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Modelling Kinetics, Thermodynamics And Physical Properties Of Drying Five Coconut (Cocos Nucifera L.) Varieties

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Abstract

The drying kinetics, thermodynamic properties, and energy consumption of five potential coconut cultivars identified by Ghana's CSIR-Oil Palm Research Institute were studied. Drying was carried out in a convectional dryer using four temperatures (70, 80, 90 and 100 oC) and 2.0 m/s air velocity. The asymptotic model was adjudged the best fit model in predicting moisture content based on maximized coefficient of determination (0.9589-0.9998) and minimized residual sum of squares (8.427-252.61), chi-square (0.52671-16.8409) and root mean square error (2.8744-3.4421). Temperature and structural composition of the varieties caused between 66.8-96.5% variations in moisture diffusivity. Thermodynamic study revealed endothermic and non-spontaneity reaction in the drying system resulting from enthalpy change and Gibbs free energy change. Meanwhile, a direct relation was established among higher spontaneity and higher temperature and loose structural composition of the variety. Despite the high drying temperatures used for the experiment, internal cellular composition was not affected as a result of excellent rehydration capacity. In effect, the Vanuatu Tall was adjudged as the best coconut variety based on its lower energy consumption and activation energy, shorter drying time and higher moisture diffusivity.

Keywords*: *coconut drying; activation energy; energy consumption; rehydration; asymptotic model

Introduction

Coconut (Cocos nucifera L.), often referred to as "The tree of life" has become an important fruit crop in tropical countries including Ghana. Compositionally, matured coconut fruit consists of water (25%), meat (28%), hard shell (12%) and thick husk (35%) (Chakraborty & Mitra, 2008). The coconut meat has several health benefits including; reducing risk of heart diseases (Hajar, 2017), supporting weight loss as a result of high fibers to boost fullness(Howarth et al., 2001), aid digestion (Hervik & Svihus, 2019), stabilizes blood sugar (Vijayakumar et al., 2018), lower blood pressure (Sacks et al., 1998) and improves immunity (Patil & Benjakul, 2018). Also, research has suggested that coconut diet prevent kidney stones and stone formations (Worcester & Coe, 2010). In recent times, as a result of health consciousness of people globally; intake of fruits has increased tremendously where the consumers focus are geared toward an additive-free diet (Da Silva et al., 2013). Fruit shelf life is reduced to fewer days when kept without any additives and one of the traditional preservatives practices has been drying (Sarpong et al., 2018).

Drying of fruit basically removes moisture to improve nutritional and organoleptic properties which also extend the shelf-life for several days during storage (Rashid et al., 2019). The convectional drying has been applied most often at the industrial level due to the uniformity, cheap and fast drying time of the approach. However, drying process is very complex method as a result of many complex reactions that occur simultaneously. This complex process can be understood through the control of model parameters which could be used to design, predict and improve the drying process (Sarpong et al., 2019). In recent times, mathematical models have successfully been used in predicting and improving drying systems in both the academia and industry.

For drying of coconut, several methods such as the use of fluidized bed dryer, solar and sun dryers, microwave and oven dryers have been evaluated for some varieties (Niamnuy & Devahastin, 2005;

Valadez-Carmona et al., 2016). The Oil Palm Research Institute under the Council for Scientific and Industrial Research (CSIR), with the research mandate on coconut, has identified promising coconut varieties with regard to exportability, tolerance to the devastating Lethal Yellowing Disease (LYD) known locally as Cape St Paul Wilt Disease, among others. Specifically, the study sought to evaluate the drying kinetics, thermodynamics and physical properties of five promising coconut varieties in Ghana and recommend the best variety for export

Materials and methods

Material preparation and drying

Fifty-kilogram (50 kg) sample each of matured nuts (11-12 months) of five highly promising coconut varieties in Ghana namely, Sri Lanka Green Dwarf crossed Vanuatu Tall (SGD x VTT), Catigan Green Dwarf (CATD), Tacunan Green Dwarf (TAGD), Vanuatu Tall (VTT) and Indonesian Brown Dwarf (IBD) were selected based on the absence of mechanical and physical wounds and fungal growth. Samples were washed, sanitized and afterward rinsed with distilled water. Coconuts were then de-husked, de-shelled and sliced into approximately 3 cm length and 1.0 cm thick using ceramic knife (CK11A/6, Dolphin Series, CREASHARP China) prior to drying. Drying was carried out with convective oven dryer (SLN 75 POL-EKO-APARATURA, Śląski, Poland) on sieve tray tarred to zero before loading samples (447 g) at four temperatures (70 °C, 80 °C, 90 °C and 100 °C) and 2.0 m/s air velocity. The drying condition of the system was run for 1 h to ensure steady drying condition before loading. Weight measurement was obtained at 1 h interval until consecutive readings became less than 0.001 mg

