# Influence of Water Activity and Temperature on Dehulling of Buckwheat

G. MAZZA and C. G. CAMPBELL[1]

## ABSTRACT

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Dehulling and moisture sorption characterisitics of three buckwheat cultivars were determined at water activities of 0.11–0.98 and at 1, 10, 25, and 40° C. The dehulling recovery varied among cultivars and water activities of the seed. Of the three cultivars, Mancan yielded the most groats and CM 169 yielded the least. The dehulling yield of each cultivar decreased as the water activity of the seed increased but was essentially unaffected by temperature. The amount of whole groats in the dehulled fraction was constant at water activities of 0.11–0.50 but more than doubled as the water activity was increased from 0.50 to 0.98. The optimum water activity for minimizing the rate of degradation of buckwheat seed during storage and for maximizing the dehulling yield and percentage of whole groats was approximately 0.18.

Buckwheat (*Fagopyrum esculentum* Moench.) is a cool climate dicotyledonous plant that has been adapted to a short growing season and high elevations. It is grown primarily in Russia, Poland, Canada, Japan, France, and the northern United States. In eastern Europe, buckwheat flour is a basic food item in porridges and soups. In North America, it is marketed primarily as pancake mixes, which may contain buckwheat mixed with wheat, corn, rice, or oat flours, and a leavening agent. Buckwheat is also used in mixtures with wheat flour for bread, noodles, spaghetti, macaroni, ready-to-eat breakfast flakes, health foods, and ethnic dishes. In Japan, buckwheat is marketed as flour for manufacturing noodles and as groats for a variety of products. Groats, that part of the grain left after the hulls are removed from the seeds, and farina made from groats are used for breakfast food, porridge, and thickening materials in soups, gravies, and dressings (Taira 1974, Marshall and Pomeranz 1982).

Dehulling buckwheat, which is done by passing the buckwheat seed between a stationary and a rotating abrasive stone, is necessary for the production of groats. Moisture content and temperature of the seed, as well as seed size and shape, although suspected of influencing the dehulling characteristics of buckwheat, have hitherto received no attention. Consequently, the work presented here includes the influence of water activity, temperature, and cultivar on dehulling buckwheat, as well as adsorption isotherms of undehulled seeds.

## MATERIALS AND METHODS

Two commercial cultivars, Mancan and Tokyo, and an experimental line, CM 169, grown at the Agriculture Canada Research Station in Morden, Manitoba, were used. The samples were cleaned to remove sand, weeds, and small and immature buckwheat seeds; dried at 30° C to reduce the moisture content to approximately 5%; and placed in vacuum desiccators containing saturated salt solutions, which give different constant relative humidities (Rockland 1960). The desiccators were kept in a constant temperature cabinet (± 0.5° C) until equilibrium was reached. The time required for the samples to reach equilibrium varied with the relative humidity and the temperature. Relative humidities of 11–98% and temperatures of 1, 10, 25, and 40° C were used.

After equilibrium was reached, determined by periodic weighing of the samples, each sample was divided into two subsamples. One 20-g subsample was used to determine the moisture content, by drying it in a vacuum oven at 70° C and 101 kPa vacuum for 24 hr, and one 100–150-g subsample was dehulled with the dehulling unit described by Campbell and Chubey (1985). The dehulling was done within 2 min from the time the sample was taken out of constant temperature and relative humidity conditions by passing the buckwheat seed once between a stationary and a rotating emery stone. The spacing between the stones was adjusted to accommodate different sized material. The dehulled seed was weighed and the percentage reported as dehulling recovery. The broken or damaged groats were separated from the whole groats by screening and hand picking, and each fraction was weighed to determine the yield and was assessed for color.

Color was measured on a Hunter Lab model D25 colorimeter. The Hunter *L*, *a*, and *b* scales measure color in units of approximate visual uniformity throughout the solid: *L* measures lightness and varies from 100 for perfect white to zero for black; *a* measures redness when positive and greenness when negative; and *b* measures yellowness when positive and blueness when negative.

Adsorption isotherms were obtained by plotting the moisture content of the samples, expressed as kg $H_2O$/kg dry matter (DM), versus water activity ($a_w$) or vapor pressure (Pa).

[1]Agriculture Canada, Research Station, Morden, Manitoba, R0G 1J0, Canada.

