Adsorption and Desorption Equilibrium Moisture Content for Roselle Calyx

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ABSTRACT

Under the acceleration of climate variability of Sudan, food storage should be undertaken seriously the moisture content and temperature which significantly affected the product quality. The objective of this study was to determine the adsorption and desorption equilibrium moisture content for Roselle Calyx. The study was carried out at the Faculty of Agriculture, University of Khartoum, Shambat, Sudan. Three adsorption isotherms (10°C, 30°C and 50°C) and two desorption (30°C and 50°C) were used to determine equilibrium moistures content (EMC) of whole and broken Roselle calyx. Regression technique showed that no difference between adsorption and desorption equilibrium moisture content values for both whole and broken Roselle calyx. As relative humidity (RH%) increases up to 85% equilibrium moisture content will be increased, while Above 85% of relative humidity no equilibrium moisture content values were detected due to the growth of mould on the tested sample. On the other hand, temperature was found to have negative relationship with equilibrium moisture content. No hysteresis effects between adsorption and desorption equilibrium moisture content. The study recommended that whole or broken Roselle calyx could be stored safety at 10°C - 50°C air temperature and at a relative humidity below 85% to avoid mould growth on food stored.

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Under the acceleration of climate variability of Sudan, food storage should be undertaken seriously the moisture content and temperature which significantly affected the product quality. The objective of this study was to determine the adsorption and desorption equilibrium moisture content for Roselle Calyx. The study was carried out at the Faculty of Agriculture, University of Khartoum, Shambat, Sudan. Three adsorption isotherms (10°C, 30°C and 50°C) and two desorption (30°C and 50°C) were used to determine equilibrium moistures content (EMC) of whole and broken Roselle calyx. Regression technique showed that no difference between adsorption and desorption equilibrium moisture content values for both whole and broken Roselle calyx. As relative humidity (RH%) increases up to 85% equilibrium moisture content will be increased, while Above 85% of relative humidity no equilibrium moisture content values were detected due to the growth of mould on the tested sample. On the other hand, temperature was found to have negative relationship with equilibrium moisture content. No hysteresis effects between adsorption and desorption equilibrium moisture content. The study recommended that whole or broken Roselle calyx could be stored safety at 10°C - 50°C air temperature and at a relative humidity below 85% to avoid mould growth on food stored.

Keywords: adsorption; desorption; equilibrium moisture content; roselle calyx.

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I. INTRODUCTION

Roselle (*Hibiscus sabdariffa L.*) belongs to the family *Malvaceae*. It originated in India and it is widely distributed in tropical and subtropical regions as a potential new food crop of considerable economic potential as mentioned by Jitka *et al.* (2013). Sudan is categorized as one of the largest exporters of Roselle (Karkade or Ingara) worldwide. The crop is grown as a cash crop in the rainfed areas. According to the commercial terminology used in Sudan, there are two main types of Karkade calyx, namely El Rahad and El Fashir types. Grain storage is important especially for developing countries where food grain stuff constitutes the staple food for human beings. Safe storage must maintain grain quality and quantity. This means protecting it from weather, mould microorganism resulting from addition of moisture, destructive high temperature, insects, rodents and birds. During storage different factors bring about losses in food grain and they may be grouped into biological and non-biological factors such as temperature, moisture content and relative humidity which have a great impact on grain quality and storability as mentioned by Krishnamurthy et al. (1989). Adsorption isotherm can be used for establishing a storage method, while desorption isotherm data is useful in the drying analysis as reported by Kingsly and Ileleji (2009) and Aroraet al. (2011). Hysteresis refers to the difference between the adsorption and desorption curves isotherms for biological materials have generally sigmoid shapes (S-shaped) and approach very high moisture content as the relative humidity approaches 100%. Adsorption moisture content describes the equilibrium moisture content

(EMC), which is the limit of the moisture that can be attained when food is exposed to air at a given temperature and water activity as stated by Alakali et al. (2010). Equilibrium moisture content depends on the relative humidity and temperature of environment as well as the product characteristics as revealed by Luampon and Charmongkolpradit (2019). The rate of respiration increases with increasing temperature up to 40°C., while above this temperature viability of the grain as well as the rate of respiration significantly decreased at temperature above 50°C as mentioned by Chakaverty (1981) and supported by Jiang and Yuan (2013). Effect of 40°C storage temperature on the anthocyanin content was significant ($p < 0.05$) while there was no significant difference between 4 and 25°C as mentioned by Turker et al. (2004). In Sudan, food storage cannot be undertaken seriously the moisture content and temperature, therefore the objective of this study was to determine the adsorption and desorption equilibrium moisture content for Roselle Calyx.