Modeling of drying kinetics

Drying theory described by Lewis (1921), which is pillared on law of cooling in heat transfer proposed by Newton was used to describe the mass transfer in thin layer drying for agricultural products.

$$MR = \frac{M - M_e}{M_o - M_e} = exp(-kt)$$

Eq. (1)

Where MR is moisture ratio, M is moisture content at time t, are initial and equilibrium moisture (assumed as zero) respectively in dry basis (db) and k is drying constant. The experimental data of MR was fitted into 2 thin layer drying models depicted in Eq.1-2. Origin-Pro 9.2 was used for model regression analysis and good fit of the model was evaluated using coefficient of determination (R^2), residual sum of squares (RSS), chi-square (X^2) and root mean square error (RMSE).

Modified Parabolic Eq. (2)

Asymptotic Eq. (3)

Moisture effective diffusion (Deff)

Moisture effective diffusion was evaluated based on Fick's second law of difusion used for describing drying process at the falling rate period in agricultural materials and is depicted in Eq. 4

$$\frac{\partial M}{\partial t} = D_{eff} \nabla^2 M$$ Eq. (4)

D_{eff} (m²/s) was estimated for slab geometry based on the following assumption of constant (uni-dimensional moisture movement, volume change, constant temperature and negligible external resistance) according to Crank (1979). The equation is of the form:

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} exp\left[-\frac{(2n-1)^2 \pi^2 D_{eff}\, t}{4L^2}\right]$$ Eq. (5)

Where D_{eff} is the constant effective diffusivity (m²/s)? L and t represent half the thickness of the coconut slice and the drying time (s) respectively. Only the first term of the Eq. (6) is used for long drying times

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{8}{\pi^2} exp\left(-\frac{\pi^2 D_{eff}\ t}{4L^2}\right)$$ Eq. (7)

The slope is calculated by plotting In () against time

Eq. (7)

Thermodynamics properties

Activation energy () was estimated based on temperature dependency of drying kinetic using the Arrhenius equation shown in Eq. 8

Deff) $D_o \exp\left(-\frac{E_a}{R(T+273.15)}\right)$ Eq. (8)

Where T represent temperature (K), R is universal gas constant (8.314 J/ (mol K)) and Do is the Arrhenius constant. was measured in kJ/mol. The and rate of constant of drying kinetic were used for the following parameters; **the enthalpy change (Δ//H), the Gibbs free energy change (ΔG) and entropy change (ΔS) exhibited in Eq. 9-11**

$$\Delta G = R * T * In\left(\frac{k * h_P}{T * K_B}\right)$$ Eq. (9)

$$\Delta H = E_a - RT$$ Eq. (10)

$$\Delta S = \left(\frac{\Delta H - \Delta G}{T}\right)$$ Eq. (11)

Where the Boltzmann is constant (1.3806 x 10^{-23} J/K) and h_p is the Planck constant (6.6262 x 10^{-34} J s)

Energy consumption

The energy consumption (total) used for drying coconut varieties under varied temperatures was measured through electric energy meter with 0.01 kWh accuracy. In the case of specific energy consumption which is defined as the required energy to dry 1 kg of coconut was evaluated using

Eq. 12

$$E_s = \frac{E_t}{W_w} x1000$$ Eq. (12)

Where is the specific energy consumption, is the total energy consumption, and is the initial weight of coconut

Rehydration capacity (RC)

RC was performed at 30 °C in distilled water by immersing approach. A glass beaker containing the distilled water with ratio of 1:50 (w/w) was used where samples (100 g) were immersed to evaluate the RC. Data of RC was collected at 1, 2, 3, 4, 5, 6, and 7 h where after immersing, samples were blotted with tissue paper to remove excess water before weighing with electric balance (model SL2002N Shijiazhuang Sanli Grain Sorting Machinery Co. Shijiazhuang City, China). The RC was determined using Eq. 13

$$RC = \frac{W_r}{W_d}$$ Eq. 13

Where, and are weight after and before rehydration respectively measured in kg**Statistical analysis**

Data collection was performed in triplicate and presented as means ± s.d. through the processing of Origin-Pro 9.2 (Origin Lab Corporation, Northampton, MA, USA). Data comparison was performed with both one-way Analysis of variance (ANOVA) and Fisher's multiple comparison tests.

