Misr J. Ag. Eng., 23(3): 198- 215 PROCESS ENGINEERING

EQUILIBRIUM MOISTURE CONTENT FOR SOME NATURAL INSULATING MATERIALS

TAHA H. ASHOUR *

ABSTRACT

Equilibrium moisture content (EMC) is very important to determine the desirable conditions of grain storage, microorganisms growth which cause material deterioration, and all drying and humidification processes. This work aimed to determine the EMC of four biomaterials namely, sheep wool (animal material), kenaf, flax and cellulose plates (plant materials) under different conditions of temperature (5-30°C) and relative humidity (43-96%). The results indicated that the EMC of the four materials increased with increasing the relative humidity while, it decreased with increasing temperature. The EMC of sheep wool recorded the highest value (20.9%) followed by, kenaf (18.5%), cellulose plates (15.9%) and flax (15%) respectively. The EMC of sheep wool, kenaf, cellulose plates and flax ranged from 13.4-32.1, 12-26.8, 10.1-23.7 and 9.2-22.6 %, respectively at the ambient conditions under study. Empirical equations of the relationship between temperature, relative humidity and EMC for the materials under study were determined at different conditions.

INTRODUCTION

Molecules of water are constantly leaving and returning to the surface of biomaterials. If the number of molecules of water return to on leave from the surface are the same, the material is neither gaining or losing water of is said to have an equilibrium moisture content (EMC). In the other words when air remains in contact with the material for sufficient time, the partial pressure of the water vapor in the air reaches equilibrium with partial pressure of the water vapor in the material. The moisture content of the material at equilibrium with the given environment, i.e. relative humidity and temperature is called the equilibrium moisture content.

Padfield (1966) mentioned that, absorbent materials such as wood, paper and cotton stabilize the atmosphere of show cases against the relative

*Agric. Eng. Dept., Fac. Agric., Moshtohor, Toukh, Qalubia, P.O. Box, 13736, Egypt.
Phone: +2 013 2467 034 Fax: +2 013 2467 786 E-Mail thashour@yahoo.com

humidity changes caused by temperature variation and by exchange of air with the surroundings.

There are several exchange processes between the air in the case and the outside air: diffusion through porous construction materials, air flow caused by temperature and pressure changes and air flow by convection in a show-case whose relative humidity differs from that of its environment. The air changes about once a day in show-cases made by conventional joinery techniques. The rate of exchange can show-case so that only one small hole is left for pressure equalization.

At ordinary temperatures liquid water is in equilibrium with a definite concentration of water vapour in the space around it. This concentration is almost unaffected by the presence of other gases **Tveit (1966)** mentioned that, the sorption and permeance of water vapor of approximately 50 different porous materials have been studied under stationary conditions for various temperature and humidity levels within the hygroscopic range. **Bainbridge (1986)** reported that, 'safe' moisture content is specified, 15% being a common value that corresponds to a water activity level or equilibrium relative humidity. **Peralta (1994)** evaluated the intermediate desorption curves at 30 °C for yellow poplar wood samples subjected to relative humidity ranges of 92% to 0%, 75% to 0%, 53% to 0%, and 32% to 0%. The desiccator method was used to establish the full desorption curve, while a high-vacuum system was employed to obtain the full adsorption and the four intermediate desorption curves. The desired relative humidities were maintained by saturated salt solutions. The generated intermediate desorption curves all fall within the full adsorption and desorption isotherms, with the isotherms originating from 92, 75 and 53% relative humidity (RH) change being needed for an intermediate desorption curve to cross over from the full adsorption isotherm to the full desorption isotherm. The intermediate curve from 92% RH has the characteristic sigmoidal shape, but those from 75%, 53%, and 32% RH are concave towards the X-axis. All the intermediate curves exhibit hysteresis, even at low RH levels and narrow RH ranges. **Watts et al. (1995)** found that, the deterioration of straw can be a result of microbial activity, such as growth, survival, death, sporulation and toxin production. This activity is a function of such environmental variables as temperature, pH, oxygen, radiation and availability of moisture. Moisture availability for microbial activity is measured by (water activity) which is numerically equal to the equilibrium relative humidity divided by 100. It is a rule of thumb that below approximately 70% equilibrium relative humidity, little microbial activity occurs and the straw is stable. The exact relationship between the equilibrium relative humidity and the moisture content of the straw is a function of the type of straw and the temperature and is given by the moisture sorption isotherm. **Ritschkoff et al. (2000)** studied the mould contamination at 80, 90 or 97% RH and 5, 15, 23 and 30°C (at constant humidity and temperature conditions) for several wood-based materials, stone-based materials and insulation materials. All building materials tested were susceptible to mould growth in humidities higher than 90% RH at temperature above 15°C. However, building materials of different origin showed variable tolerance against fungal growth under the test conditions. In the stone-based materials the critical humidity level and exposure time needed for the initial fungal growth was higher than in the wood-based materials. In the material combinations the initial mould growth principally retarded in the contact surface. Equilibrium moisture content is very important factor in drying and storing the agriculture products, drying and saving building materials such as wood.

