Critical Assessment of Oven Drying of Potato (*Solanum Tuberosum*) with Continuous and Intermittent Methods

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Abstract: Potatoes are very popular cool-season crop rich in starch, vitamins, minerals and protein; but very perishable once harvested. Open sun drying is one of the most prevailing methods of preservation in Nigeria which is unhygienic and results in unattractive dried potato chips. The present study aimed at determining and comparing the rates of moisture removed in continuous and intermittent methods of drying at 100°C. Fresh peeled and washed potatoes were cut into an approximate value of 5 cm thick. Equal weights of 200 g were used in the two methods. In continuous method, the sample was withdrawn from the oven after ten minute. Within a period of 40 seconds, the sample was weighed and replaced; and did not significantly affect the drying condition. In intermittent method, for every 10 minute, sample was withdrawn from the oven, weighed and then placed in a ventilated area for 15 minute intervals and then placed back into the oven.The dry rates in continuous method were found to be increasing from 0 – 40 minute and decreases from 40 – 70 minute due to hygroscopic structure of the crop while intermittent method shows a decreased from 0 – 70 minute due to the activities of the two kinetic factors. But when compared -0.049 was obtained which shows the perfect negative relationship between the two methods; and it was significantly big since it was close to minus one (- 1). The results obtained in the two methods are important in choosing the right method of drying in food processing industry.
Keywords: Oven drying of Potato, Continuous and Intermittent Methods, Comparative Analysis,

1. INTRODUCTION

Potato (*Solanum tuberosum*) is an herbaceous cool-season vegetable. It is an annual crop that grows up to 100 c*m* tall and produces a tuber. The edible part of the plant is an underground stem called a tuber (not a root). It contains 2 % of protein and 18 % of starch. It is rich in starch, vitamins and minerals. Potato ranks fourth (4) in the World as most important food crop, after maize, wheat and rice. Its scientific name is *Solanum tuberosum* L. It belongs to the family *Solanaceae,* genus *Solanum* and common name *Irish potato* or *table potato*. A recent research indicates that *S. tuberosum* is divided into two namely Andigenum, and Chilotanum [1]; [2]; [3]; and [4]. Potato can be used as food for man, feed for animal and industrial purposes [2].

Drying is a simultaneous heat and mass-transfer process that yields a dry product. It is achieved by applying the sufficient latent heat of vaporization to the water present in the food, thereby removing the resultant vapor from the food [5]. Drying is one of the oldest known food preservation methods practiced probably thousands years ago which aimed at extending the shelf-life of foods by reducing their water content [6]. This prevents food from microbiological spoilage as well as from the occurrence of chemical reactions such as enzymatic and non-enzymatic browning. Moreover, drying is also reducing the cost or difficulty of postharvest operation such as (transportation, processing, packaging, and storage) by converting the raw food into a dry product Heldman and Hartel, 1997; Karel and Lund, 2003; Ramaswamy and Marcotte, 2006; Sokhansanj and Jayas, 1995 study (as cited in [5]; [7].

There are different methods for drying food; these include sun drying, osmotic drying, microwave drying and convectional hot-air drying. Among these methods, convectional hot-air drying is the most common for food materials Jayaraman and Das Gupta, 1995; Lewis, 1987; Raghavan and Harper, 1974; Rahman and Perera, 1999; Us and Khan, 2007 study (as cited in [5]. According to [5], the most important thermodynamic process in food drying is heat and mass transfer. Heat transfer involves convective heat transfer, this means from the air to the food's surface (external heat transfer) and conductive heat transfer occurs within the food (internal heat transfer). Mass transfer this is the transportation of moisture within the food toward its external surface (internal mass transfer) and evaporation and convective transfer of the vapor into the air (external mass transfer). The two factors that affect drying were itemized by [5] as: Process conditions (i.e. drying temperature, relative humidity and air velocity) and nature of the food sample (i.e. thickness, surface area, composition, and structure). Intermittent drying is a non-continuous drying process with tempering periods. It involves strict control of the heat input (drying temperature) such that the food material is subjected to particular air conditions at different points in the course of drying [8].