Results and discussion Drying behaviors of coconut varieties under varied temperatures

The changes in mass from initial weight of 447 g was used to study the drying behavior of coconut slices with an initial moisture content of 48±3.1 % wet basis (w.b.). Changes in moisture were determined on hourly basis and drying was halted when a constant weight was achieved. Observably, an exponential decrease in moisture was noticed in the overall drying behavior as depicted in **Fig. 1**. The constant period in drying kinetic theory was absent in the drying behavior of coconut but a faster rate of dehydration was spotted in early stages and decreased over time. Most often high free moisture availability and water diffusion principle accounts for initial and falling stages of drying kinetic behaviors respectively (Mghazli *et al.*, 2017; Sarpong *et al.*, 2019). Clearly, temperature and variety structural composition (food matrix) were the determining factors in causing the variation in rate of dehydration accounting for the differences in drying time as shown in **Fig.1**. All the varieties achieved constant weight at 10 h for 100 °C as the faster drying time whilst 17-17.5 h drying time was observed in 60 °C as longest drying time. The effect of temperature is widely known in literature and is attributed to higher driving force by higher temperatures for heat and mass transfer (Doymaz, 2004; Madamba, 2003). Observably, the VTT variety demonstrated higher dehydration rate among the varieties at 100 and 90 °C drying temperatures whilst at 80 °C, similar dehydration rate was observed for all varieties.

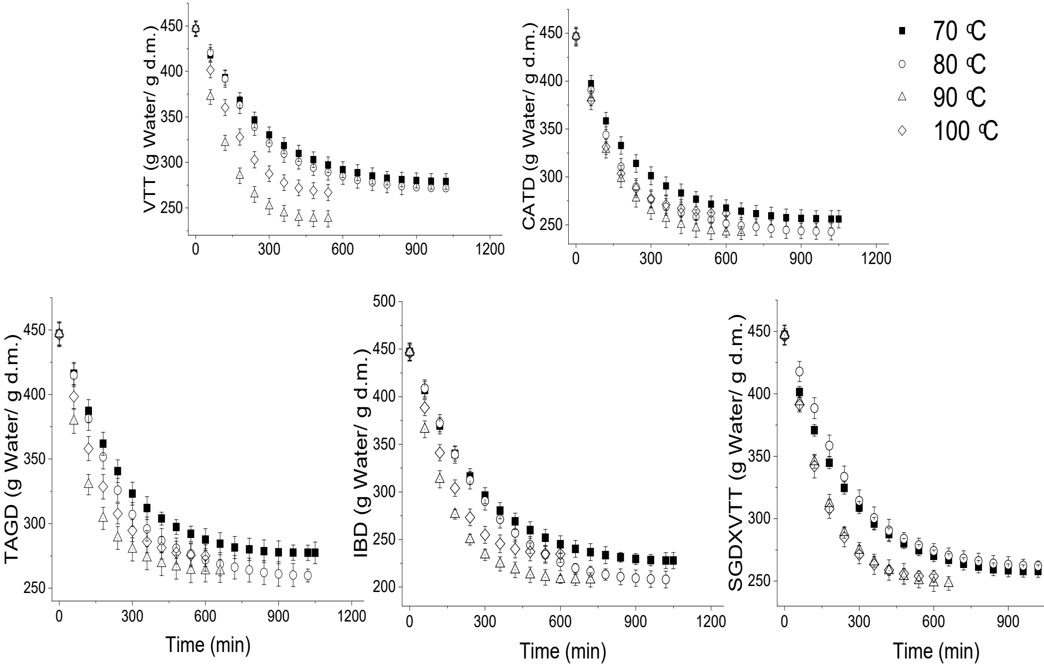

Fig 1: **Drying kinetics coconut slices under varied temperatures for five varieties**

For 70 °C drying condition, the SGD × VTT and VTT achieved the fastest drying time of 1020 min and these variations are as a result of loose copra structural composition which determined the permeability of heat of drying air temperatures to speed rate of dehydration. This also implies that large amount of surface moisture was found in VTT variety when compared with bound moisture which is often attributed to faster dehydration rate in agricultural products (Fernando & Amarasinghe, 2016).

