fat acidity by the AACC method (7); peroxides according to Hills and Thiel (8); reducing sugars by the Hanes method (9). Catalase activity was determined with the modification of Euler-Josephson (10), and was shown by the velocity constant "K"; alpha-amylase activity by Fuwa's blue value (11); and beta-amylase activity by measuring reducing sugars by the Hanes method at the start and end of the reaction.

The amount of water-soluble substance of ground white rice was determined by extracting 5 g. ground white rice with 50 ml. of distilled water at 30°C. for 1 hr. and measuring solids by drying the extract at 105°C. for 18 hr. Cooking qualities of white rice were determined by a modification (12) of the method of Batcher *et al.* (13). Gelatinizing and pasting characteristics of ground white rice were measured with the Brabender Amylograph by the modification of Halick and Kelly (14): 40 g. (dry basis) of ground white rice was suspended in 450 ml. of distilled water and heated from 30° to 92°C. at the rate of 1.5°C. per min., kept for 20 min. at 92°C., and then cooled to 30° at the rate of 1.5° per min. The setback on cooling was evaluated at 30°.

In the study of effect of heating temperature, Mihonishiki brown rice at 14.3% moisture was heated in loosely stoppered tubes in a water bath for 1 hr. at 50°, 60°, 70°, and 80°C. and the heated rices were compared with an unheated control portion. Moisture loss of rices during heating was little: in most cases below 0.2%; 0.5% maximum.

In the study of moisture content effect, portions of Norin No. 22 brown rice were adjusted to 15, 17, 19, and 21% moisture and heated as in the previous experiment for 1 hr. at 60°C. Comparisons were made with an unheated portion of the rice having 14.3% moisture.

Norin No. 29 brown rice with 14.8% moisture was used to study the effect of heating time. Portions were heated at 60°C. for 1, 2, and 4 hr. and at 70°C. for 1 and 4 hr. Comparisons were made with an unheated portion.

Results and Discussion

Results of experiment I, effect of temperature, indicated (Table I) as follows:

Ability of rice to germinate was well preserved at 60° but was completely lost at 70°C. These results coincide with results of experiments by McFarlane *et al.* (3).

Changes in acidity of water-extract, and in pH of residual liquid in the cooking-quality test, were typical effects of heating. In both cases, rice became more alkaline during heating. As the amount of free volatile acids is small, changes in acidity would not be accounted for by evaporation of volatile acids.

Fat acidity is a good indicator for judging deterioration during storage (1,4), but heating had no effect on fat acidity. It is impossible to use fat acidity as an indicator for judging deterioration during heating.

The water-soluble substance approximates the combined amounts of water-soluble carbohydrates and water-soluble protein. Both water-soluble carbohydrates (1) and water-soluble protein (2) are good indicators for judging deterioration during storage. The water-soluble substance changed appreciably even by 1-hr. heating at 50°C. and it was definitely sensitive to heating, although the change was not always proportional to the increase in temperature. It is difficult to use this test as an indicator for judging deterioration during heating.

TABLE I

EFFECT OF HEATING TEMPERATURE ON BROWN RICE CHARACTERISTICS

(Mihonishiki variety, 14.3% moisture, 1 hr. heating)

CHARACTERISTIC AND UNIT	UNHEATED CONTROL	HEATING TEMPERATURE (°C.)			
		50	60	70	80
Germination, %	100	100	100	0	0
Acidity of water extract, mg. KOH/100 g. d.m.	114.4	111.0	95.2	80.1	71.0
Fat acidity, mg. KOH/100 g. d.m.	27.1	25.1	25.3	26.9	26.5
Water-soluble substance, g./100 g. d.m.	1.29	1.08	0.97	1.01	0.94
Peroxide content, μmol. oxygen/kg. d.m.	0.81	0.68	0.58	0.41	0.72
Reducing sugars, mg. glucose/100 g. d.m.	189.0	189.3	192.2	197.3	200.1
Enzyme activity					
Catalase, K × 100	5.32	5.12	4.60	2.04	0.24
Alpha-amylase, % decrease in light abs.	14.8	14.1	9.2	6.8	0
Beta-amylase, mg. glucose produced	61	51	49	35	23
Cooking quality, pH	6.8	7.3	7.3	7.4	7.5
Water uptake, %	268	257	264	269	266
Expanded volume, ml.	31.4	32.7	32.7	35.2	35.2
Total solid, mg.	230	220	142	148	198
Iodine blue value, light abs./mg. solid	0.181	0.169	0.218	0.205	0.230
Amylograph					
Gelatinization temperature, °C.	66	66	66	66	66
Maximum viscosity, B.U.	435	450	445	470	610
Breakdown, B.U.	145	155	165	165	215
Setback, B.U.	285	325	280	280	365