Potato has a limited shelf life at ambient conditions and is highly perishable this makes its processing and preservation inevitable. In the processing of potato, moisture removal is one of the most important stages. Sun drying is the most common methods of preservation in Nigeria. An open sun dried on a bear ground results in an unattractive dried potato chips and it is exposed to so many contaminants which might be harmful to man. This calls for other methods of processing and preservation that are faster, less cost and hygienic. The present study is tailored towards determining and comparing the dry rates of potato in continuous and intermittent method of drying at a temperature maintained at 100°C. The objectives of the study are to determine and compare the weight of moisture removed in continuous and intermittent methods of drying of at 100°C; while taken account of periods. It involves strict control of the heat input (drying temperature) such that the food material is subjected to particular air conditions at different points in the course of drying [8].

2. MATERIALS AND METHOD

The agricultural crop used in determining the dry rates is Potato (*Solanum tuberosum*). Similar weights of 200 g were used for continuous and intermittent drying methods. The Potatoes were obtained from Main Market, Birnin Kebbi, Kebbi State, Nigeria within the month of March, 2015. The equipment used include: Calibrated oven thermometer, Digital weigh balance, and Venire caliper. The samples were selected at random and extra care was ensured not to select bad potato so as to avoid obtaining incorrect results Narsi, 2006 study (as cited in [9]. The potatoes were cleaned, peeled, and washed before slicing using a kitchen knife in to an approximate value of 5 cm thick. The drying experiments were carried out in a calibrated oven thermometer at convective temperature of 100°C. A sliced layer of potatoes weighing about 200 g was distributed uniformly on the oven shelf. Moisture loss was recorded periodically using a digital balance as a function of drying time. The drying samples were withdrawn from the oven at ten minute intervals. The experiments were repeated in seven replicates. It was rapidly weighed and replaced into the oven. The weighing of the product was performed in approximately 40 seconds and did not significantly change the steady-state of drying conditions. In the intermittent drying method, for every ten minute in the oven, samples were withdrawn, weighed and then placed on a ventilated area for 15 minute intervals and then placed back into the oven. During these 15 minute periods (tempering) the sample weight was recorded at five (5) minute intervals in order to account the moisture loss in the absence of heat application which was finally added to the moisture removed in intermittent method of drying. Data collected were analyzed and compared statistically using SPSS 21 package.

3. RESULTS AND DISCUSSION

3.1 Effect of Moisture on Continuous Method of Drying

The data obtained in table 1 shows that, at constant temperature (100°C) the weight of moisture removed increases from 0 to 40 minute and decreases from 40 to 70 minute. This corresponds with [5] and [10]. The amount of moisture removed was dependent on the temperature and hygroscopic structure of the material. According to Fortes and Okos, 1981 and Lewis, 1987 study (as cited in [5], the moisture at the surface of the crop leaves pores and replaced by gas (air). This led to the decrease in thermal conductivity of the surface since the thermal conductivity of water is higher than air. However, the surface behaves like an insulator and water is transferred more slowly to the surface where evaporation occurs through *Diffusion*. Therefore, further application of hot air will only lead to surface dryness [5]. Figure 1 detailed the rates at which moisture is removed from the biomaterial.