## RESULTS AND DISCUSSION

Moisture content of seeds, dehulling recovery, percentage of whole and broken groats, and Hunter color values of the groats of Mancan, Tokyo, and CM 169 buckwheat equilibrated and dehulled at 25° C and 0.11–0.97 water activity are shown in Table I. In the 0.11–0.75 water activity range, the equilibrium moisture contents of the three buckwheat cultivars were approximately the

**TABLE I**
**Influence of Cultivar and Moisture Content on Dehulling Characteristics and Color of Buckwheat Seeds Stored at 25°C and Water Activities of 0.11–0.97 for 45 Days**

| | | | | Dehulled Groat | | Hunter Color Values[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Moisture | Dehulling | | | Whole Groat | | | Broken Groat | | | Mixed Groat | | |
| Cultivar | Water Activity | Content (%) | Recovery (%) | Whole (%) | Broken (%) | *L* | *a* | *b* | *L* | *a* | *b* | *L* | *a* | *b* |
| Mancan | 0.11 | 4.42 | 68.6 | 36.9 | 63.1 | 52.7 | −0.1 | + 19.3 | 64.1 | +0.3 | +14.1 | 64.6 | −0.2 | +13.9 |
| | 0.23 | 5.98 | 69.2 | 30.1 | 69.9 | 52 | +0.1 | +19.6 | 68.7 | +0.3 | +12 | 63.5 | +0.1 | +14.8 |
| | 0.33 | 7.27 | 67.9 | 34.3 | 65.7 | 51.5 | +0.4 | +19.1 | 60 | −0.3 | +17 | 64.7 | −0.1 | +14.6 |
| | 0.52 | 9.79 | 67 | 33.3 | 66.7 | 53 | −0.1 | +19.6 | 60 | +0.4 | +16.3 | 58.7 | +0.5 | +16.5 |
| | 0.67 | 12.3 | 65 | 39.2 | 60.8 | 53.8 | +0.3 | +19.4 | 61.5 | +0.1 | +15.3 | 55.9 | +0.3 | +18.2 |
| | 0.75 | 13.47 | 65.4 | 44.5 | 55.5 | 52.3 | +0.3 | +19.1 | 56.5 | −0.4 | +16.9 | 57.4 | +0.4 | +16.8 |
| | 0.86 | 15.3 | 65.6 | 48.9 | 51.1 | 52.1 | +0.6 | +19.1 | 55.9 | +0.5 | +16 | 54.8 | +0.4 | +16.9 |
| | 0.97 | 19.8 | 65 | 68.5 | 31.5 | 51 | +0.4 | +18.4 | 57.87 | +1.3 | +15.1 | 53.2 | +0.7 | +17.7 |
| Tokyo | 0.11 | 4.36 | 65.2 | 31.8 | 68.2 | 51.9 | +0.6 | +19.3 | 64.6 | +0.2 | +13.2 | 60.5 | +0.4 | +15.4 |
| | 0.23 | 5.84 | 66.3 | 28.7 | 71.3 | 51.7 | +0.7 | +19.5 | 62.7 | +0.5 | +14.6 | 60.6 | +0.3 | +16 |
| | 0.33 | 7.23 | 65.4 | 30.4 | 69.6 | 52.6 | +0.5 | +19.6 | 60 | −0.2 | +16.3 | 64.7 | +0.6 | +13.6 |
| | 0.52 | 9.77 | 60.5 | 33.5 | 66.5 | 51.1 | +0.7 | +19.1 | 58.4 | +0.1 | +16.7 | 57.6 | +1.3 | +17.6 |
| | 0.67 | 12.22 | 58.8 | 36.7 | 63.3 | 51.6 | +0.8 | +19 | 63.1 | +1 | +13.6 | 59.1 | +1.1 | +16 |
| | 0.75 | 13.3 | 58.2 | 45.5 | 54.5 | 51.3 | +0.7 | +19.1 | 54.8 | +0.3 | +17.5 | 54.6 | +0.8 | +18.8 |
| | 0.86 | 14.3 | 56.5 | 46.4 | 53.6 | 51.1 | +1.3 | +19.1 | 54.2 | +0.5 | +16.8 | 58.4 | +1 | +15.8 |
| | 0.97 | 18.74 | 51.6 | 75.1 | 24.9 | 50.3 | +1.8 | +18.1 | 58.3 | +1.1 | +14.7 | 52.1 | +1 | +18.6 |
| CM 169 | 0.11 | 4.46 | 52.5 | 37 | 63 | 51.8 | +1.7 | +19.6 | 64.5 | +0.5 | +13.9 | 62.4 | +1.1 | +15.3 |
| | 0.23 | 5.93 | 54.9 | 37.1 | 62.9 | 52.6 | +1.4 | +20 | 60.6 | +0.8 | +16.7 | 59 | +1 | +17 |
| | 0.33 | 7.34 | 52.8 | 37.3 | 62.7 | 52.1 | +1.1 | +19.6 | 59.5 | +0.9 | +16.1 | 63.6 | +0.7 | +15.1 |
| | 0.52 | 9.90 | 50.4 | 35.7 | 64.3 | 52.9 | +1.9 | +19.6 | 58 | +0.7 | +17.3 | 58.9 | −0.7 | +17.3 |
| | 0.67 | 12.35 | 47.7 | 41.8 | 58.2 | 52.6 | +1.5 | +19.7 | 60.5 | +1.1 | +15.3 | 54.3 | +1.7 | +18.8 |
| | 0.75 | 13.5 | 41.6 | 48.4 | 51.6 | 52.9 | +1.5 | +19.7 | 56.6 | +1.4 | +17.6 | 54.5 | +1.2 | +18.8 |
| | 0.86 | 14.68 | 40.1 | 55 | 45.6 | 52.3 | +2 | +19.5 | 67.8 | +1.3 | +11.7 | 56 | +2 | +17.9 |
| | 0.97 | 19.13 | 32.5 | 61.5 | 38.5 | 51.7 | +2.1 | +19 | 61.3 | +1.7 | +13.5 | 53.2 | +0.4 | +15.4 |