Considering the reasons for the increase in reducing sugars, the effect of amylase activity must be small; this increase was greater at higher temperature, though amylase was inactivated at the higher temperature. Decomposition of glycosides during heating might account for a large part of the reducing sugar increase.

Beta-amylase is easily destroyed at high temperature in solution, and heating beta-amylase solution at 80°C. for 1 hr. is enough to destroy the activity completely. On the other hand, beta-amylase in grains is not completely destroyed even by heating at 80°C. for 1 hr. This suggests that beta-amylase in rice grains is protected from thermal destruction by some mechanism.

Among the changes in cooking qualities, the increase in rice expansion and the decrease in substance soluble in cooking water were considerable and may be attributed mainly to the difference in texture and denaturation of protein. The authors found similar changes in rices during storage (2), and Hogan (15) reported similar differences in cooking quality during aging and heating.

Gelatinization temperature did not change among the specific amylogram values. On the other hand, maximum viscosity, breakdown, and setback tended to increase.

It may be concluded generally from experiment I that:

Although changes in a few characteristics were proportional to the higher temperature, most characteristics changed abruptly at specific points of temperature; those points are, so to speak, the limit of keeping stability. Above these points reactions start suddenly or are accelerated abruptly. The existence of these specific points may enable the stepwise evaluation of degrees of quality changes in rice during heating.

Some rice properties show complicated changes which are not considered to be single reactions but combinations of two or more kinds of reactions occurring at the same time or consecutively.

It is impossible to conclude much about the effect of heating upon organoleptic properties of cooked rice, judging only from the characteristics investigated in this experiment. But heat-treated rice expands more during cooking than nonheated rice, and the amount of substance soluble in cooking water of heat-treated rices is smaller than that of nonheated rice.

Changes in cooking quality during heating are similar to those during aging. Those changes are not favored by people who prefer fresh, sticky rice to aged, nonsticky rice, but some degree of change during heating may be welcome to people who like aged, nonsticky rice.

Many kinds of changes in rice properties were distinctive when rice was heated at 60°C. for 1 hr. Moreover, considerable change in texture and some off-flavor were detected when rice heated at 60°C. for 1 hr. was cooked and eaten. It is clear that rice quality definitely deteriorates in 1-hr. heating at 60°C.

Some change was noticeable in acidity of water-extract, soluble substance of white rice flour, volume expansion, and total solids in cooking water, even in rice heated at 50°C. for 1 hr.; a slight change in eating quality was also detected. The safe limit of heating during artificial drying, at the stage when rice moisture is around 14%, must be below 50°C. if complete preservation

of rice quality is required; lower than this when the moisture is higher, as described later.

TABLE II

EFFECT OF GRAIN MOISTURE ON CHARACTERISTICS OF HEATED BROWN RICE
(Norin No. 22 variety, 14.3% moisture. Heated at 60°C. for 1 hr.)

