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# Adsorption and Desorption Characteristics of Buckwheat

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## ABSTRACT

Adsorption and desorption characteristics of buckwheat at various temperatures of 16ºC, 24ºC and 35ºC were determined over a range of relative humidity of 20-80%. The equilibrium moisture content of samples was determined by drying a thin layer of grain in a constant temperature and relative humidity environment until the grain reached equilibrium with the drying air. A nonlinear regression was performed to estimate the constants of the Chung-Pfost and the modified-Henderson equations. The Chung-Pfost equation gave the best fit to the experimental data with a mean relative percent error ranging from 3.8 to 5.3% and standard error of 2 to 2.8 with coefficient of determination ranging from 0.97 to 0.99.

**Key Words:** Buckwheat; Adsorption; Desorption, Equilibrium Moisture Content; Relative Humidity

## INTRODUCTION

Buckwheat is one of the staple grains in Japan. "*Soba*" made from buckwheat is a typical food (Tagawa *et al.*, 1993). Noodles made from dough of buckwheat flour and water is popular in Japan. It is also common practice in many countries to prepare grouts from buckwheat seeds, which are eaten as a cooked porridge (Ideka *et al.*, 1991).

Buckwheat (*Fagopyrum esculentum*) originated from China and is cultivated all over the world (Lin & Jia, 1998). Manitoba is the major producer of buckwheat in Canada with about 70% of the acreage. Canadian processors use buckwheat in pancake mixes, breakfast cereals, breads and poultry stuffing (Agriculture & Agri-Food Canada, 1999).

A fundamental property of biological material, which influences dehydration and storage stability, is its water sorption characteristics (Ajisegiri, 1990). The sorption characteristics are influenced by environmental conditions such as temperature and relative humidity (Iglesias *et al.*, 1986). Data relating equilibrium moisture content (EMC) and equilibrium relative humidity (ERH) are necessary to design handling, storing and drying systems for hygroscopic materials. Equilibrium moisture content is the minimum moisture content to which grain can be dried under a given set of drying conditions. It can be defined as the limiting moisture content approached by a material after it has been exposed to a particular environment for an infinitely long time (Olesen, 1987).

The relationship between EMC and ERH is usually expressed by means of a sorption isotherm. The modified Henderson and Chung-Pfost equations are recommended as a standard to describe the EMC-ERH data of cereals in ASAE Data D245.4 (Jayas *et al.,* 1988; Chen & Morey, 1989). Therefore, a non-linear least square method was applied to these equations and the parameters for the best fit with the measured data was estimated.

The modified-Henderson equation is:

$$1 - RH = \exp[-A(T + C)M_e^B] \qquad (1)$$

The modified Chung-Pfost equation is:

$$RH = \exp[(-E/(T + F))\exp(-GM_e)] \qquad (2)$$

Where T is grain temperature (ºC), $M_e$ is moisture content (decimal dry basis), RH is relative humidity (decimal). Constants A, B, C, E, F, and G are product dependent.

The objectives of this investigation were to determine the moisture sorption isotherms of buckwheat, and to estimate the product-dependent constants of the modified Henderson equation and the modified Chung-Pfost equation.

## MATERIALS AND METHODS

Buckwheat cultivar 'Koto' harvested in 2003 was obtained from the Agricore United Grain Company in Winnipeg, Canada. The buckwheat seeds were at initial moisture content of 5% wet basis. The seeds were stored in air tight jars at 5°C until used.

The samples were conditioned to the desired moisture content by adding calculated quantities of distilled water and rotating for several hours. The rewetted samples were then kept in sealed plastic bags in a refrigerator 48 h for moisture content equilibration.

The moisture content of grain were measured using the oven-drying method in which 10 g of the grains of buckwheat were dried at 135°C for 24 h according to the standard of the Japanese Society of Agricultural Machinery (Ban & Suwa, 1973; cited in Tagawa *et al.*, 1993).

The EMC method was based on adsorption and desorption of a thin-layer of grain in a constant temperature and relative humidity environment until the grain reached the equilibrium with the drying or rewetting air. The air conditioning system was a climate-lab-AA (C-L-AA) unit (*Parameter Generation and Control Inc., Black Mountain, NC*), which provided constant air temperature and relative humidity.