[a] *L* = lightness; *a* = redness when + and greenness when −; *b* = yellowness when + and blueness when −.

**TABLE II**
**Dehulling Characteristics and Color of Mancan, Tokyo, and CM 169 Buckwheat Seeds Stored at 40°C and Water Activities of 0.11–0.96 for 23 Days**

| | | | Dehulled Groat | | Hunter Color Values[a] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Dehulling | | | Whole Groat | | | Broken Groat | | |
| Cultivar | Water Activity | Recovery (%) | Whole (%) | Broken (%) | *L* | *a* | *b* | *L* | *a* | *b* |
| Mancan | 0.11 | 70.6 | 41.1 | 58.9 | 51.9 | 1 | 18.6 | 64.5 | 0.6 | 13.5 |
| | 0.23 | 68.4 | 42.1 | 57.9 | 52.3 | 0.4 | 19.2 | 59.3 | 0.4 | 16 |
| | 0.31 | 69.7 | 41.5 | 58.5 | 50.1 | 1.5 | 18.8 | 61.2 | 0.6 | 15.5 |
| | 0.51 | 69 | 42.6 | 57.4 | 51.2 | 0.9 | 18.6 | 62.3 | 0.8 | 14.5 |
| | 0.67 | 68.7 | 52.3 | 47.7 | 51.9 | 1.7 | 18.9 | 60 | 0.9 | 15.1 |
| | 0.75 | 69.9 | 67.6 | 32.4 | 51.7 | 2.1 | 19.1 | 65.6 | 1.1 | 13.2 |
| | 0.83 | 70.1 | 70.2 | 29.8 | 50.6 | 2.5 | 18.5 | 60.1 | 1.6 | 13.8 |
| | 0.96 | 61.7 | 90.4 | 9.6 | 48.2 | 2.9 | 17.6 | 61.7 | 1.7 | 12.2 |
| Tokyo | 0.11 | 58.4 | 58.9 | 41.1 | 51 | 0.7 | 18.5 | 61.3 | 0.8 | 14.2 |
| | 0.23 | 56.5 | 59.2 | 40.8 | 49.9 | 1.2 | 18.7 | 62.4 | 0.7 | 14.5 |
| | 0.31 | 55.3 | 61.8 | 38.2 | 52 | 2.2 | 19.7 | 63.4 | 1.1 | 14.9 |
| | 0.51 | 52.7 | 61.8 | 38.2 | 52.3 | 2.6 | 18.8 | 60.8 | 1.4 | 15.7 |
| | 0.67 | 42.3 | 77.2 | 22.8 | 51.2 | 1.8 | 19.3 | 63.1 | 1 | 14.3 |
| | 0.75 | 40.4 | 82.6 | 17.4 | 51 | 2.3 | 19 | 62.8 | 1.4 | 13.7 |
| | 0.83 | 39.4 | 87.4 | 12.6 | 50.7 | 2.5 | 18.7 | 59.5 | 1.6 | 15.4 |
| | 0.96 | 28.6 | 92.7 | 7.3 | 48.8 | 3.1 | 18.3 | 60.1 | 1.1 | 14.9 |
| CM 169 | 0.11 | 55.2 | 33.1 | 66.9 | 51.3 | 2.2 | 18.8 | 62.6 | 1.5 | 13.5 |
| | 0.23 | 53.4 | 33.7 | 66.3 | 51.4 | 2.3 | 19.2 | 63.3 | 1.4 | 14.3 |
| | 0.31 | 54.7 | 29.7 | 70.3 | 51.9 | 0.3 | 19.3 | 61.5 | 0.4 | 15.2 |
| | 0.51 | 51.1 | 32.5 | 67.5 | 51 | 0.5 | 18.7 | 62.5 | 0.7 | 15.7 |
| | 0.67 | 50.1 | 45 | 55 | 52 | 3 | 19.2 | 62.2 | 1.7 | 15.1 |
| | 0.75 | 46.3 | 64 | 36 | 50.6 | 3.4 | 18.8 | 57.5 | 2.5 | 15.9 |
| | 0.83 | 46.1 | 63.2 | 36.8 | 51.2 | 3.3 | 19.2 | 58.6 | 2.6 | 15.4 |
| | 0.96 | 35.7 | 79.5 | 20.5 | 48.1 | 4 | 18.3 | 59.5 | 2.7 | 12 |