CHARACTERISTIC AND UNIT	UNHEATED CONTROL	MOISTURE CONTENT %			
		15	17	19	21
Germination, %	100	96	96	90	24
Acidity of water extract, mg. KOH/100 g. d.m.	129.8	110.0	111.7	105.4	119.8
Reducing sugars, mg. glucose/100 g. d.m.	191.4	194.4	209.6	259.0	361.2
Enzyme activity					
Catalase, K × 100	5.64	4.64	2.64	1.96	0.60
Alpha-amylase, % decrease in light abs.	17.6	16.8	7.5	4.6	0
Beta-amylase, mg. glucose produced	90	80	74	58	22
Cooking quality, pH	7.0	7.3	7.4	7.4	7.5
Water uptake, %	242	240	240	239	259
Expanded volume, ml.	34.5	35.8	36.9	37.7	37.7
Total solid, mg.	386	420	400	508	544
Iodine blue value, light abs./mg. solid	0.164	0.248	0.219	0.266	0.359

Results of experiment II (Table II) indicated that the higher the rice moisture, the more sensitive rice is to heating. McFarlane *et al.* (3) reported a similar tendency, but determined germination percentage only and did not make comparison with other measures of change.

Germination percentage of rice having 17% moisture showed little change after 1-hr. heating at 60°C.; on the other hand, in rice with 21.6% moisture it reached the very low value of 24%.

The acidity of water-extract of all samples decreased, but the trend of decrease showed no definite correlation to rice moisture.

The reducing sugar content of all samples increased, and markedly so in rices with moisture above 19%.

The decrease in enzymatic activities of high-moisture rices was more distinctive than that of low-moisture rices, and the effect of moisture increase on enzymatic activities was very similar to that of temperature increase. Activity of catalase and of alpha-amylase was extremely sensitive to heating when moisture was high; in rice with 17% moisture it was almost half that of 15% moisture rice after heating. Because these two enzymes are unstable, they are good indicators for judging rice quality (2,4,16). The rather high temperature (60°C.) was adopted in experiment II to magnify the effects of rice moisture during heating; experiments at lower temperatures will be necessary to determine safe limits of heating for high-moisture rices.

The effects of heating on individual characteristics which are sensitive enough to be indicators for judging rice quality from the results of experiments I and II indicated that:

Changes were significant in acidity of water-extract, beta-amylase activity, water-soluble substance of ground white rice, and total solid soluble in cooking water even by heating at 50°C. for 1 hr.

The change in acidity of water-extract has little relation to the moisture of the rice to be heated; on the other hand, the change in reducing sugar content is much influenced by rice moisture.

Good indicators of the effect of heating temperature are acidity of water-extract, catalase activity, alpha-amylase activity, and beta-amylase activity.

Good indicators of the effect of different rice moisture content are reducing sugar content, catalase activity, and alpha-amylase activity.

Measures of catalase activity, alpha-amylase activity, acidity of water-extract, beta-amylase activity, and reducing sugar content are recommended for judging quality in general of rice artificially dried or processed.

TABLE III

EFFECT OF HEATING TIME ON BROWN RICE CHARACTERISTICS

(Norin No. 29 variety, 14.8% moisture)

CHARACTERISTIC AND UNIT	UNHEATED CONTROL	HEATING TIME AND TEMPERATURE				
		60°C.			70°C.	
		1 hr.	2 hr.	4 hr.	1 hr.	4 hr.
Germination, %	100	98	98	89	0	0
Acidity of water extract, mg. KOH/ 100 g. d.m.	110.3	84.1	78.4	76.5	61.7	62.9
Reducing sugars, mg. glucose/100 g. d.m.	186.0	189.0	188.5	194.2	189.3	221.5
Enzyme activity						
Catalase, K × 100	6.60	6.20	5.96	5.32	2.08	0.76
Alpha-amylase, % decrease in lights abs.	12.5	10.0	7.6	7.9	4.9	3.6
Beta-amylase, mg. glucose produced	65	59	53	52	28	28

The results of experiment III (Table III) showed that the longer the heating time, the larger were changes in rice properties. Also, the effect of duration of heating was greater at 70° than at 60°C. But in almost all characteristics, the effects of heating time were small compared with the effects of temperature; the change in reducing sugars was the only exception, showing a greater increase after 4-hr. heating at 60°C. than after 1-hr. heating at 70°C.

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