3.2 Modelling fitting selection

The performance of the tested models were evaluated using four key statistical parameters (R^2, RMSE, χ^2 and RSS) and the obtained constants are depicted in **Table 1**. For best model selection, maximized R^2, and minimized RMSE, χ^2 and RSS were used as the criteria and as a result many tested models were rejected in preliminary study. The used models gave consistently R^2 range of 0.9589-0.9998 demonstrating a significant correlation between drying and predicted moisture content suggesting that the two model can be used in defining the drying behaviors of the variety of coconut. Asymptotic model was selected based on chosen criteria and was used for the first time as a more accurate model in predicting drying kinetics of coconut varieties due to highest R^2 (0.9589-0.9998) and lowest RMSE (2.8744-3.4421), RSS (8.427-252.61) and χ2 (0.52671-16.8409) in **Table 1**. Similarly, this model has been applied in predicting moisture content in coffee bean (Fadai *et al.*, 2018), fish (Jain & Pathare, 2007) and onion slices (Jain & Pathare, 2004)

Table 1: The coefficients of the tested models on coconut varieties in Ghana

Variety	TEMP (°C)	Model Name	Coefficients			R^2	RMSE	χ^2	RSS
SGD×VTT	70	Parabolic	a=-0.4263	$b=2.6\times10^{-4}$	c=423.850	0.9708	9.9326	98.6566	1578.50
		Asymptotic	a=254.92	b=-191.24	c=0.99578	0.9998	2.8744	0.52671	8.427
	80	Parabolic	a=-0.4451	$b=2.7\times10^{-4}$	c=435.620	0.9791	8.7594	76.7280	1227.64
		Asymptotic	a=256.32	b=-198.37	c=0.99609	0.9960	2.6754	14.7329	235.72
	90	Parabolic	a=-0.7456	$b=7.2\times10^{-4}$	c=434.433	0.9820	9.5997	92.1548	829.39
		Asymptotic	a=241.82	b=-208.63	c=0.99406	0.9985	3.4471	7.71304	69.41
	100	Parabolic	a=-0.8150	$b=8.8\times10^{-4}$	c=436.118	0.9848	8.8840	78.9267	631.41
		Asymptotic	a=246.21	b=-204.00	c=0.99350	0.9969	2.4460	15.9307	127.44
IBD	70	Parabolic	a=-0.4965	$b=3.0\times10^{-4}$	c=429.271	0.9829	9.1445	83.6234	1337.97
		Asymptotic	a=438.70	b=-222.92	c=0.99612	0.9979	2.7870	8.92130	142.74
	80	Parabolic	a=-0.5635	$b=3.4\times10^{-4}$	c=436.166	0.9925	6.8830	47.3757	710.63
		Asymptotic	a=203.59	b=-243.40	c=0.99605	0.9847	3.1424	85.4987	1282.48
	90	Parabolic	a=-0.8357	$b=7.8\times10^{-4}$	c=438.704	0.9619	15.837	250.812	2508.12
		Asymptotic	a=206.17	b=-240.82	c=0.99278	0.9985	2.8742	8.15348	81.53
	100	Parabolic	a=-0.8860	$b=9.3\times10^{-4}$	c=438.704	0.9922	7.0939	50.3237	402.59
		Asymptotic	a=232.87	b=-213.20	a=0.99209	0.9589	2.8788	212.509	1700.07
TAGD	70	Parabolic	a=-0.4024	$b=2.5\times10^{-4}$	c=433.190	0.9780	8.0872	65.4033	1046.45
		Asymptotic	a=275.96	b=-171.03	c=0.99542	0.9896	2.6641	30.9723	495.55
	80	Parabolic	a=-0.4602	$b=2.9\times10^{-4}$	c=432.806	0.9734	9.9529	99.0604	1485.90
		Asymptotic	a=256.95	b=-190.0	c=0.99588	0.9954	3.4421	16.8409	252.61
	90	Parabolic	a=-0.7008	$b=7.2\times10^{-4}$	c=423.161	0.9473	14.539	211.398	1902.58
		Asymptotic	a=262.39	b=-184.60	c=0.99195	0.9994	4.6211	2.36261	21.26
	100	Parabolic	a=-0.7014	$b=7.3\times10^{-4}$	c=438.208	0.9890	6.7211	45.1739	361.39
		Asymptotic	a=273.115	b=-173.17	c=0.99253	0.9820	2.8742	73.8743	590.99