Due to the lack of information about the thermal and physical properties of the agricultural materials, the main aim of this work was to obtain the EMC of four different materials. Those materials could be used successfully as insulating material. Swearingen (2001) reported that, the behavior of moisture within buildings is complex and dependant upon several variables such as seasonal climate, site conditions, building usage, heating and cooling systems and wall construction. Moisture trapped within the building envelope (walls, floor and roofs) can cause degradation of wood or straw, and reduce the efficacy of insulation materials. The composition of wood and straw are quite similar. Both consist largely of cellulose plus inorganic materials. At about 18% moisture content, fungi which are present in wood and straw as spores become active and begin breaking down cellulose, creating what we know as dry rot. Below 18% M.C, the active fungi go dormant. Good building design prevents moisture accumulating in the building envelope from reaching level where fungi will grow and multiply.Ashour (2003) mentioned that, the equilibrium moisture content of the wheat straw increased with increasing the relative humidity but it decreased with increasing the temperature. The equilibrium moisture content of barley straw was higher than that of the wheat straw or wheat straw get to the equilibrium with the ambient conditions faster than the barley straw. The relative humidity has greater effect on the change of moisture content of bales compared to the effect of the temperature. He reported that the EMC equilibrium moisture content ranged between (8.4-22.9%) for all conditions (5-30 °C temperature and 43-96% relative humidity).

EXPERIMENTAL PROCEDURES

Four different bio materials were selected for two reasons, first, to express both kinds of plant and animals materials, second, most of them are considered wastes. Theses materials are sheep wool (animal material), kenaf, flax and cellulose plates (plant material).

A 5 g of sheep wool, kenaf, flax and cellulose plates samples were taken and put it on a wire mesh, then above a plastic dish contains a saturated salt solution. The samples, wire mesh and dishes were placed inside a basket of dimensions (50X30X20 cm) Length X Width X Height. The basket was put in a plastic bag which has an air-tight closed.

These bags were put inside a climate chamber at different temperatures (5, 10, 15, 20, 25 and 30 °C) and relative humidity values (43, 53, 65, 75, 85, 90, and 96 %). For each value of relative humidity, three samples of same material were used as replicates. This means that 63 samples of each material were used.

Until a constant relative humidity inside the bag was reached. The development was controlled with a combined T/RH. sensors. After 1 to 2 weeks the samples were weighed and the moisture contents were calculated.

A climate chamber dimensions of 3.5 x 2.75 x 3.0 m (length x width x height), was used to control the temperature and relative humidity conditions. Capacitive humidity sensors (Aluminum 12 mm ϕ ± 2 % for RH, and 1 K for temperature accuracy, made in Germany) contain a glass substrate with a humidity-sensitive polymer layer between two metal electrodes were used. By absorption of water, corresponding to the relative humidity, the dielectric constant and as a result, the capacity of the thin-film capacitor change. The measuring signal is directly proportional to the relative humidity and is not dependent on the atmospheric pressure.

In order to obtain different relative humidity values in the materials surroundings, the following chemicals substances were used as listed in Table (1).

Table (1): Chemicals substances used for adjusting different relative humidity values.

Name	Materials	Relative humidity(%)
Sodium sulphate	$Na_2SO_4.10\ H_2O$	96
Barium chloride	$BaCL_2\ .2\ H_2O$	90
Magnesium sulphate	$MgSO_4.H_2O$	90
Potassium chloride	KCl	85
Sodium chloride	NaCl	75
Sodium nitrite	$NaNO_2$	65
Magnissium nitrate	$(Mg\ NO_3).6\ H_2O$	53
Potassium carbonate	$K_2CO_3.2\ H_2O$	43

Moisture content for the materials was measured according to **ASHRAE, (1997)**. The materials were put in the drier at 105 °C for 24 hours or at constant mass. The following equation was used to calculate the M.C. as follows:-

$$MC.(\%) = \frac{(W_m - W_d)}{W_d} * 100 \qquad (1)$$

Where:

MC : Moisture content (%, db)

W_m : Moist weight (kg)

W_d : Dry weight (kg)

RESULTS AND DISCUSSION

1. Sheep wool

Table (2) and Fig.(1) show the equilibrium moisture content (EMC, % db) of sheep wool at different predetermined relative humidity values and temperatures. The samples were placed under conditions of relative humidity ranged from 43 – 96 % and temperatures of 5 – 30 °C.

