MOISTURE ADSORPTION ISOTHERMS AND ADSORPTION ISOSTERIC HEAT OF DRY GROUND MEAT

Prof. Dr. Nesimi AKTAŞ

UNIVERSTY OF NEVSEHIR HACI BEKTAS VELI

FACULTY OF ENGINEERING ARCHITECTURE

DEPARTMENT OF FOOD ENGINEERING

NEVSEHIR/TURKEY

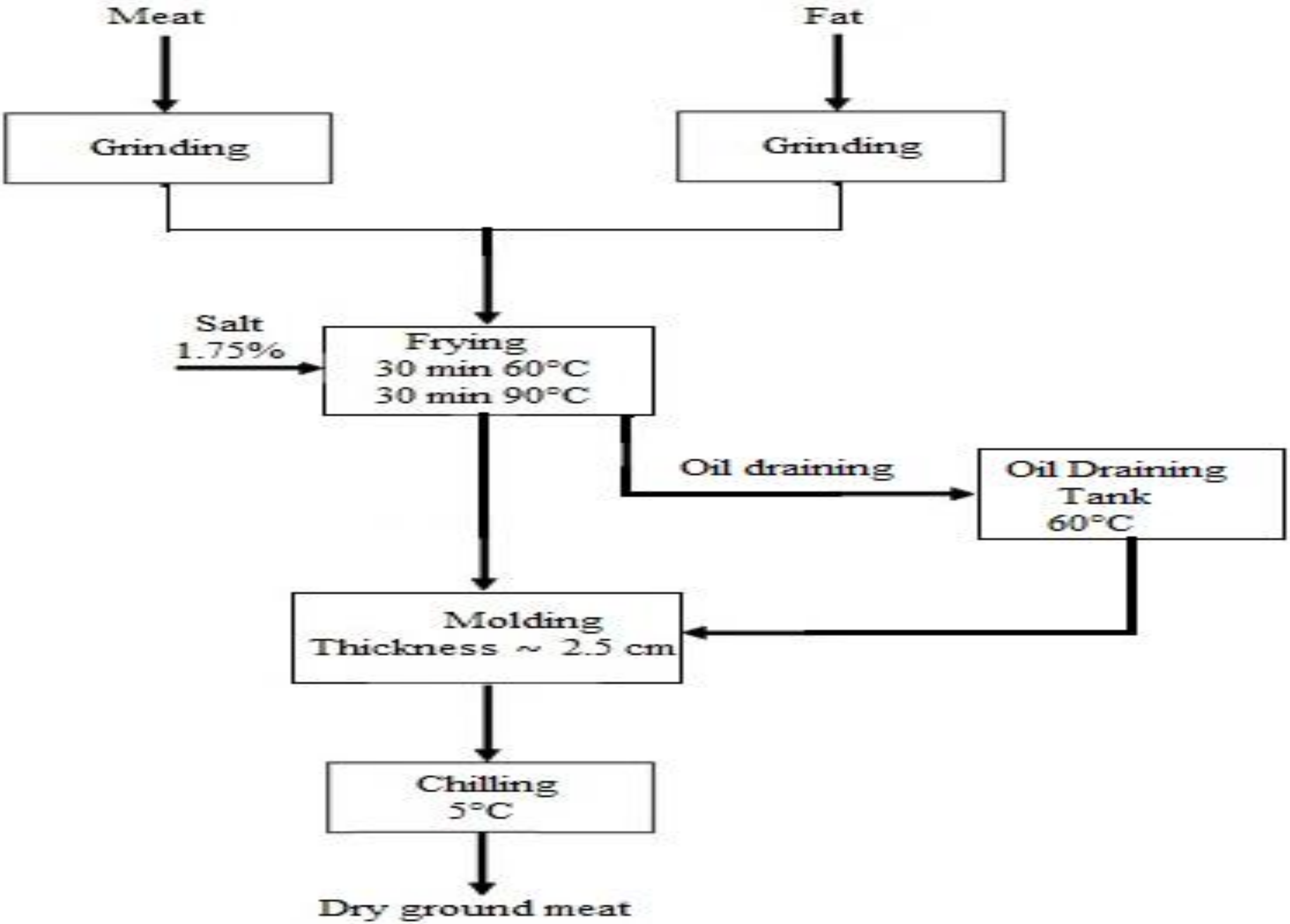

Figure 1. Block diagram of dry ground meat production

Materials and Methods

Materials

Dry ground meat samples with triplicate, which were produced on separate processing days by the same production technique, were purchased from a local company (Kavdirlar, Nevşehir, Turkey).

Methods

Physicochemical Analysis

pH

Moisture

Fat — (Ockerman, 1985)

Protein

Ash

Thiobarbituric acid reactive substances (TBARS) (Lemon, 1975)

Adsorption isotherms

Saturated salt solutions and relative humidity values

LiCl 11.30%,

KCH_3COO 23.11%,

$MgCl_2$ 33.07%,

K_2CO_3 43.16%,

$Mg(NO_3)_2$ 54.38%,

$NaNO_2$ 65.40%,

NaCl 75.47%,

KCl 85.11% and

$BaCl_2$ 90.69%

The temperatures used for the adsorption isotherms:

5, 15 and 25°C.

Fitting of adsorption data to various isotherm equations