[a] *L* = lightness; *a* = redness; *b* = yellowness.

same. At water activities of more than 0.75, Mancan adsorbed more water than CM 169 and Tokyo, and CM 169 adsorbed more than Tokyo.

The adsorption isotherms of CM 169 buckwheat at 1, 10, 25, and 40° C are shown in Figure 1. When the data for Mancan and Tokyo buckwheat were plotted in the conventional way (i.e., water concentration [X] as ordinates against activities [$a_w$] as abscissae), they were similar to those of CM 169 and showed no effect of temperature on the adsorption isotherm of buckwheat seeds. However, when the data were plotted by using vapor pressure instead of the corresponding activity (Fig. 2), the higher temperature isotherms were well below those of lower temperatures—as they should be according to the physical adsorption theory. A zero or positive temperature dependence has been reported for some other foods, such as potatoes (Saravacos and Stinchfield 1965, Mazza 1982) and prunes (Bolin 1980). For potatoes and prunes, this behavior is a result of high sugar content, but for buckwheat seeds it may be the result of structural changes of the protein matrix due to swelling as well as to the sugars.

Because the adsorption isotherms of buckwheat were found to have the typical sigmoid shape of type II isotherms, they were

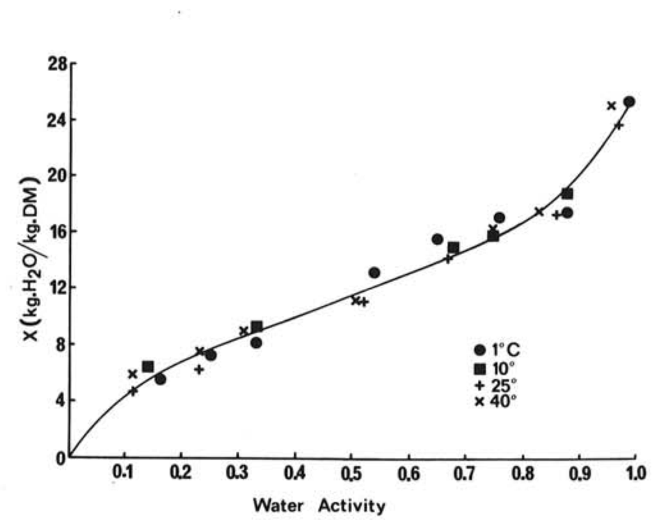


**Fig. 1.** Adsorption isotherms of CM 169 buckwheat at 1, 10, 25, and 40° C.

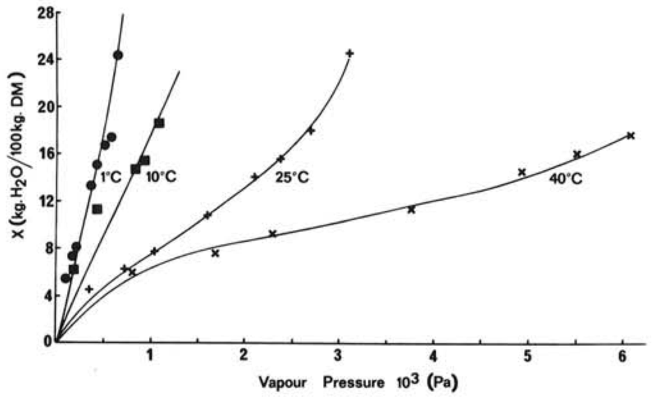


**Fig. 2.** Adsorption isotherms of Mancan buckwheat at 1, 10, 25, and 40° C.

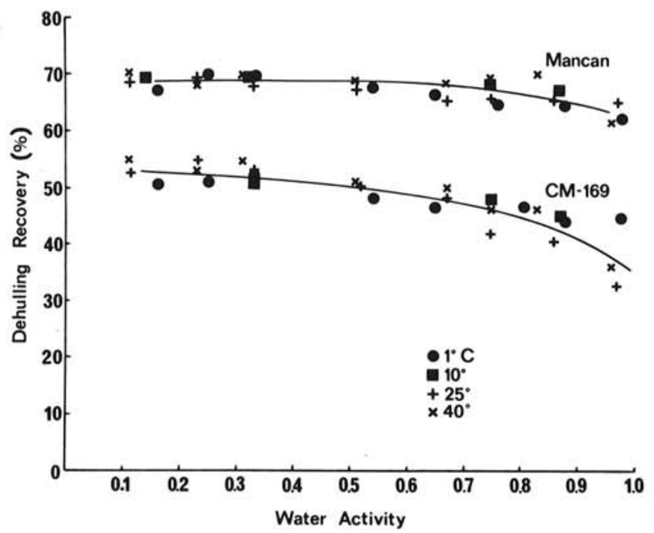


**Fig. 3.** Dehulling recovery of Mancan and CM 169 buckwheat at four temperatures as a function of water activity.

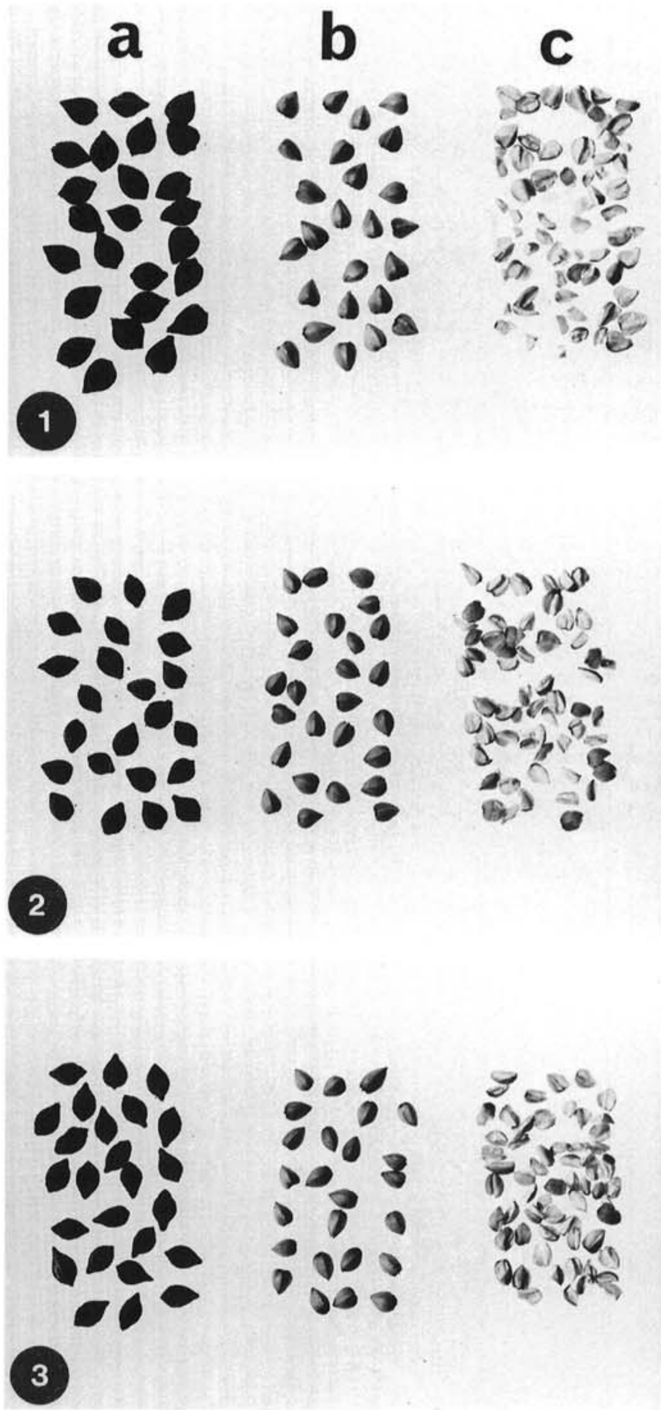