Table(2): Equilibrium moisture content (% db) of sheep wool at different temperatures and relative humidity values

R.H(%)	Equilibrium Moisture Content (%db)						Average
	5 °C	10°C	15°C	20°C	25°C	30°C	
43	14.3	14	13.5	13.9	12.6	12.2	13.4
53	17.2	16.8	15.9	16.2	14.8	14.4	15.9
65	18.7	17.9	17.2	16.8	16.6	16.5	17.3
75	19.9	19.5	18.8	18.3	18.3	18	18.8
85	25.5	24.4	23.8	23.4	21.7	21.4	23.4
90	27.4	26.5	26	25.5	24.6	23.2	25.5
96	35.7	33.9	33.1	32.9	29	27.7	32.1
Average	**22.7**	**21.9**	**21.2**	**21**	**19.7**	**19.1**	**20.9**

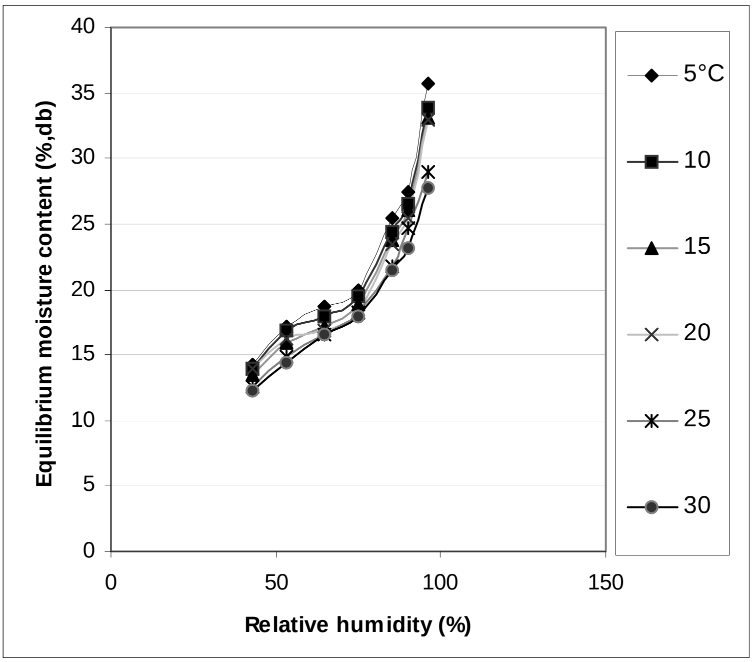

Fig.(1): Equilibrium moisture content for sheep wool materials.

The results revealed that the equilibrium moisture content of the sheep wool increased with increasing the relative humidity but it decreased with increasing the temperature. It seems that the relative humidity has greater effect on the equilibrium moisture content than the temperature, where, changing the relative humidity from 43 to 96% lead to an increase of 21.4 % in the moisture content of the sheep wool at 5 °C temperature. On the other hand, increasing the temperature from 5-30 °C caused a decreasing of 2.1 % in the equilibrium moisture content of the sheep wool at 43 % relative humidity, while at the higher temperatures and relative humidity (30 °C and 96 %), increasing the relative humidity from 43 to 96 % at 30 °C caused an increase of 15.5 %, whereas it was 8 % when the temperature increased from 5-30 °C at 96 % relative humidity.

This may be due to, the moisture content is identical to the sorption isotherms, where, water is adsorbed from the vapor of the ambient air, and the moisture content is in equilibrium with the ambient relative humidity. Two mechanisms are responsible for this sorption phenomenon, at low relative humidity values, water molecules are attached to the pore walls forming a thin water film, as relative humidity rises, this film becomes thicker and capillary condensation starts taking place in the narrow pores, the two mechanisms overlap each other, but at high relative humidity, the capillary condensation becomes dominant **Kuenzel (1991)**.

At low relative humidity (43 %) the maximum equilibrium moisture content was14.3 % at 5 °C while it was a low of 12.2 % at 30 °C. As relative humidity rises, the equilibrium moisture content (EMC) reached a high of 35.2 % at 5 °C and a low of 27.7 % at 30 °C.

Equilibrium moisture content of sheep wool increases with the rise of relative humidity the same temperature. That was due to the vapor pressure deficit (VPD) decreases with increasing relative humidity which creates an atmosphere close to saturation and that increases the ability of sheep wool to absorb more moisture from the surrounding atmosphere. On the other hand, with increasing the temperature from 5-30 °C, equilibrium moisture content decreases from 14.3 % to 12.2 % at 43 % relative humidity and from 35.7 % to 27.7% at 96 % relative humidity.

This was due to that the vapor pressure deficit increases with increasing temperature which is considered the main factor of moisture movement from or to the sheep wool Fig. (2) show the vapor pressure deficit (VPD) increased by more than 10 times when temperature increased from 5 to 30

°C, consequently, equilibrium moisture content decreased and reached a level lower than the initial moisture content of the sheep wool that shows, the sheep wool has lost some of its moisture to the surrounding.

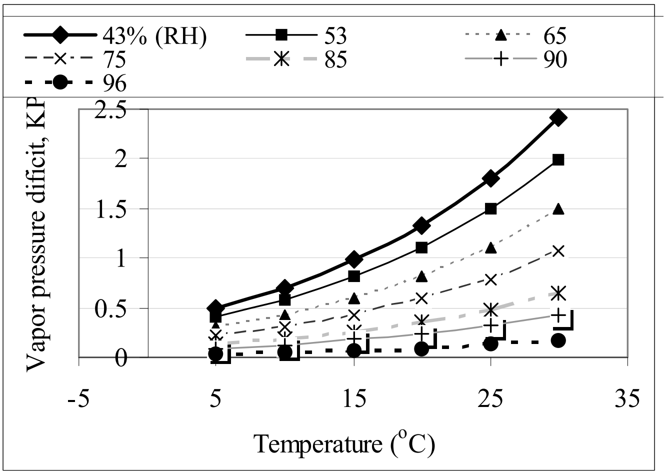

Figure (2): Vapor pressure deficit at different relative humidity levels and temperatures for the test conditions.