CATD	70	Parabolic	a=−0.4243	b=2.6×10^{-4}	c=416.867	0.9513	12.574	158.118	2529.90
		Asymptotic	a=255.598	b=−189.38	c=0.99519	0.9990	2.3331	3.21237	51.39
	80	Parabolic	a=−0.4849	b=3.3×10^{-4}	c=410.136	0.9216	17.109	292.734	4391.02
		Asymptotic	a=244.253	b=−204.21	c=0.99401	0.9987	3.1125	4.85960	72.89
	90	Parabolic	a=−0.7758	b=7.8×10^{-4}	c=427.206	0.9674	13.029	169.768	1527.91
		Asymptotic	a=238.65	b=−210.22	c=0.99310	0.9992	3.4125	3.71861	33.46
	100	Parabolic	a=−0.7683	b=8.5×10^{-4}	c=427.363	0.9634	12.663	160.353	1282.83
		Asymptotic	a=259.89	b=−187.10	c=0.99214	0.9995	2.8971	1.99018	15.92
VTT	70	Parabolic	a=−0.3709	b=2.1×10^{-4}	c=433.829	0.9697	9.7266	94.6072	1513.71
		Asymptotic	a=267.79	b=−181.92	c=0.99662	0.9903	3.1150	26.9288	430.86
	80	Parabolic	a=−0.4288	b=2.7×10^{-4}	c=437.498	0.9808	8.0746	65.2002	978.00
		Asymptotic	a=265.962	b=−187.95	c=0.99616	0.9958	2.4552	12.3967	185.95
	90	Parabolic	a=−0.9743	b=0.001	c=432.658	0.9819	10.715	114.824	803.76
		Asymptotic	a=231.02	b=−217.50	c=0.99248	0.9988	3.2254	5.76996	40.38
	100	Parabolic	a=−0.7809	b=8.5×10^{-4}	c=444.3854	0.9969	3.91538	15.3301	107.31
		Asymptotic	a=251.64	b=−199.36	c=0.99466	0.9955	3.5540	17.4215	121.95

Moisture effective diffusivity (D*eff*)

Mode of mass transfer in a drying system may be varied and often occur simultaneously, however may be dominated or governed by one in a complex reaction (Anabel *et al.*, 2018). In describing the driving force in drying system, effective diffusivity (D*eff*) is calculated to estimate rate of water loss and in this case this ranged from 9.85×10^{-9} to 1.36×10^{-9} (**Table 2**) which is an indication of moisture movement in liquid state. The variation in D*eff* is attributed to drying temperature and structural composition (food matrix) of coconut variety which has direct effect on drying forces to vaporize free and bound water (Anabel *et al.*, 2018; Doymaz & Kocayigit, 2012). The D*eff* values were similar to coconut effective diffusivity of 1.75×10^{-9}–3.92×10^{-10} observed by Da Silva *et al.* (2014). D*eff* increased with increasing temperature and in this case between 66.8-96.5% increase was observed from 60 °C to 100 °C drying air temperatures. Again, increase in D*eff* collaborated with highest rate of dehydration in the VTT variety for all temperatures revealing the availability of free and bound water due to lose matrix in the variety.