II.   MATERIALS AND METHODS

The study was conducted at the Department of Agricultural Engineering, Faculty of agriculture, University of Khartoum, Sudan. Roselle (*Hibiscus sabdariffa* L.) var. Sabdariffa was used as indicator plant. Calyces of flowers were traditional harvested, collected, treated and tested with static method that controlled temperature by incubator (Heraeus Electronic Make, temperature range 0-100°C) and controlled relative humidity with saturated salt solution in closed system, as it convenient and low cost. Saturated salt solutions usually have good properties to control relative humidity that depends on temperature. Salt saturated solutions in this experiment were (LiCl, MgCl2.6H2O, NaBr, Nacl, CaCl2, NH4Cl, K2CO3, K2CrO7, K2SO4, KI and KNO3). The initial moisture content of Roselle calyx was determined in triplicate according to the association of official analytical chemists' procedures (Association Official Analytical Chemists, 1990).

2.1 Equipments

The following equipments were used in the experiments:
- Sample containers for the determination of the moisture content of the calyx.
- Aluminum foil to warp the conditioned samples until they were weighed or tested.
- Plastic bags to hold the product.
- An oven (Memmert) makes for the determination of the moisture content of calyx.
- A sensitive balance of (Meller) make with an accuracy of ±0.01 g.
- Conical flask (250ml) for the preparation of the saturated salt solutions.
- A graduated cylinder for measuring the volume of distilled water that was used in the preparation of the saturated salt solutions.
- Three incubators of Heraeus Electronic make with a temperature range of 0 - 1000C.
- A thermometer to measure the temperature.
- A glass rod to stir the saturated salt solutions.
- Desiccators in which samples of calyx were tested for EMC determination.
- A hygrometer to check the relative humidity (RH) of the saturated solutions.
- Petri dishes in which the sample were put on the perforated plates of the desiccators.

2.2 The sample weight

The sample weight containing moisture content 6.6% was described by Pixton (1983) as follows:
B =

Where:
B = final weight of the sample after drying (g).
A = initial weight of the sample, (g).
a = initial moisture content (MC) of the sample, (w.b).
b = desired find moisture content (MC) of the sample, (w.b).
Determination of equilibrium moisture content (EMC) values

Samples were used for the determination of equilibrium moisture content (EMC) for adsorption and desorption at 10°C, 30°C, and 50°C). The samples were weighed everyday and

placed back in the incubator until the weight was constant. Then the Roselle samples were removed from the incubator and put in the moisture content balance (accuracy±0.01g) to evaluate the equilibrium moisture content. The above mentioned procedure was repeated with incubator temperature of 10, 30, and 50 °C for determining adsorption isotherm. Sample tested in desiccators containing salts with a relative humidity (RH) above 90% mould development was observed. To determine desorption EMC, samples were conditional to have moisture consent of 20% (w.b.) by putting the samples in desiccators containing saturated salt solution of potassium sulphate (K2SO4). The desiccators were placed inside incubator at 5°C. The exerted relative humidity of the salt was measured to be 98.6%.

III. RESULTS AND DISCUSSION

Relative humidity of the surrounding air (RH %), temperature of the surrounding air (T) and particles size of the Roselle calyx were used to determine the equilibrium moisture content (EMC) for Roselle calyx. A polynomial function is found to fit both the adsorption and desorption equilibrium moisture content (EMC) values satisfactorily. Graphical representations and regression technique showed that as RH increases EMC will be increased as shown in Figs 1, 2, 3 and 4. The range of the regression equation of relative humidity and temperature were 11.2% - 96% and 10°C - 50°C, respectively. At a relative humidity above 85%, both the adsorption and desorption EMC values of the Roselle calyx could hardly be determined because of mold growth on the tested samples. The results were in agreement with the results obtained by Ashaye (2013) who mentioned that equilibrium moisture content (EMC) increased as relative humidity increased in all Roselle calyces irrespective of the temperature regimes. On the other hand, graphical representations and regression technique indicated that as temperature increases equilibrium moisture content (EMC) will be decreased. The results showed that, the temperature affects the adsorption and desorption EMC values. The results agreed with the results obtained by Jiang and Yuan (2013) and supported by Jitka et al. (2013) who reported that, the equilibrium moisture content EMC decreases with increasing temperature, at constant Aw.