The thin-layer drying and rewetting tests were planned for different relative humidity conditions. Accordingly, the air and dew point temperatures were selected. For a test at constant relative humidity, the temperature of the drying air and water were set at the air conditioning unit. Prior to starting the tests the unit was left running at least 5 h to stabilize the air conditions. The unit was set to obtain air temperatures ranging from 15 to 35°C and relative humidity of 20 to 80%. The air velocity was fixed at 0.35 m/s.

The apparatus consisted of a chamber with nine separated tray sections ventilated with air at the same temperature and relative humidity in each section (Sinicio, 1994). The average air temperature for each tray section was sensed by nine thermocouples installed 25 mm below the sample trays. The air temperatures were read by a digital thermometer (*Model Pronto Plus, Thermo-Electric Instruments, Saddle Brook, NJ*) with a resolution of $\pm$ 0.1°C. Dew point temperature was monitored at the air inlet section using a dew point sensor (*Model Hygro-M1, General Eastern Instruments Inc., Watertown, MA*) with a resolution of $\pm$ 0.1°C. The sample trays were $0.212 \times 0.212$ m inside dimensions and were made of square aluminium frames with wire mesh screen to hold the grains. The mass of grain and tray was measured using an electronic balance. The chamber was insulated with 25-mm-thick expanded polystyrene to minimize the effect of heat loss to the surroundings.

Three samples with initial moisture content of 15% dry basis in triplicate were spread on trays, which were placed in the chamber. Prior to putting trays in the chamber, empty trays were weighed and 100 g of buckwheat were uniformly spread over each tray to form a one-kernel thick layer. The mass of the tray with grains was recorded every 9-15 h using a digital balance (*Model Mettler PE1600, Mettler Instruments Corporation, Greifensee, Zurich, Switzerland*) with a resolution of $\pm$ 0.01 g, until the mass was within $\pm$ 0.01 g between two successive readings. The moisture content at this point was taken as the equilibrium moisture content. The time to reach equilibrium ranged from 3 to 7 days depending on the air conditions.

## RESULTS AND DISCUSSION

The sorption characteristics of buckwheat are depicted in fig. 1, 2 to emphasise adsorption and desorption phenomena and the effect of environmental temperature. From the curves obtained, the isotherms are sigmoid and slight hysteresis was evident over the entire range. Increased treatment temperatures significantly reduced water-holding ability. The isotherms are identical in form to those presented by Chung and Pfost (1967) for wheat and Caurie (1970) for corn flour.

The effect of drying temperature on the isotherms of buckwheat is shown in fig. 2. At the same relative humidity, higher drying temperatures showed reduced hysteresis. The curves indicate that an increase in temperature of the environment decreased the equilibrium moisture content at a known relative humidity, and that the adsorption and desorption modes follow different paths.

A nonlinear least-squares program was used to fit the modified Henderson and Chung-Pfost equations to the experimental data. The estimated parameters and comparison criteria such as, coefficient of determination, the standard error of estimate and mean relative percent error are given in Table I. Fig. 3 shows the comparison of the measured values with those calculated from the modified Henderson and Chung-Pfost equations. Based on table I and fig. 3, the Chung-Pfost equation was the best fit to the experimental data.

**Table1. Estimated EMC/ERH parameters and comparison criteria for two models of sorption data at three temperatures**

| | Modified Chung-Pfost | | | | Modified Henderson | | | |
|---|---|---|---|---|---|---|---|---|
| | Adsorption | | Desorption | | Adsorption | | Desorption | |
| | 16ºC | 24ºC | 16ºC | 24ºC | 16ºC | 24ºC | 16ºC | 24ºC |
| A | 298 | 405 | 391 | 364 | 0.0017 | 0.003 | 0.0013 | 0.0025 |
| B | 0.018 | 0.013 | 0.015 | 0.016 | 1.79 | 1.55 | 2.08 | 1.65 |
| C | 24.02 | 9.61 | 27.17 | 14.11 | 94 | 74 | 82 | 81 |
| $R^2$ | 0.981 | 0.986 | 0.987 | 0.989 | 0.957 | 0.959 | 0.968 | 0.961 |
| SE | 2.09 | 2.1 | 2.01 | 1.97 | 3.38 | 3.11 | 3.07 | 3.21 |
| P | 4.13 | 3.83 | 3.92 | 3.8 | 5.91 | 5.48 | 5.24 | 5.32 |

A, B and C are constants
SE is standard error of estimated value
P is mean relative percent error (%)

