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Research Article

# Physical Properties and Drying kinetics of Green Peas

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## Abstract

The present work was conducted to study the physical parameter of field green peas (Variety: KPS 10) and using different drying methods for drying kinetics. The initial moisture content in green pea (KPS 10) was observed 80.96%. The average values of dimensional and geometrical parameter like Diameters (D1, D2 and D3), AMD, GMD and SMD were found 9.517 mm, 9.343 mm, 7.707 mm, 8.856 mm, 8.816 mm and 15.305 mm respectively. The mass of 1000 grains of green peas, volume, bulk density and true density were found 329.501g, 0.2 ml, 0.275g/cm3 and 0.304 g/cm3 respectively. Average angle of repose, sphericity, porosity and moisture content were calculated as 24.7o, 0.926, 9.528% and 80.96%, respectively. In drying experiment, it was observed that moisture content continuously decreased with increase in drying time. Drying rate was found maximum in the initial stage which decreased gradually with the time of drying. In tray drying, at 700C most of the water removed in fourth hour during drying for variety KPS 10. The page model was found to be better fit than Newton's model for predicting the drying behaviour of green peas for tray drying at $60^0$C temperature.

**Keywords:** Physical Properties; Drying Kinetics; Drying Constant; Moisture Content; Peas

## Introduction

Green peas (*Pisum sativum*) are considered as an important agricultural crop and an integral part of the human diet worldwide. The pea is most commonly small spherical seed or the seed-pod of the pod fruit. Each pod contains several peas. Peapods are botanically a fruit, since they contain seeds developed from the ovary of a (pea) flower. A pea is most commonly green, occasionally purple or golden yellow, pod-shaped vegetable, widely grown as a cold season vegetable crop. Pea is an important and highly nutritive vegetable widely grown throughout the world. In India, it is grown as a winter vegetable in plains of North India and as a summer vegetable in hills. Peas are the choicest vegetable grown for shelled green seeds. It acquired a place of prominence not only in sumptuous banquets but in diets of ordinary and poor class of people also. Green peas are a good source of protein as well as other nutritional elements like vitamins, mineral and fibre. Green peas are also rich in folic acid; this acid can help prevent cardiovascular illnesses. It has been studied that if per person consumption was made 400 mg of green peas it would greatly reduce the extent of cardiovascular deaths. Fiber helps in proper digestion of food; it is extremely important in fighting against cancer because fiber binds toxins to it and assists in removal of toxins from body. Fresh green peas are very good in ascorbic acid (vitamin C). 100g of fresh pods carry 40 mg or 67% of daily requirement of vitamin C. Vitamin C is a powerful natural water-soluble anti-oxidant. Vegetables rich in this vitamin would help human body develop resistance against infectious agents and scavenge harmful, pro-inflammatory free radicals from the body. Canned, frozen and dehydrated peas are very common for use during off-season. Like any legume crop, pea is an integral component of sustainable agriculture due to its soil enriching and conditioning properties. Green peas are the best when eaten fresh; we can eat these raw like peanuts or by making dishes out of the peas. Green peas are rich coloured and fine textured, apart from their nutritional content, so these are ideal to make an attractive dish. We can also use green peas to make green peas cutlets and other such fun dishes. Green peas can be included in salads and rice recipes.

The knowledge of engineering (physical and mechanical) properties constitutes important and essential data in the design of machines, storage structures and processes. The value of this basic information is not only important to engineers but also to food scientists, processors, and other scientists who may exploit these properties and find new uses. The size and shape are, for instance, important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery [1]. The shape of the material is important for an analytical prediction of its drying behaviour. Bulk density and porosity are major considerations in designing near-ambient drying and aeration systems, as these properties affect the resistance to airflow of the stored mass. The theories used to predict the structural loads for storage structures have bulk density as a basic parameter. The angle of repose is important in designing the equipment for mass flow and structures for storage. The frictional characteristics are important for the proper design of agricultural product handling equipment [2].

Removing water from food and agricultural products constitutes a significant portion of the processing activity for persons working in the food and agricultural processing industries. The main purpose of drying is to enhance storability, minimize handling and packaging costs [3]. From literature cited that method of green pea drying as used like multistage combined heat pump microwave vacuum drying [4], fluid bed drier [5] sun drying, Poly house drying (solar drying), tray/cabinet drying, fluidized bed drying, vacuum drying, microwave drying and freeze drying. It was reported that mechanical method, a promising and cost-effective technique of preservation, is more useful in the Indian condition for drying of pea and other vegetables. The physical properties of pea seeds are essential for the design and facilities for the harvesting, handling, conveying, separation, drying, aeration, storage and processing the pea seeds. Various types of cleaning, grading and separation equipment are designed on the basis of their physical properties as a function of moisture [6].

Despite an extensive search, no published literature was available on the detailed physical properties of green pea and their dependence on operation parameters that would be useful for the design of processing machinery. Therefore, an investigation was carried out to determine physical properties and drying kinetics of green pea. The purpose of this study was to investigate some physical properties, namely, axial dimensions, geometric mean diameters, sphericity, thousand grain mass, surface and projected areas, bulk and true densities, porosity of green peas. It is also seemed that there is not much published work related to dehydration of peas.