Hysteresis effect and particle size dose not affecting the equilibrium moisture content (EMC) values for both adsorption and desorption EMC values for both whole and broken Roselle calyx as presented in Tables 1 and 2. This trend agrees with published study of Alakali et al. (2010).

Table 1: Adsorption isotherm for whole and broken Roselle calyx

Adsorption isotherm		95% confidence interval for μ1 - μ2	μ1 = μ2 VS μ1 = μ2			
Whole	Broken		t0	t1	P	d.f
10°C	10°C	(-44.8, 37.0)	-0.24	2.571	0.82	5.0
30°C	30°C	(-14.7, 13.2)	-0.14	2.571	0.97	5.0
50°C	50°C	(-9.10, 11.0)	0.48	4.303	0.66	3.0

Table 2: Desorption isotherm for whole and broken Roselle calyx

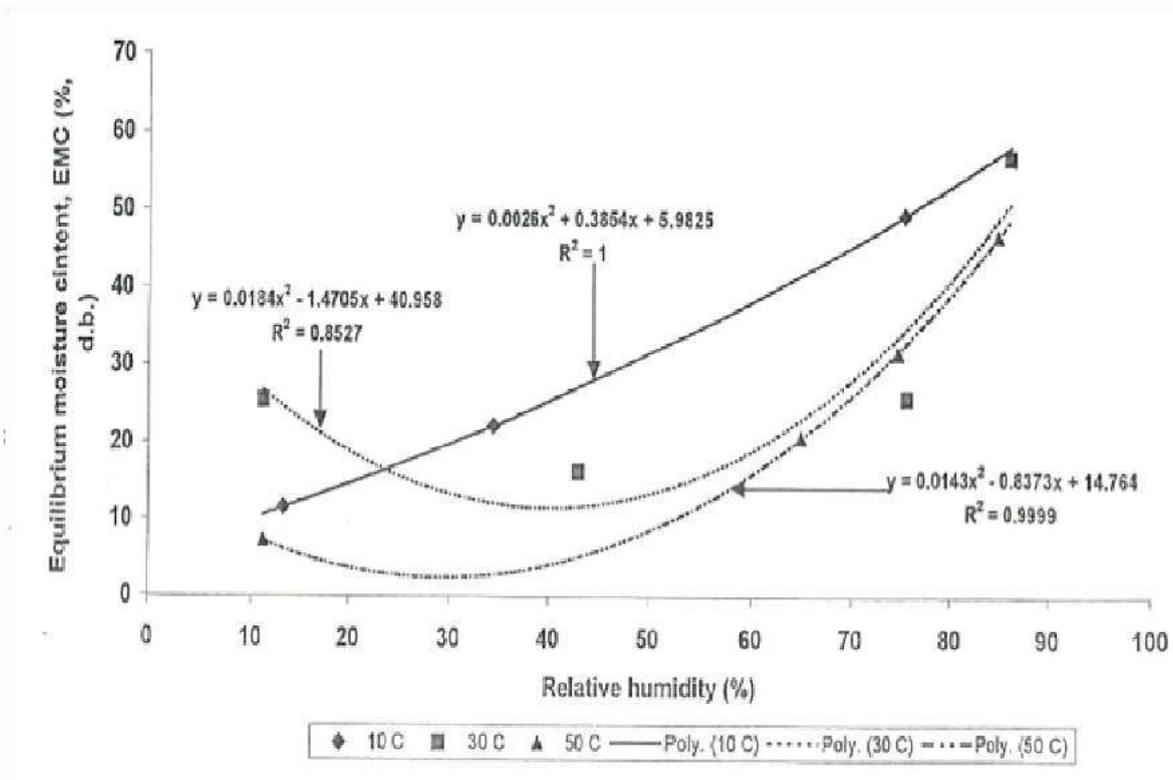| Desorption isotherm		95% confidence interval for μ1 - μ2	μ1 = μ2 VS μ1 = μ2			
Whole	Broken		t0	t1	P	d.f
30°C	30°C	(-14.7, 13.2)	-0.14	2.571	0.90	5.0
50°C	50°C	(-9.10, 11.0)	0.48	4.303	0.66	3.0