Vapor pressure deficit (VPD) at lower temperature at different relative humidities has no differences which reflects, that effect of changing relative humidity at the lower temperature is not effective. According to **Künzel (1994)** and **Krus (1995)** the apparent increase in vapor diffusion at high relative humidity is due to a liquid flow on the surface of the pore walls. The driving potential of this is the surface diffusion which is controlled by the vapor pressure gradient.

2. Kenaf

Table (3) and Fig.(3) show the equilibrium moisture content (EMC, % db) of kenaf fiber at different relative humidity values and temperatures. At low relative humidity (43 %) the maximum equilibrium moisture content was 12.5 % at 5 °C while it was a low of 10.3 % at 30 °C. As relative humidity rises, the equilibrium moisture content (EMC) reached a high of 30.1 % at 5 °C and a low of 24.3 % at 30 °C. It is also noticed that, changing the relative humidity from 43 to 96% lead to an increase of 17.6 % in the moisture content of the kenaf fiber at 5 °C temperature. On the other hand, increasing the temperature from 5-30 °C caused a decreasing of 2.2 % in the equilibrium moisture content of the kenaf fiber, while at the higher temperatures and relative humidity (30 °C and 96 %), increasing the relative humidity from 43 to 96% at 30 °C caused an increase of 34 %, whereas it was 5.8 % when the temperature increased from 5-30 °C at 96 % relative humidity.

Table (3): Equilibrium moisture content (% db) of kenaf fiber at different temperatures and relative humidity values.

R.H(%)	Equilibrium Moisture Content (%db)						Average
	5 °C	10°C	15°C	20°C	25°C	30°C	
43	12.5	12.6	12.4	12.2	11.7	10.3	12
53	15.3	15.2	14.8	14.7	13.5	12.7	14.4
65	16.6	16.4	15.9	15.8	14.6	14.2	15.6
75	17.9	17.5	17.2	16.9	15.7	15.3	16.8
85	22.4	21.9	21.4	21.2	17.9	17.1	20.3
90	25.3	24.9	24.6	24.4	20.7	20.9	23.5
96	30.1	28	27.2	26.4	24.5	24.3	26.8
Average	20	19.5	19.1	18.8	16.9	16.4	18.5

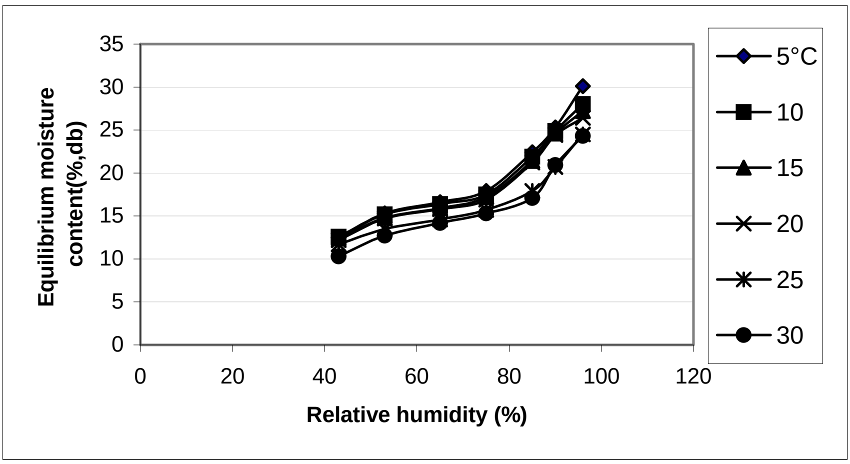

Figure (3): Equilibrium moisture content for kenaf material

3. Cellulose plates:

Table(4) and Fig.(4) shows the equilibrium moisture content (EMC. %, db) of cellulose at different relative humidity values and temperatures. At relative humidity of 43 %, the maximum equilibrium moisture content was 10.9 % at 5 °C while it was a low of 9.2 % at 30 °C. As relative humidity rises, the equilibrium moisture content (EMC) reached a high of 25.7 % at 5 °C and a low of 21.8 % at 30 °C. It is also noticed that, changing the relative humidity from 43 to 96% lead to an increase of 14.8 % in the moisture content of the cellulose at 5 °C temperature. On the other hand, increasing the temperature from 5-30 °C caused a decreasing of 1.7 % in the equilibrium moisture content of the cellulose material, while at the higher temperatures and relative humidity (30 °C and 96 %), increasing the relative humidity from 43 to 96% at 30 °C caused an increase of 12.6 %, whereas it was 3.9 % when the temperature increased from 5-30 °C at 96 % relative humidity.