**Fig. 1. Adsorption and desorption characteristics of buckwheat**

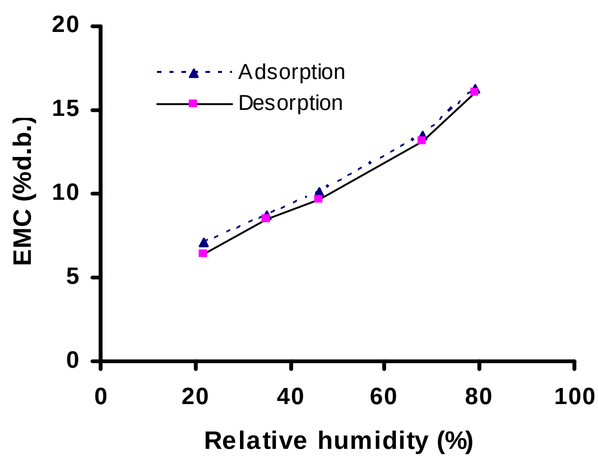

**Fig. 2. Effect of temperature on the sorption isotherms of buckwheat**

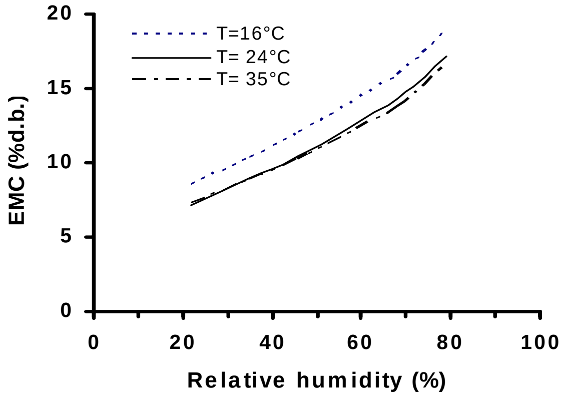


**Fig. 3. Comparison of observed and predicted sorption isotherms of buckwheat at 24ºC by two equations**

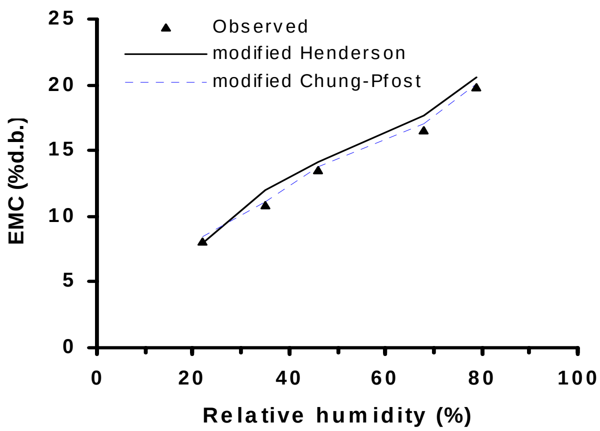


**Fig. 4. Comparison of the measured and predicted EMC by the modified Chung-Pfost equation for buckwheat at three different temperatures**

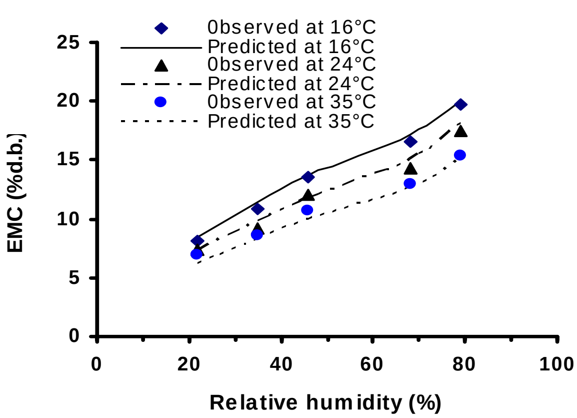


Fig. 4 indicates the comparison of the measured and predicted equilibrium moisture content by the modified Chung-Pfost equation at three different temperatures for buckwheat. The agreement is excellent, particularly at 24ºC with a mean relative percent error of 3.8% and standard error of 2 with R-squared of 0.99.

Comparing the two equations, we found that the modified Chung-Pfost equation had a higher $R^2$ with smaller standard error (SE) and mean relative percent error (P). As a result, the modified Chung-Pfost equation is suitable to present the equilibrium moisture content of buckwheat.

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