The experimental data obtained were applied to different isotherm equations that are as follows: Iglesias-Chirife, Oswin, BET, Harkins-Jura, Smith, Henderson, Halsey, GAB, Peleg, modified Chung-Pfost, modified Oswin. The goodness of fit as applied to the experimental data were evaluated through the determination coefficient (R^2) and mean relative percentage deviation (P).

$$R^2 = 1 - \frac{\text{Residual sum of squares}}{\text{Corrected sum of squares}} \quad (1)$$

$$P = \frac{100}{n} \sum_{i=1}^{n} \frac{|X_i - X_{pi}|}{X_i} \quad (2)$$

Isosteric heat of adsorption

The isosteric heats of adsorption were calculated by using Eq. (3), which originates from the Clausius–Clapeyron equation, to the adsorption isotherms at different temperatures.

$$\frac{d \ln a_w}{d\left[\frac{1}{T}\right]} = -\frac{Q_n^{st}}{R} \qquad (3)$$

The isosteric heat of sorption (Q^{st}) is calculated by including the latent heat of vaporization for pure water (L_r) to the net isosteric heat of sorption (Eq. (4)), considering L_r as the average value for the temperatures taken into account (2466.18 J/g for 5–25 °C).

$$Q^{st} = Q_n^{st} + L_r \qquad (4)$$

Results and Discussion

Physicochemical analysis

Table 1. Physicochemical characteristics of dry ground meat samples

pH	**6.26±0.03**
Moisture (%)	51.82±0.10
Protein (%)	24.62±0.18
Fat (%)	21.52±0.48
Ash (%)	2.04±0.22
TBARS (μmol MDA/ kg)	6.28±0.17