Thermodynamic analysis

Evaluation of activation energy (*Ea*) was based on Arrhenius equation where the natural logarithm of D*eff* was plotted against absolute temperature (1/(T+273.15)) as depicted in **Fig. 2** and the resulting slope represented the *Ea.* The general concept of *Ea* is to define the required energy needed to reach active state to initiate reaction (Sarpong *et al.*, 2019). The ***Ea*** ranged 18.48-25.16 kJ/mol (R^2=0.9769-1.000) for 70-100 °C, almost half of 44.7 kJ/mol for 50–70 °C obtained by Da Silva *et al.* (2014). However, the ***Ea*** was within 10.7-110 kJ/mol for various agricultural products (Zogzas *et al.*, 1996). This is explained by the concept that increase in thermal agitation speed up moisture self-diffusion. Hence, it is expected that increase temperatures will generally reduce ***Ea***. Food matrix of the coconut variety was responsible for variation of ***Ea*** confirming the high dehydration rate in VTT variety as lowest values were observed.

Fig 2: Demonstrating Arrhenius relationship between the inverse of temperature (Kelvin) and effective diffusivity.

To measure the energy alterations between the activated complex and the reactant, enthalpy change (ΔH) was estimated in the system (Table 2). The ΔH obtained were between 12.58-22.22 kJ/mol. The effect of temperature on the ΔH was insignificant due to the fact ideal gas constant (R) value was very small (Eq. (9), thus changes observed could be attributed to structural composition of the varieties. The ΔH values also attested to the fact that loose composition variety such as VTT observed smaller energy difference (12.58-15.63 kJ/mol) when compared with the other varieties. The implication in this assertion is that little energy is required to achieve drying of VTT variety when compared with others. Again the positive ΔH values revealed the endothermic reaction during the drying process. Another thermodynamic property worth noting is the spontaneity of reaction also termed as Gibbs free energy change (ΔG) in the drying system. This value ranges from 199.98-214.65 kJ/mol, an indication of non-spontaneous reaction which were affected by both temperature and variety (Sarpong *et al.*, 2019).

Table 2: Moisture effective diffusivity and thermodynamic properties of coconut variety in Ghana

VARIETY	Temp (°C)	Deff (m^2/s)	Ea (kJ/mol)	R^2	ΔH(kJ/mol)	ΔG(kJ/mol)	ΔS (kJ/mol)
SGD×VTT	70	7.31×10^{-9}	20.20	0.9851	17.35	199.05	-529.51
	80	8.24×10^{-9}			17.26	204.41	-529.94
	90	1.02×10^{-8}			17.18	209.46	-529.49
	100	1.22×10^{-8}			17.10	214.61	-529.32
IBD	70	6.43×10^{-9}	25.16	1.000	22.31	199.41	-516.12
	80	8.00×10^{-9}			22.22	204.50	-516.15
	90	9.85×10^{-9}			22.14	209.58	-516.15
	100	1.20×10^{-8}			22.06	214.65	-516.13
TAGD	70	7.03×10^{-9}	22.14	0.9886	19.29	199.16	-524.18
	80	8.23×10^{-9}			19.20	204.42	-524.46
	90	1.02×10^{-8}			19.12	209.46	-524.14
	100	1.23×10^{-8}			19.04	214.57	-524.01
CATD	70	6.93×10^{-9}	21.60	0.9769	18.75	199.20	-525.88
	80	9.05×10^{-9}			18.66	204.14	-525.20
	90	1.1×10^{-8}			18.58	209.25	-525.03
	100	1.27×10^{-8}			18.50	214.47	-525.18
VTT	70	6.92×10^{-9}	18.48	0.9974	15.63	199.21	-534.98
	80	8.13×10^{-9}			15.54	204.45	-534.93
	90	1.15×10^{-8}			15.46	209.12	-533.28
	100	1.36×10^{-8}			12.58	212.98	-502.19

A direct relation was established among higher spontaneity and higher temperature and loose structural composition of the variety. The entropy change (ΔS) measured the disorderliness of molecules in the system during drying and the negativity of values obtained seems to suggest a lower structural freedom in achieving the transition state when compared with reactants.

Energy consumption

The **Fig 3** shows the total energy consumption and specific energy consumption of dried coconut varieties. For total energy consumption, a range of 30.94-54.60 kWh was needed to achieve constant dry weight of coconut. For variety specific, lesser energy was used in VTT in all temperatures when compared with others, confirming the fastest drying time in the drying behaviors of coconut. Beside variety, higher temperatures achieved lesser energy consumption with a significant difference ($p<0.05$). Other studies have revealed that sample thickness, processing conditions and external environment also play a significant role in energy consumption (Zhao ***et al***. 2018). In similar manner, specific energy consumption increases with decreasing temperature such that 188.66-122.14 kWh/Kg was observed at 70 oC whilst 60.46-69.80 kWh/Kg was achieved at 100 °C.