**Fig. 4.** Typical appearance of seeds (a), whole groats (b), and broken groats (c). Mancan (1), Tokyo (2), and CM 169 (3) buckwheat.

analyzed by the BET method (Mazza 1980). Least squares analysis was used to obtain the slopes and the intercepts of the BET plots from which the monolayer moisture contents were calculated. The calculated values of the monolayer (Xm) were 5.79–6.75 kg $H_2O$/kg DM for Mancan, 5.75–6.70 kg $H_2O$/kg DM for Tokyo, and 5.82–6.71 kg $H_2O$/kg DM for CM 169 buckwheat equilibrated at 1, 10, 25, and 40° C.

Dehulling recovery varied between cultivar and water activity of the seed (Tables I and II, Fig. 3). Of the three cultivars, Mancan yielded the most groats and CM 169 yielded the least. Mancan buckwheat had larger seeds than Tokyo or CM 169 (Fig. 4). Also, the number of seeds with wings, which are paperlike extensions of the angles of the hulls, was different for each cultivar. The difference in dehulling yield among cultivars may, therefore, be attributed to variations in seed characteristics and to differences in groat to hull ratio.

The dehulling yield of each cultivar decreased as the water activity of the seed increased but was essentially unaffected by temperature (Fig. 3). This decrease in dehulling recovery primarily reflects increased brittleness of the hull with decreasing moisture content of the seed. With drier seed, the hulls fracture and detach from the groats more easily, which reduces the number of seeds not dehulled and thus, increases the dehulling yield and decreases the cost of dehulling.

Although the entire dehulled fraction can be used to produce flour, the production of unbroken groats is important for products using whole groats. The percentage of whole groat in the dehulled fraction was practically constant at water activities of 0.11–0.50, but doubled as the water activity increased from 0.50 to 0.98 (Tables I and II). This indicates that for maximum yield of whole groats, buckwheat should be dehulled at a water activity approaching 1.0. This water activity, however, is not practical for storage because the seed will undergo undesirable microbiological, chemical, and enzymatic changes—even though it might be possible to maximize the dehulling recovery by hydrating the seed just before dehulling.

The minimum water activity at which microorganisms are capable of growing is approximately 0.61 (Beuchat 1981), and the moisture content of buckwheat associated with this water activity is approximately 11.5%. The percentage of whole groats in the dehulled fraction of buckwheat stored and processed at water activities of approximately 0.20 and 0.61 is, however, essentially the same.

In addition to dehulling recovery and yield, the color of the groats is another important quality attribute of buckwheat. Higher prices are normally paid for buckwheat that yields light green groats. Campbell and Gubbels (1979) noted that Japanese processors import only new buckwheat crop. This is because the testa, that layer just under the hull, is light green in freshly harvested seed and gradually changes to reddish brown during storage. Tables I and II show typical Hunter color values of whole and broken groats. Samples equilibrated at higher water activities showed some discoloration, with lower readings for lightness and higher readings for yellowness, which suggests that to retain the desirable light green color of the groats, buckwheat seeds should be stored at low water activity. At water activities below the monolayer moisture content, however, lipid oxidation, leading to flavor changes, is most rapid (Labuza et al 1970). To retain the characteristic buckwheat flavor and the light green color of the groats and to maximize the yield of whole groats and dehulling recovery, buckwheat should, therefore, be stored at 17–19% relative humidity.

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