Fig. 1: Adsorption isotherm of whole Roselle calyx
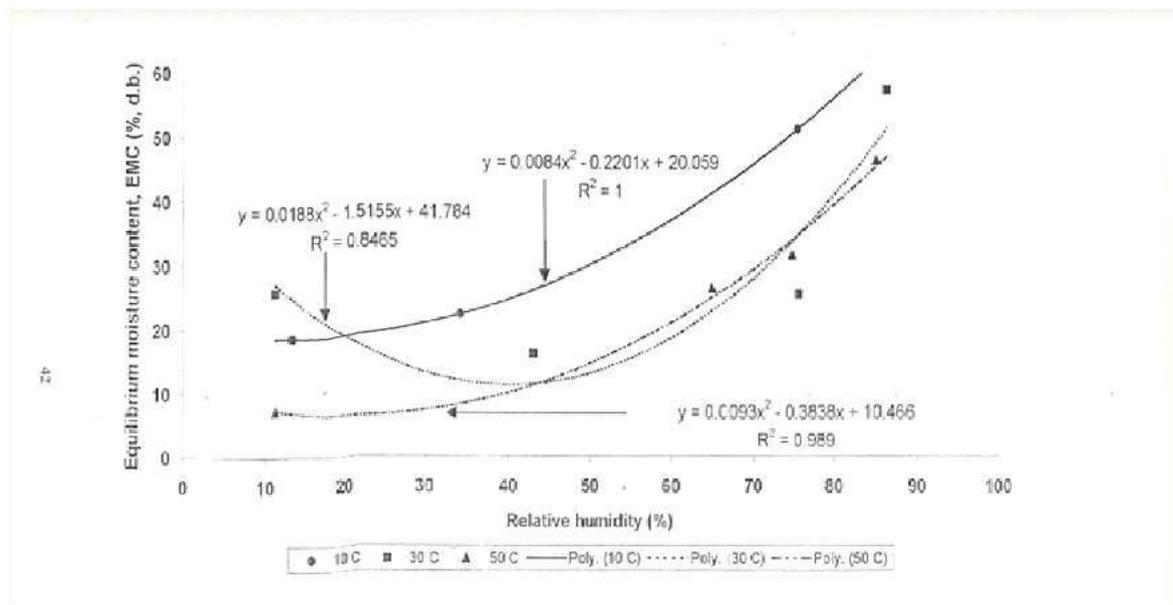
Fig.4.12 Adsorption isotherms of broken roselle cylax