Table (4): Equilibrium moisture content (% db) of cellulose at different temperatures and relative humidity values.

R.H(%)	Equilibrium Moisture Content (%db)						Average
	5 °C	10°C	15°C	20°C	25°C	30°C	
43	10.9	10.8	10.1	9.8	10	9.2	10.1
53	13	12.9	12.3	11.6	11.9	10.9	12.1
65	14.4	13.9	13.5	13.3	12.8	11.7	13.3
75	16.1	15.9	15.3	14.8	14.2	12.8	14.9
85	18.9	18.5	18.1	17.8	16.1	15.6	17.5
90	21.9	20.7	19.8	19.9	19.1	18	19.9
96	25.7	25.3	23.9	23.2	22.1	21.8	23.7
Average	17.3	16.9	16.1	15.8	15.2	14.3	15.9

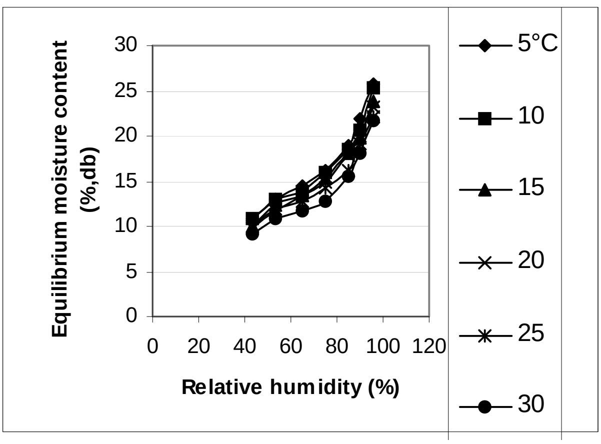

Figure (4): Equilibrium moisture content for cellulose material

4 Flax

Table (5) and Fig.(5) shows the equilibrium moisture content (EMC. %, db) of flax fiber at different relative humidity values and temperatures. At low relative humidity (43 %) the maximum equilibrium moisture content was 9.7 % at 5 °C while it was a low of 8.1 % at 30 °C. As relative humidity rises, the equilibrium moisture content (EMC) reached a high of 24.9 % at 5 °C and a low of 19.7 % at 30 °C. It is also noticed that, changing the relative humidity from 43 to 96% lead to an increase of 15.2 % in the moisture content of the flax fiber at 5 °C temperature. On the other hand, increasing the temperature from 5-30 °C caused a decreasing of 1.6 % in the equilibrium moisture content of the flax fiber, while at the higher temperatures and relative humidity (30 °C and 96 %), increasing the relative humidity from 43 to 96% at 30°C caused an increase of 11.6 %, whereas it was 5.2 % when the temperature increased from 5-30 °C at 96 % relative humidity.

Table (5): Equilibrium moisture content (% db) of flax fiber at different temperatures and relative humidity values.

R.H(%)	Equilibrium Moisture Content (%db)						Average
	5 °C	10°C	15°C	20°C	25°C	30°C	
43	9.7	9.5	9.4	9.2	9.1	8.1	9.2
53	12.5	12.1	11.9	11.5	11.3	10.5	11.6
65	13.2	13.1	12.4	12.0	12.4	11.5	12.4
75	13.9	13.6	13.5	13.1	12.9	12.4	13.2
85	17.9	17.5	16.8	16.4	15.4	15.0	16.5
90	22.4	20.9	20.1	19.6	17.7	16.9	19.6
96	24.9	24.2	23.0	22.5	21.5	19.7	22.6
Average	16.4	15.8	15.3	14.9	14.3	13.4	15.0

5 Comparison Between the different materials under study:

Fig(6) shows the relationship between the equilibrium moisture content of different materials and the relative humidity at 5 °C temperature. It can be seen that the equilibrium moisture content increased gradually with increasing relative humidity up to 65 % and this increasing slowed down between 65-80% relative humidity and the increased gradually again at relative humidity higher than 80 % for all materials. The equilibrium moisture content values were 14.3, 12.5, 10.9 and 9.7 % at 43 % relative humidity and increased to 35.7, 30.1, 25.7 and 24.9 % at 96% for sheep wool, kenaf, cellulose and flax fiber respectively. The figure showed also, that the equilibrium moisture content of sheep wool is higher than the other materials. The equilibrium moisture content of flax fiber recorded the lowest value. This means that flax fiber gets to the equilibrium with the ambient conditions faster than the other materials, this may be attributed to that flax fiber contains finer particles much more than that of the other materials which absorb more moisture to get to the equilibrium compared to other materials.