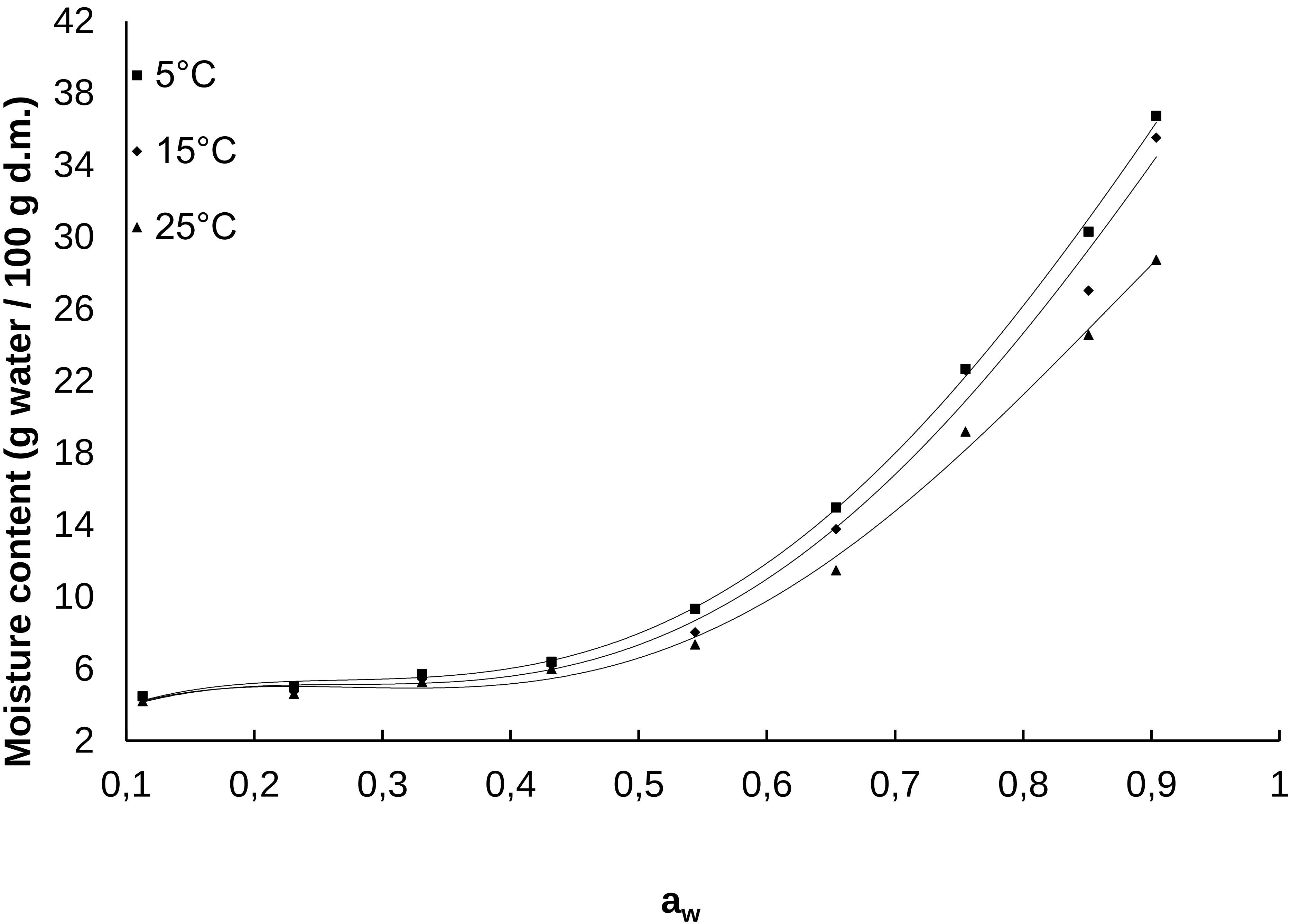

Figure 2. Moisture adsorption isotherms of dry ground meat samples at 5°C, 15°C and 25°C.