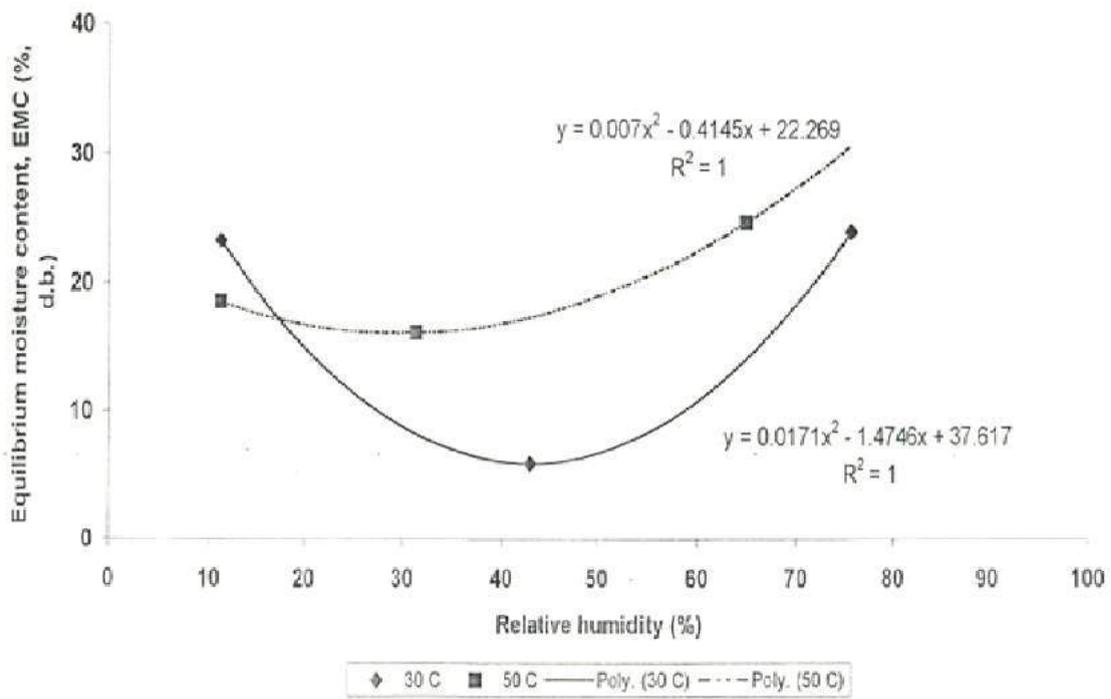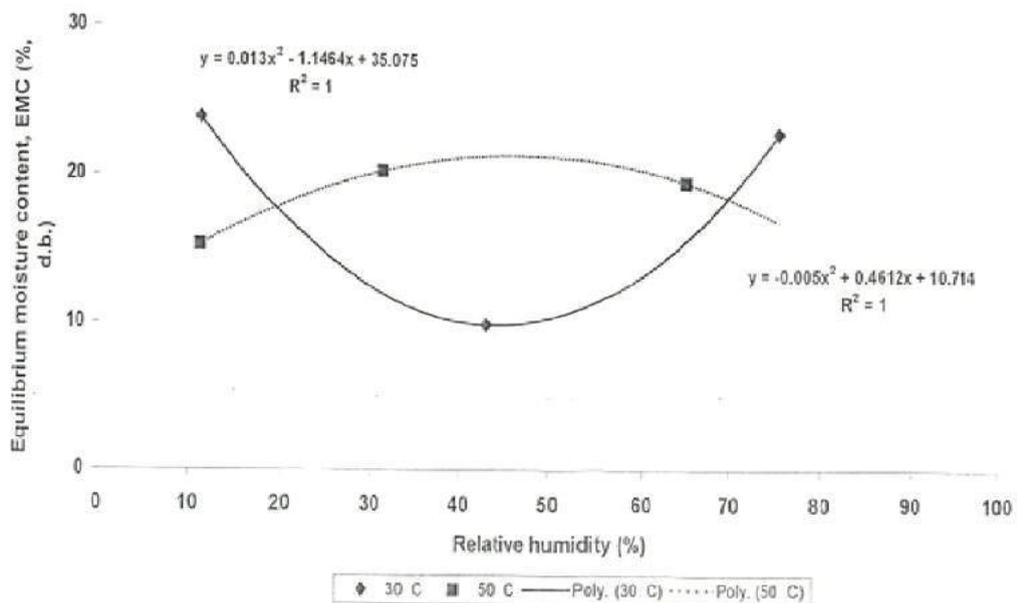**Fig. 2:** Adsorption isotherm of broken Roselle calyx

$y = 0.007x^2 - 0.4145x + 22.269$
$R^2 = 1$

$y = 0.0171x^2 - 1.4746x + 37.617$
$R^2 = 1$

Fig.4.13 Desorption isotherms of whole roselle cylax

Fig. 3: Desorption isotherm of whole Roselle calyx

$y = 0.013x^2 - 1.1464x + 35.075$
$R^2 = 1$

$y = -0.005x^2 + 0.4612x + 10.714$
$R^2 = 1$

Fig.4.14 Desorption isotherms of broken roselle cylax

Fig. 4: Desorption isotherm of broken Roselle calyx

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IV. CONCLUSION

Under the acceleration of climate variability of Sudan, food storage should be undertaken seriously the moisture content and temperature to avoid the growth of mould on the food storage which significantly affected the product quality. As relative humidity (RH%) increases up to 85% equilibrium moisture content will be increased, while Above 85% of relative humidity no equilibrium moisture content values were detected due to the growth of mould on the tested sample. On the other hand, temperature was found to have negative relationship with equilibrium moisture content.

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