Table 1: Evaluation of dry rates of continuous method of drying at 100°C

Time (minutes)	*Weight of sample (Before dr* $W_i\,(g)$	*Weight of sample (After dryi* $W_f\,(g)$	*Weight of water remov* $\boldsymbol{w(g) = w_i - w_f}$
0 – 10	200.0	192.8	7.2
10 - 20	192.8	186.0	6.8
20 – 30	186.0	176.8	9.2
30 – 40	176.8	167.5	9.3
40 – 50	167.5	158.8	8.7
50 - 60	158.8	151.3	7.5
60 – 70	151.3	144.6	6.7

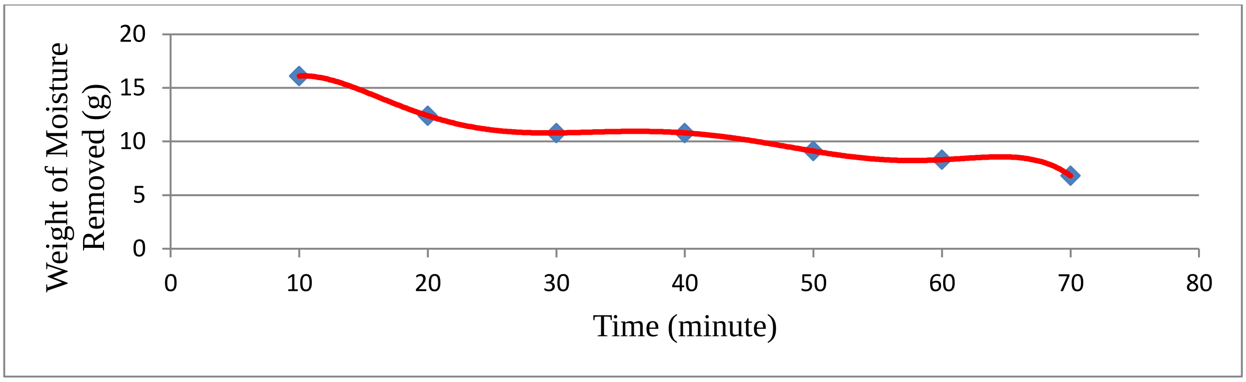

Figure 1: Continuous Method of drying at 100ºC

3.2 Effect of Moisture on intermittent Method of Drying

It was observed in table 2 that, the dry rates were decreasing from 0 to 70 minute at 100ºC which is in compliance with [5] and [11]. This was due to the activities of two kinetic factors that act on the sample (i.e. air velocity and relative humidity). The increasing air velocity takes more moisture away from the drying surface, thereby preventing the moisture from creating saturated conditions there. While the effect of relative humidity on external mass transfer is therefore, an increase in the relative humidity of the air decreases the water vapour pressure between the potato sliced surface and its surrounding air, which results in the reduction of external mass transfer rate. Similarly, a decrease in the relative humidity of the drying air increases the rate of external mass transfer [5]; [12] and [13]. It can be established that intermittent temperature process saves more time and energy than the corresponding continuous method. This is in compliance with the study of [5] and [11]. Figure 2 proves the rates at which water is removed from the biomaterial.

Table 2: Evaluation of dry rate of intermittent method of drying at 100ºC

Time (minutes)	*Weight of sample (Be drying)* W_i *(g)*	*Weight of sample (Af drying)* W_f *(g)*	*Weight of water remo* $h(g) = w_i - w_f$	*Total weight of moistur removed* $(h + t)$ *(g)*
0 – 10	200.0	192.8	7.2	16.1
10 - 20	184.2	177.9	6.3	12.4
20 – 30	171.8	165.8	6.0	10.8
30 – 40	161.0	155.3	5.7	10.8
40 – 50	149.9	145.6	4.3	09.1
50 – 60	140.8	137.1	3.7	08.3
60 – 70	132.5	129.7	2.8	06.8