Isotherm equation	a_w (range)	Temperature (°C)	Constant parameters	Determination coefficient (R^2)	P (%)
Iglesias and Chirife $ln\left(m + (m^2 + m_{0.5})^{\frac{1}{2}}\right) = p + b\,(a_w)$	0.1-0.9	5°C	b=2.83 p=1.60	0.951	0.16
		15°C	b=2.77 p=1.58	0.938	0.43
		25°C	b=2.57 p=1.60	0.939	0.29
Oswin $\ln m = \ln k + n\, ln\left(\frac{a_w}{1 - a_w}\right)$	0.1-0.9	5°C	n=0.56 k=10.12	0.939	15.44
		15°C	n=0.55 k=9.55	0.926	17.00
		25°C	n=0.51 k=8.72	0.929	15.78
BET $\frac{a_w}{m(1 - a_w)} = \frac{1}{(m_o\, c)} + \frac{(c - 1)}{(m_o\, c)} a_w$	0.1-0.9 /0.1-0.5	5°C	C=46.94/60.34 m_o=4.35/4.04	0.866/0.973	12.28/5.76
		15°C	C=44.62/166.41 m_o=4.07/3.53	0.868/0.998	11.78/5.29
		25°C	C=35.44/-53.75 m_o=3.24/3.32	0.869/0.999	12.33/1.52
Harkins-Jura $\frac{1}{m^2} = \left(\frac{B}{A}\right) - \left(\frac{1}{A}\right)\log a_w$	0.1-0.9	5°C	A=16.34 B=-0.05	0.960	13.37
		15°C	A=15.65 B=-0.03	0.941	14.44
		25°C	A=14.53 B=-0.02	0.960	13.00
Smith $m = W_b - W\, ln(1 - a_w)$	0.1-0.9	5°C	W=15.60 W_b=0.28	0.978	19.11
		15°C	W=14.74 W_b=0.31	0.968	21.22
		25°C	W=12.08 W_b=0.49	0.969	18.00
Henderson $ln[-ln(1 - a_w)] = \ln k + n \ln m$	0.1-0.9	5°C	n=0.78 k=14.96	0.880	23.33
		15°C	n=0.77 k=14.03	0.861	26.11
		25°C	n=0.71 k=12.47	0.864	23.55
Halsey $\ln m = \left[\frac{1}{n}\ln C\right] - \left(\frac{1}{n}\right) ln\left[\ln\frac{1}{a_w}\right]$	0.1-0.9	5°C	n=1.28 c=11.87	0.969	12.11
		15°C	n=1.30 c=11.45	0.961	12.44
		25°C	n=1.40 c=12.65	0.964	11.22

Isotherm equation	a_w (range)	Temperature (°C)	Constant parameters	Determination coefficient (R^2)	P (%)
GAB $\frac{a_w}{m} = \alpha\, a_w^2 + \beta\, a_w + \gamma$ $\left[\frac{-1}{(4\,\alpha\,\gamma - \beta^2)}\right]^{\frac{1}{2}}$ $C = \left[\beta - \frac{\left(\frac{1}{m_m}\right)}{(-2\,\gamma)}\right]$ $K = \frac{1}{m_m\, C\, \gamma}$	0.1-0.9	5°C	m_m=4.33 c=1.01 K'=28.23	0.850	12.60
		15°C	m_m=3.94 c=1.03 K'=41.07	0.856	14.58
		25°C	m_m=3.69 c=0.95 K'=92.02	0.891	7.13
Peleg $M = A\, a_w^{B} + C\, a_w^{D}$	0.1-0.9	5°C	A=46.33 B=3.37 C=3.72 D=-0.10	0.998	4.49
		15°C	A=44.36 B=3.43 C=3.38 D=-0.14	0.990	7.25
		25°C	A=36.13 B=3.34 C=3.35 D=-0.12	0.993	6.19
Modified Chung-Pfost $M = -\frac{1}{c}\, ln\left[\frac{(t+b)\ln(a_w)}{-a}\right]$	0.1-0.9	5°C	a=78.76 b=34.24 c=0.09	0.931	28.22
		15°C	a=34.87 b=2.40 c=0.92	0.918	31.67
		25°C	a=557.54 b=230.96 c=0.11	0.921	20.11
Modified Oswin $\left(\frac{a_w}{1-a_w}\right)^{C}$	0.1-0.9	5°C	A=-3.86x10-4 B=7.73x10^3 C=0.59	0.978	14.22
		15°C	A=-7.74x10^4 B=5.16x10^3 C=0.60	0.971	15.01
		25°C	A=1.73x10^4 B=-690.73 C=0.56	0.966	14.89

	Temperature (°C)	BET	GAB
Monolayer moisture content	5	4.35/4.04	4.33
	15	4.07/3.53	3.94
	25	3.24/3.32	3.69