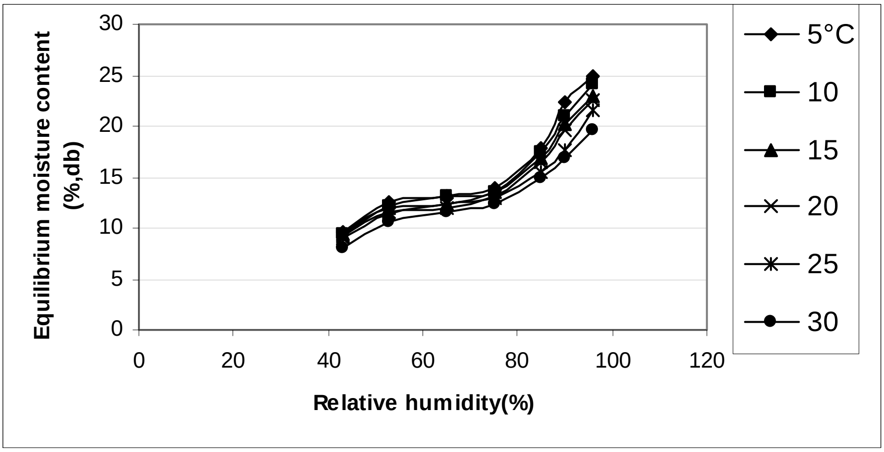

Figure (5): Equilibrium moisture content for flax material.

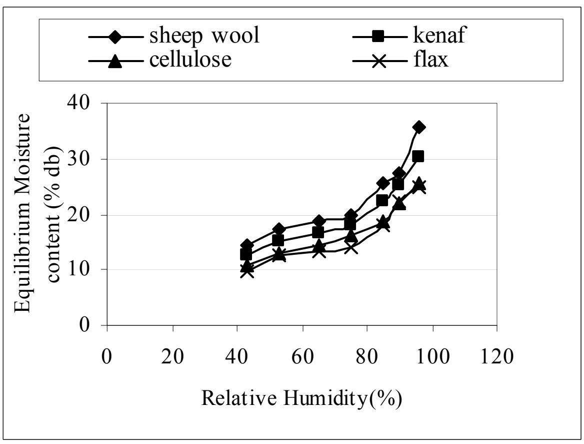

Figure (6): Equilibrium Moisture content of different materials at different relative humidity values and 5°C.

At 10°C temperature, the equilibrium moisture content values were 14, 12.6, 10.8 and 9.5 % at 43% relative humidity, while, they were 33.9, 28, 25.3 and 24.2% at 96% for sheep wool, kenaf, cellulose and flax fiber respectively as showed in fig (7). It is shown also that the equilibrium moisture content for sheep wool is higher than the other materials.

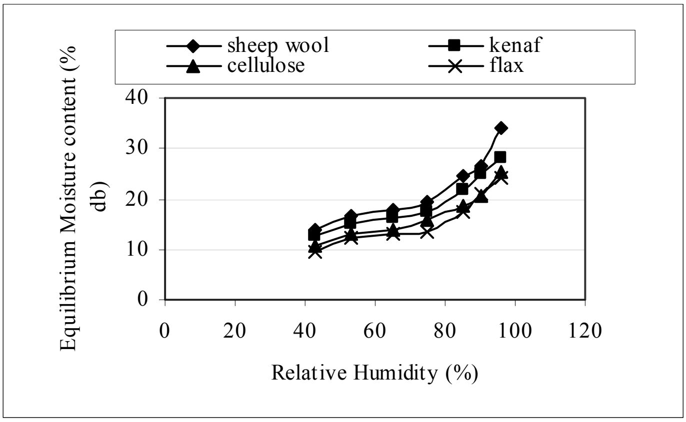

Figure (7): Equilibrium Moisture content of different materials at different relative humidity values and 10°C.

At 15 °C temperature, the equilibrium moisture content values were 13.5, 12.4, 10.1 and 9.4% at 43 % relative humidity while they were 33.1, 27.2, 23.9 and 23 % at 96% for sheep wool, kenaf, cellulose and flax fiber respectively as showed in Fig.(8).

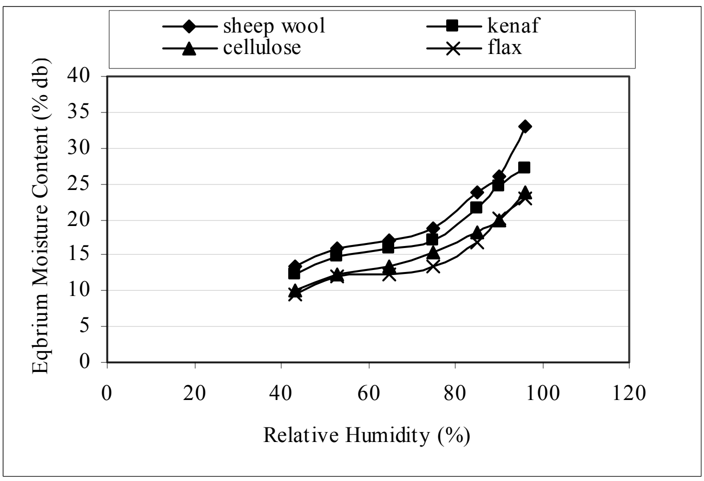

Fig.(8): Equilibrium Moisture content of different materials at different relative humidity values and 15°C.

It is shown also, that the equilibrium moisture content of sheep wool is slightly higher than that of the other materials.