Note: t refers in table 3

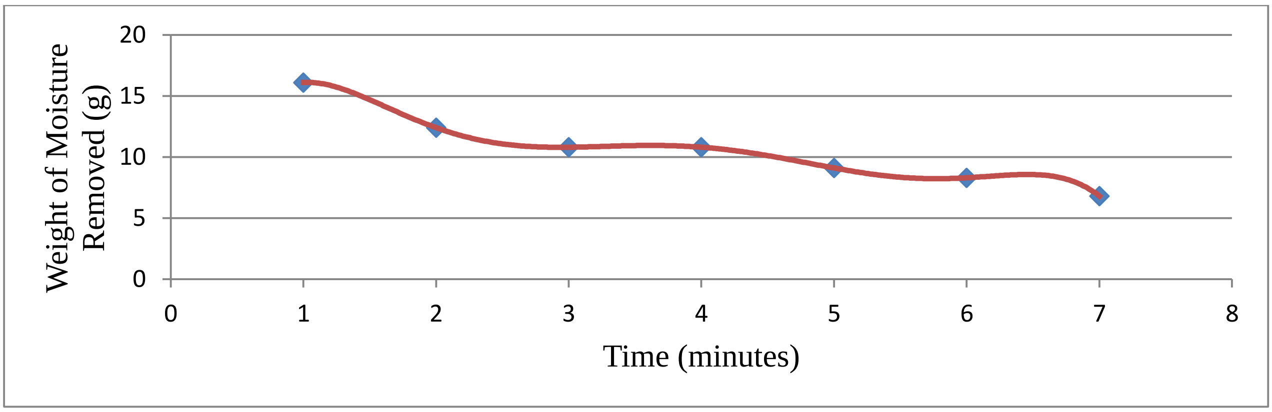

Figure 2: Intermittent Method of drying at 100ºC

3.3 Effect of Moisture on tempering (interruption) Period

The results as presented in table 3 shows that the rates of moisture removed in tempering period were higher at the first 5 minute which was due the high temperature of the biomaterial and the moisture was supplied by the biomaterial itself. The decrease in temperature of the food was due to evaporation cooling effect which was in agreement with [5] and [10] reports. According to [6], the amount of moisture removed from food was a function of specific heat present and respiration of the food. Figure 3 shows the rates at which water is removed from the biomaterial in the tempering periods

Table 3: Evaluation of tempering (interruption) period

Time (minutes)	*Weight of sample (Be cooling)* $W_i(g)$	*Weight of sample (Aft cooling)* $W_f(g)$	*Weight of water rem* $w(g) = w_i - w$	*Total moisture rem t(g)*
0 – 05	192.8	188.7	4.1	
05 - 10	188.7	186.7	2.0	
10 – 15	186.7	184.2	2.5	**8.9**
0 – 05	177.9	174.3	3.6	
05 – 10	174.3	172.7	1.6	
10 – 15	172.7	171.8	0.9	**6.1**
0 - 05	165.8	163.3	2.5	
05 – 10	163.3	161.6	1.7	
10 – 15	161.6	161.0	0.6	**4.8**
0 – 05	155.0	152.3	2.7	
05 – 10	152.3	150.9	1.4	
10 - 15	150.9	149.9	1.0	**5.1**
0 – 05	145.6	143.3	2.3	
05 – 10	143.3	141.7	1.6	
10 – 15	141.7	140.8	0.9	**4.8**
0 – 05	137.1	135.0	2.1	
05 – 10	135.0	133.3	1.7	
10 – 15	133.3	132.5	0.8	**4.6**
0 – 05	129.7	127.8	1.9	
05 – 10	127.8	126.6	1.2	
10 – 15	126.6	125.7	0.9	**4.0**