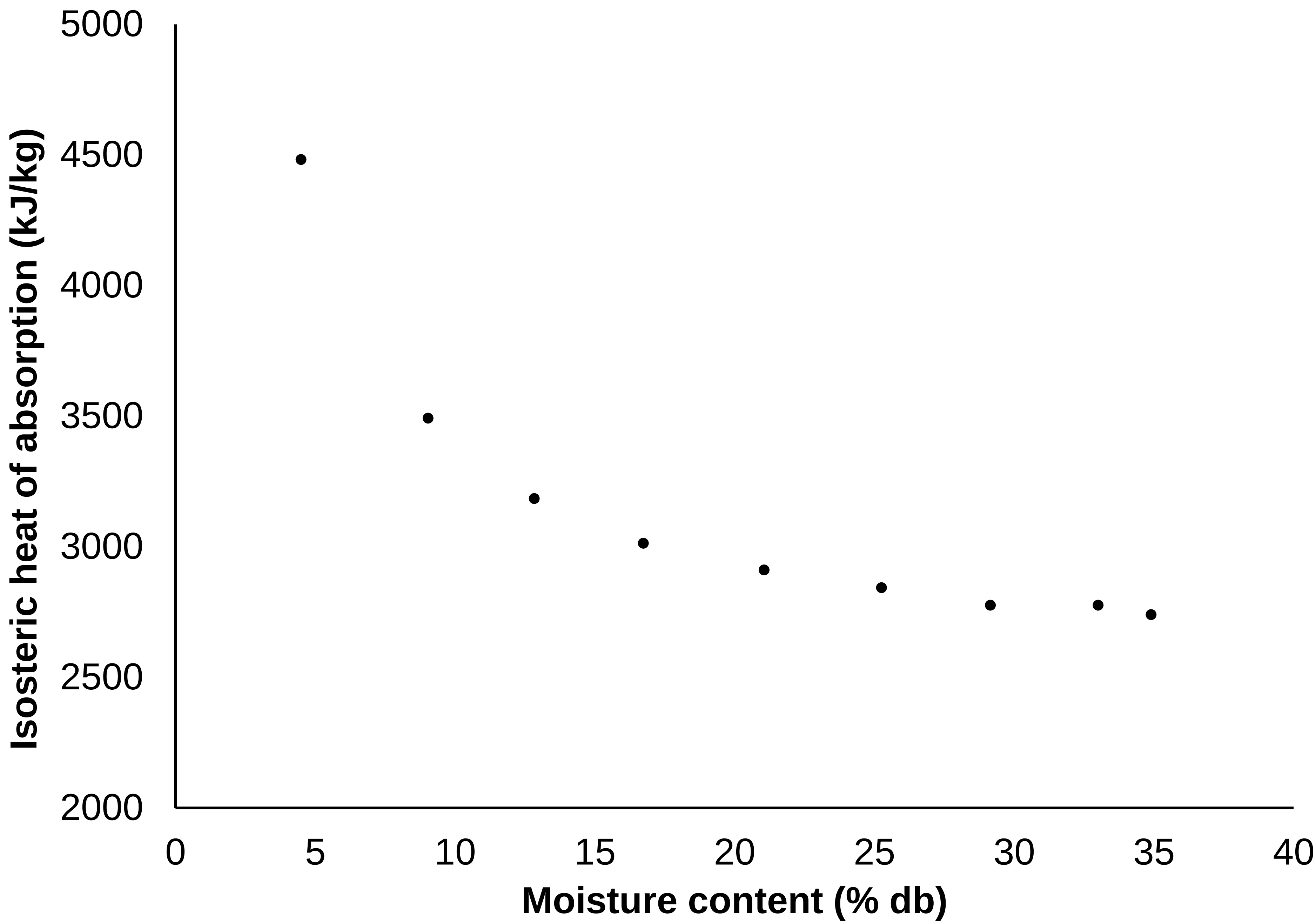

Figure 3. Isosteric heat of adsorption of dry ground meat samples

Conclusion

The sorption isotherms of dry ground meat samples were type II isotherm pattern that is commonly observed in high protein content food products. The equilibrium moisture content relationship of the dry ground meat samples in the studied temperatures were best described by the Iglesias-Chirife and Peleg models.