At 20 °C temperature, the equilibrium moisture content values were 13.9, 12.2, 9.8 and 9.2 % at 43 % relative humidity while they were 32.9, 26.4, 23.2 and 22.5 % at 96% for sheep wool, kenaf, cellulose and flax fiber respectively as showed in Fig.(9).

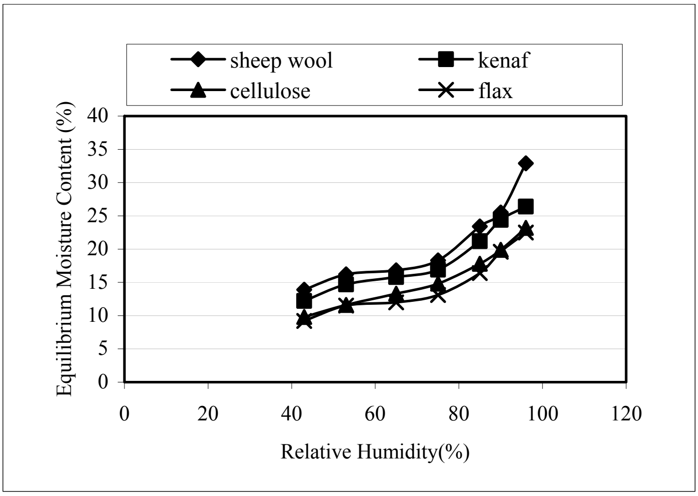

Figure (9): Equilibrium Moisture content of different materials at different relative humidity values and 20°C.

At 25°C, temperature, the equilibrium moisture content values were 12.6, 11.7, 10 and 9.1 % at 43 % relative humidity while they were 29, 24.5, 22.1 and 21.5 % at 96% for sheep wool, kenaf, cellulose and flax fiber respectively as showed in Fig.(10).

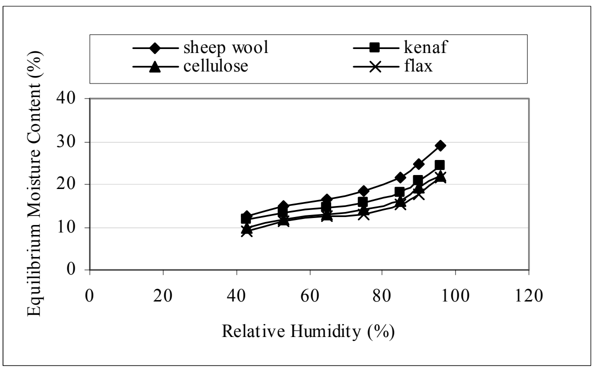

Figure (10): Equilibrium Moisture content of different materials at different relative humidity values and 25°C.

It can be seen that the equilibrium moisture content increased gradually with increasing relative humidity up to 65 % and this increasing slowed down between 65-80% relative humidity and the increased gradually again at relative humidity higher than 80 % for the different materials. The figure showed also, that the equilibrium moisture content of sheep wool fiber is higher than the other materials. Flax fiber get to the equilibrium with the ambient conditions faster than the other materials, this is due to the higher pores in the flax fiber which take less time to get to the equilibrium compared to the sheep wool. This was due to the differences between the flax and other materials in both chemical and physical properties.

At 30 °C temperature, the equilibrium moisture content values were 12.2, 10.3, 9.2 and 8.1 % at 43 % relative humidity while they were 27.7, 24.3, 21.8 and 19.7 % at 96% for sheep wool, kenaf, cellulose and flax fiber respectively as showed in Fig.(11).

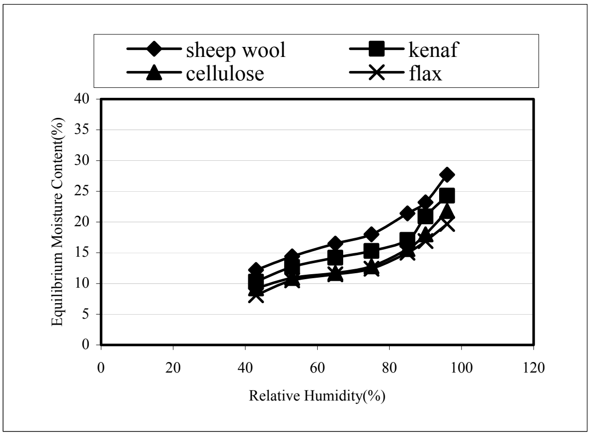

Figure (11): Equilibrium Moisture content of different materials at different relative humidity values and 30°C.

It can be seen that the equilibrium moisture content increased gradually with increasing relative humidity up to 65 % and this increasing slowed down between 65-80% relative humidity and the increased gradually again at relative humidity higher than 80 % for different materials.