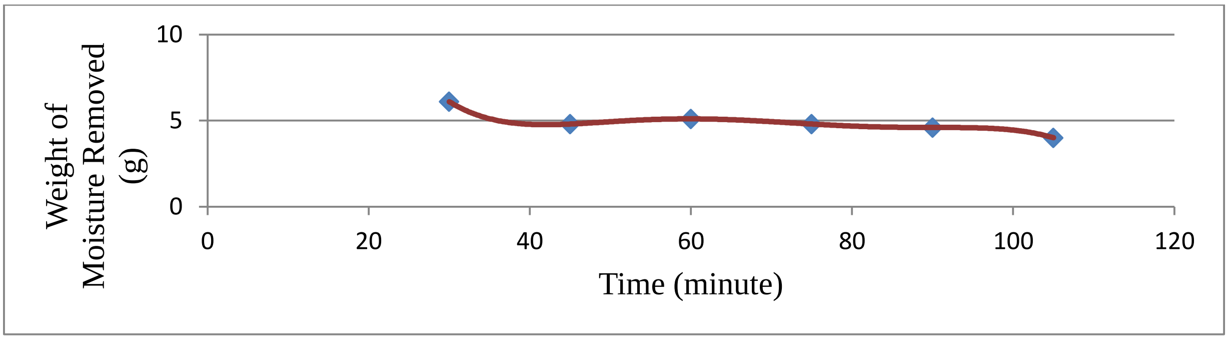

Figure 3: Tempering Period

The value obtained when compared was -0.049 as in table 4 which shows that, there was strong perfect negative relationship between continuous and intermittent methods of drying. It was significantly big because it was close to minus one (-1). However, at constant temperature, as the rate of moisture removed in continuous method was increasing; a decrease was concurrently incurred in intermittent method of drying. Figure 4 shows the relationship between the two methods which indicates that in furtherance of the drying methods there would be a point where the two would cross each other.

Table 4: Correlation analysis of drying rates in continuous and intermittent method of drying

		Continuous	Intermittent
Continuous	Pearson Correlation	1	-.049
	Sig. (2-tailed)		.916
	N	7	7
Intermittent	Pearson Correlation	-.049	1
	Sig. (2-tailed)	.916	
	N	7	7

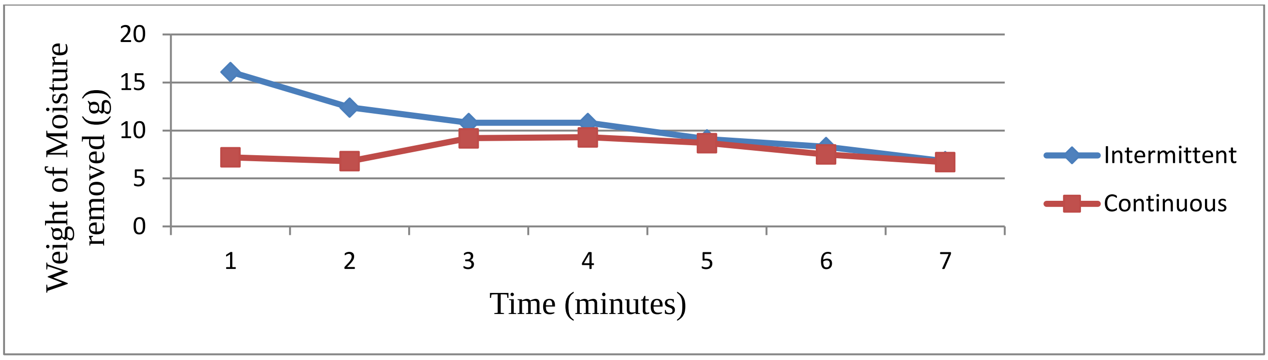

Figure 4: Continuous and Intermittent Methods of Drying as compared

4. CONCLUSION

The two methods of drying used in determining the rate of moisture removed were continuous and intermittent. The rate of moisture removed in continuous method of drying was observed to be increasing from 0 – 40 minute and decreases from 40 – 70 minute which was a function of hygroscopic structure of the crop. Conversely was observed in intermittent method of drying. The rate of moisture removed was completely decreasing from 0 – 70 minute, consequently, the activities of the two kinetic factors (air velocity and relative humidity). When compared -0.049 was revealed which means that, there was perfect negative relationship between the two methods; and it was relatively big since it was close to minus one (- 1).

From the results obtained in the two methods of drying, it can be established that, intermittent method of drying is faster than continuous method of drying therefore, it is recommended for food industries.

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