THANKS FOR YOUR ATTENTION

References

Ansari, S., Farahnaky, A., Majzoobi, M., & Badii, F. (2011). Modeling the effect of glucose syrup on the moisture sorption isotherm of figs. *Food Biophysics*, 6, 377–389. DOI 10.1007/s11483-011-9213-4

Badii, F., Farahnaky, A., & Behmadi, H. (2014). Effect of storage relative humidity on physical stability of dried fig. *Journal of Food Processing and Preservation*, 38, 477-483. doi:10.1111/j.1745-4549.2012.00797.x

Bell, L., & Labuza, T. (2000). *Moisture Sorption: Practical Aspects of Isotherm Measurements and Use*; American Association of Cereal Chemists: St. Paul, MN.

Falade, K. O., & Aworh, O. C. (2004). Adsorption isotherms of osmo-oven dried african star apple (*Chrysophyllum albidum*) and african mango (*Irvingia gabonensis*) slices. *European Food Research and Technology*, 218, 278–283. DOI 10.1007/s00217-003-0843-8

Labuza, T. P., Kannane, A., & Chen, J. (1985). Effect of temperature on the moisture sorption isotherm and water activity shift of two dehydrated foods. *Journal of Food Science*, 50, 385–392. https://doi.org/10.1111/j.1365-2621.1985.tb13409.x

Lemon, D. W. (1975). An improved TBA test for rancidity. *New Series Circular No. 51. Halifax Laboratory,* Halifax, Nova Scotia.

Mbarga, M. C. N., Nde, D. B., Mohagir, A., Kapseu, C., & Nkenge, G. E. (2017). Moisture sorption isotherms and properties of sorbed water of neem (*Azadirichta indica A. Juss*) kernels. *Journal of Engineering Physics and Thermophysics*, 90, 35-42. DOI 10.1007/s10891-017-1536-7

Mrad, N. D., Bonazzi, C., Boudhrioua, N., Kechaou, N., & Courtois, F. (2012). Moisture sorption isotherms, thermodynamic properties, and glass transition of pears and apples. *Drying Technology*, 30, 1397–1406. https://doi.org/10.1080/07373937.2012.683843

Prasantha, B. D. R., & Amunogoda, P. N. R. J. (2013). Moisture adsorption characteristics of solar-dehydrated mango and jackfruit. *Food Bioprocess Technology*, 6, 1720–1728. DOI 10.1007/s11947-012-0832-7

Quirijns, E., Van Boxtel, A., Van Loon, W., & Van Straten, G. (2005). Sorption isotherms, GAB parameters and isosteric heat of sorption. *Journal of the Science of Food and Agriculture*, 85, 1805–1814. https://doi.org/10.1002/jsfa.2140

Sanchez, E. S., Juan, N. S., Simal, S., & Rossello, C. (1997). Calorimetric techniques applied to the determination of isosteric heat of desorption for potato. *Journal of Science Food and Agriculture*, 74, 57–63. https://doi.org/10.1002/(SICI)1097-0010(199705)74:1%3C57::AID-JSFA770%3E3.0.CO;2-8

Timmermann, E. O., Chirife, J., & Iglesias, H. A. (2001). Water sorption isotherms of foods and foodstuffs: BET or GAB parameters? *Journal of Food Engineering*, 48, 19–31. https://doi.org/10.1016/S0260-8774(00)00139-4

Vega-Galvez, A., Lopez, J., Miranda, M., Di Scala, K., Yagnam, F., & Uribe, E. (2009). Mathematical modelling of moisture sorption isotherms and determination of isosteric heat of blueberry variety O'Neil. *International Journal of Food Science and Technology*, 44, 2033–2041. https://doi.org/10.1111/j.1365-2621.2009.02027.x