6 Empirical equations

Multiple regression analysis was carried out on the equilibrium moisture content data for sheep wool, kenaf, cellulose and flax as a function of both the temperature and relative humidity and the following equation was obtained:

$$EMC = a+b\,T+c\,RH$$

Where,

EMC : Equilibrium moisture content, (%)
RH : Relative humidity, (%)
T : Temperature, (°C)
a, b, c : Constants are listed in Table (6)

Table (6) The constants for the different materials :

Materials	Constants			R^2
	a	b	c	
Sheep wool	1.161	-0.142	0.310	0.866
Kenaf	2.548	-0.149	0.255	0.894
Cellulose	1.341	-0.116	0.229	0.906
Flax	0.451	-0.112	0.228	0.876

CONCLUSION

The results revealed that the equilibrium moisture content of all the materials under study increased with increasing the relative humidity but it decreased with increasing the temperature. The equilibrium moisture content of sheep wool was higher than the other materials under study or sheep wool get to the equilibrium with the ambient conditions faster than the other materials.

The relative humidity has greater effect on the change of moisture content of different materials compared to the effect of the temperature where, moisture content changes ranges from 1.9 – 5.7 % when temperature changed from 5 – 45 °C at 43 and 96 % relative humidity. While moisture content changes ranged from 13.4 – 17.3 % when relative humidity changed from 43 – 96 % at 5 and 45 °C. The equilibrium moisture content increased gradually with increasing relative humidity up to 65 % and this increasing slowed down between 65-80% relative humidity and the increased gradually again at relative humidity higher than 80 % for different materials.

Further work should be done to consider more biomaterials with different physical properties.

REFERENCES

Ashour,T.H. 2003. The use of renewable agricultural by- products as building materials. Ph.D thesis, Benha University, Egypt. (http://www.downloads.fasba.de/TahaAshour-2003-complete.pdf).

ASHRAE. 1997. ASHRAE Handbook, Fundamentals. New York. American Society of Heating and Refrigerating and Air conditioning Engineers, Inc.

Bainbridge, D.A. 1986. High performance low cost buildings of straw. Agricultural, Ecosystems and Environment, 16: 281-284.

Krus, M. 1995. Feuchtetransport und speicherkoefficienten poröser mineralischer Baustoffe. Theoretische Grundlagen und Messtechniken. Disseration, Universität Stuttgart.

Kuenzel, H. 1991. Feuchteeonfluss auf die Waermeleitfaehigkeit bei Hygroskopischen und nicht Hygroskopischen Stoffen. WKSB. 36:15-18.

Künzel, H. M. 1994. Verfahren zur ein-und zweidimensionalen Berechnung des gekoppelten Wärme und Feuchtetransports in Bauteilen mit einfachen Kennwerten. Disseration, Universität Stuttgart.

Peralta, N. P. 1995: Sorption of moisture by wood within a limited range of relative humidities. Wood and fibre Science, 27(1) p. 13-21.

Padfield, T. 1966: The control of relative humidity and air pollution in showcases and picture frames. Studies in conservation 11 : 8-30.

Ritschkoff, A., Viitanen and Koskel. 2000. The response of building materials to the mould exposure at different humidity and temperature conditions. Proceedings of Healthy Buildings, Vol.(3): 317-322.

Swearing, J. 2001. Moisture Barriers in straw-bale construction. www.skillful-means.com

Tveit, A. 1966. Measurements of moisture sorption and moisture permeability of porous materials. Norwegian Building Research Institute, Oslo.

Watts, K.C, K. I. Wilkie, K. Tompson and J. Corson. 1995. Thermal and mechanical properties of straw bales as they relate to a straw house. Canadian Society of Agricultural Engineering, Paper no. 1995-209.

الملخص العربى

المحتوى الرطوبى التعادلى لبعض المواد العازلة الطبيعية

طه عاشور

تهتم هذه الدراسة بتقدير المحتوى الرطوبى التعادلى لبعض المواد الطبيعية والتى قد تستخدم كمواد عازلة. ويعتبر المحتوى الرطوبى التعادلى هام جدا فى تقدير الظروف المثلى لتخزين الحبوب وكذلك نمو الكائنات المسببة لتدهور المواد وكذلك كل عمليات التجفيف والترطيب. لذا كان الهدف من هذا البحث هو تقدير المحتوى الرطوبى التعادلى لأربعة مواد مختلفة وهى صوف الأغنام ، التيل ، الكتان ، والخشب الحبيبى المضغوط تحت ظروف مختلفة من درجات الحرارة (٥ – ٣٠ °م) والرطوبة النسبية (٤٣ – ٩٦%).

وقد أظهرت النتائج أن المحتوى الرطوبى التعادلى يزداد بزيادة الرطوبة النسبية المحيطة ويقل بزيادة درجة الحرارة لكن تأثير الرطوبة النسبية أكبر من تأثير إرتفاع درجة الحرارة. وقد حققت مادة صوف الأغنام أعلى قيم للمحتوى الرطوبى التعادلى (٢٠.٩%) ، ١٨.٥% للتيل ، ١٥.٩% للسليلوز ، ١٥% للكتان تحت الظروف المختلفة. وقد تم عمل معادلات تجريبية للربط بين تأثير درجة الحرارة والرطوبة النسبية وقيمة المحتوى الرطوبى التعادلى.

جامعة بنها – كلية الزراعة بمشتهر- قسم الهندسة الزراعية