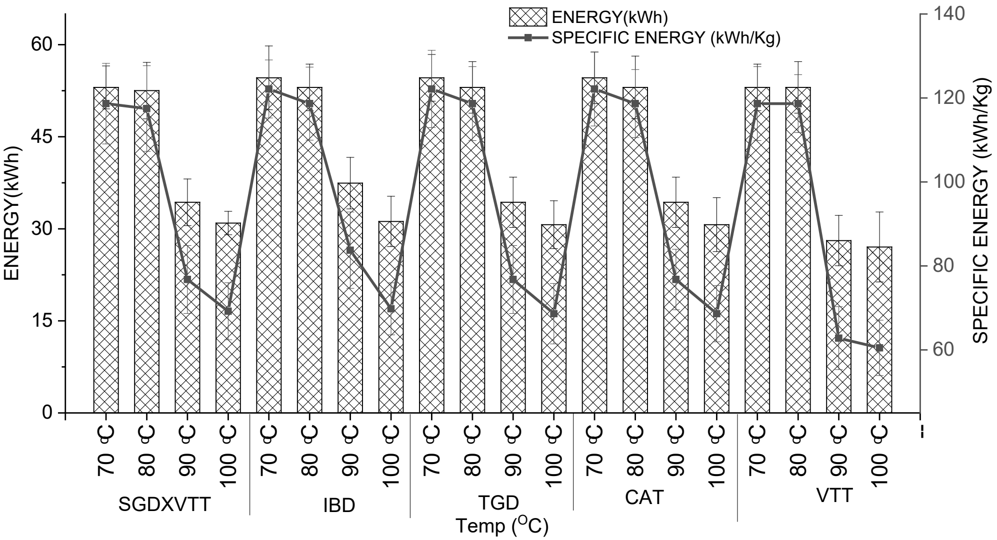

Fig 3: Energy and specific energy consumption in drying of coconut varieties under varied temperatures.

Rehydration capacity

For quality and injury assessment, rehydration capacity (RC) is one of the important parameters often applied to measure quality and injury caused by drying air temperatures of dried product (Doymaz & Kocayigit, 2012). Data of RC plotted against time is displayed in **Fig 4**. An analyses of the result revealed a higher rate of absorption at the initial stage followed by a gradual lower rate which is typical characteristics of dried product. This is as a result of filling up of cappillaries and intercellular space by osmosis prinicples and with time the available spaces were filled up to slow rate of absoprtion. Despite the use of higher temperatures in the drying experiment, the internal cellular composition of the coconut seems not to be altered and injured as result of excellent rehydrability for the data. Here again, temperature played a significant role in causing variation in rehydration capacity.

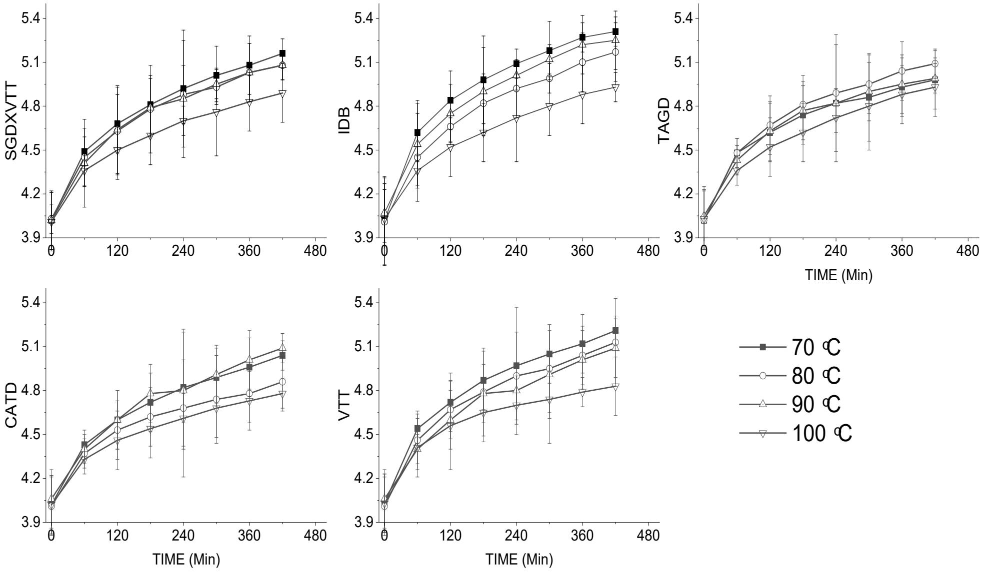

Fig. 4: the Rehydration capacity of dried coconut variety conducted at 30 °C.

Conclusion

In this study, five promising coconut varieties identified by the CSIR-Oil Palm Research Institute in Ghana were evaluated in terms of drying kinetic, thermodynamic, energy consumption and some physical properties. Temperature and variety structural composition (food matrix) were factors in causing the variation in rate of dehydration accounting for the difference in drying behaviors. For the first time in coconut drying, the asymptotic model was selected based on maximized R^2, and minimized RMSE, χ^2 and RSS. Between 66.8-96.5% increase in D*eff* was attributed to variation temperature and food matrix of variety. Activation energy (E*a*) observed revealed that VTT variety was more porous thus has a highest dehydration rate. Again, the tested ΔH and ΔG revealed endothermic and non-spontaneity reaction in the drying system and were directly affected by both temperature and structural composition of the variety. The internal cellular composition were little altered despite the high drying temperatures as a result of excellent rehydration capacity. In summary, the drying characteristics of the tested variety in terms of energy consumption, thermodynamics and D*eff* follows the order: IBD< TAGD <CATD<SGD×VVT<VTT

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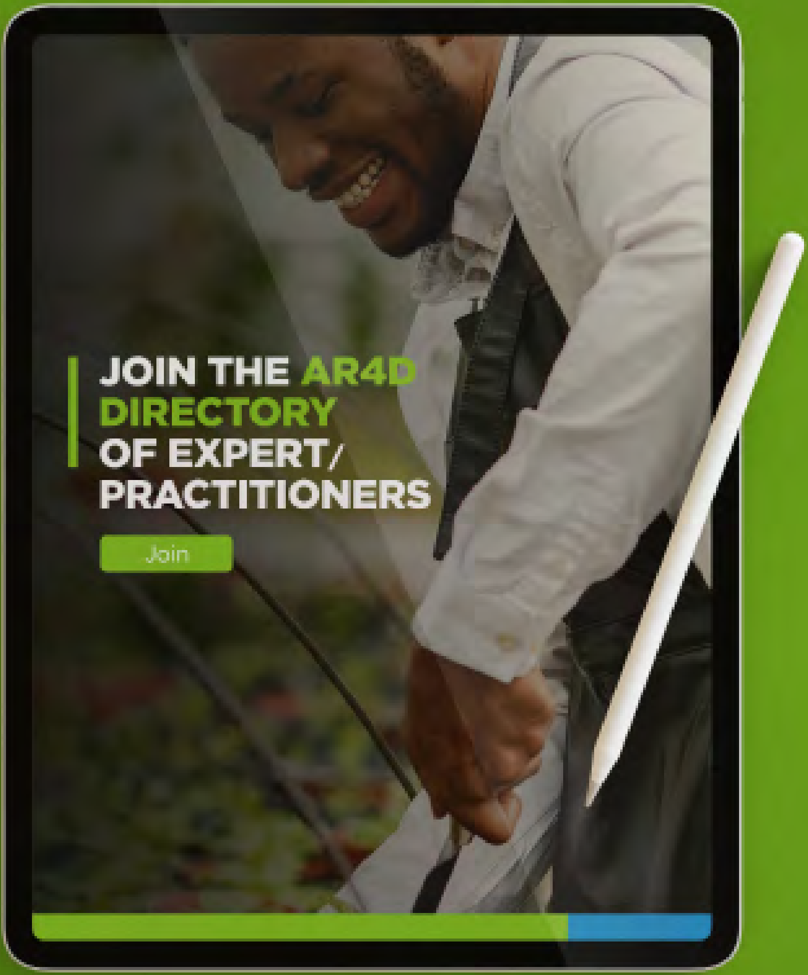

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