## Materials and Methods

Experiments were conducted to studies the physical properties of Green Peas (*Pisum sativum*) and drying kinetics. The study was done in the Food Analysis Laboratory and Process and Food Technology Laboratory, S.V.P. University of Agriculture and Technology, Meerut. Studies were conducted to evaluate the various physical properties of green pea and their dehydration at different types of drying such as sun drying, solar drying and tray drying at $50^0$C, $60^0$C and $70^0$C. Green peas (KPS 10) were produced from local market of Saharanpur for the present study. Kalash seeds private limited produced an improved variety KPS 10 which were taken for the present study. The green peas were cleaned manually to remove all foreign matter.

### Determination of physical properties

The determination of physical properties of agricultural materials is considerably complex due to their irregular shape and variability in size. Currently therefore is no single standard method is applied for determining the physical dimensions of agricultural products [7]. The dimensions of agricultural materials are measured by Vernier calipers in case of relatively small objects.

- **1000 kernel weight:** Thousand kernel weight (TKW) is an important parameter for evaluating the grain yield. The 1,000 kernel denoted as TKW, is a measure of seed size, representing the weight in grams of 1,000 seeds. By using the 1,000 K weight, allows producers to adjust for size variations when calculating seeding rates, calibrating seed drills and estimating shattering and combine losses.

- **Dimensions:** To determine the average size of the pea, 10 peas were randomly picked and their three linear dimensions ($D_1$), ($D_2$) and ($D_3$) were measured using a Vernier Caliper (least count 0.01mm). The measurements were taken at room temperature.
- **Mass, volume and density:** Mass of fresh peas was determined using a high precision electronic balance. The volume of peas was determined individually by water displacement method using a cylinder of 100 ml capacity. The mass and volume were expressed in g and ml respectively (1 ml=1cm$^3$). Densities of peas were calculated using the following equation:

$$\text{Density} = \frac{\text{weight(g)}}{\text{volume (cm}^3\text{)}} \text{-----(1)}$$

- **Geometrical and morphological dimensions:** Sphericity, arithmetic mean diameters (AMD), geometric mean diameter

(GMD) and square mean diameter (SMD) for peas were calculated using the following equations as suggested by Mohsenin [8].

$$AMD = \frac{D_1+D_2+D_3}{3} \quad \text{-----(2)}$$

$$GMD = \sqrt[3]{D_1D_2D_3} \quad \text{-----(3)}$$

$$SMD = \sqrt{D_1D_2 + D_2D_3 + D_3D_1} \quad \text{-----(4)}$$

$$Sphericity = \left(\frac{GMD}{D_1}\right) \quad \text{-----(5)}$$

Where,

$D_1$ = Major diameter, $D_2$ = Intermediate diameter, $D_3$ = minor diameter

- **Bulk and True Density:** Bulk density of grain is the ratio of mass of grain to its bulk volume, where as true density is the measure of the ratio of the mass of grain to its actual volume. The bulk density of peas was determined by measuring the mass of sample of known volume. The peas sample was placed in a cylindrical container of volume 250 $cm^3$. To standardize the packing of peas in the container, the cylinder was tapped gently downwards onto a table 10 times, ensuring the method was consistent across all measurements. The excess grains on the top of the cylinder were removed by sliding a string along the top edge of the cylinder. After levelling the cylinder, the mass of the grain sample was measured using an electronic balance.
- **Porosity:** The total porosity (ε) was determined by using the formula stated by Mohsenin [1].

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad \text{----- (6)}$$

Where

ε = Porosity (%), = bulk density ($kg/m^3$), = true density ($kg/m^3$).

### Initial moisture content (%)

The following method recommended by [9]. was used for determination of moisture content.

### Drying data processing

Moisture content (g water/g dry solid) of the sample (M) is calculated by the following equation (7) and recommended by Ranganna [10]

$$\text{Moisture content (g water/g of dry solid)} = \left(\frac{Mt-Md}{M_d}\right) \text{-------- (7)}$$

where $M_t$ is the mass of sample at time $t$ and $M_d$ is mass of dry solid.

The moisture content is essential to be the same for all samples in the base measure because of natural and inherent differences in initial moisture content of the samples. Therefore, the moisture ratio (MR) expression is calculated using the following equation:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad \text{----- (8)}$$

where $M_t$, $M_e$, and $M_0$ are moisture content at any time, equilibrium moisture content, and initial moisture content, respectively. In this method, samples were placed in an environment maintaining relative humidity and temperature constant. When the change in the weight of samples was insignificant, the moisture of the samples was measured and adopted as the equilibrium moisture content ($M_e$). In order to low humidity in ambient (dry and hot weather), equilibrium moisture content is negligible and

$$MR = \frac{M_t}{M_0} \text{------------------ (9)}$$

Drying curves were constructed by MR versus time. Numerical differentiation of drying curves is proportional with drying rate. This concept is used as dimensionless drying rate (DR) through the paper.

Drying kinetics models does not take into account the effects of interactions by parameters other than the time of drying. Models that incorporate a large number of variables still do not exist but due to the complex non-linear relationship between the kinetics of drying and variables related, the development of such models is not feasible [11,12]. The concept of thin-layer drying models for characterizing the drying behaviour was suggested, initially, by [13] who derived the semi-theoretical model for porous hygroscopic materials, which is analogous with Newton's law of cooling. The following model was developed

$$\frac{M_t - M_e}{M_0 - M_e} = \exp(-kt) \quad \text{------- (10)}$$

where MR is moisture ratio, k is drying constant ($m^{-1}$), t is drying time, $M_t$, $M_e$, $M_o$ is moisture content at any time, equilibrium and initial, respectively. The semi-logarithmic plot of moisture ratio and drying time represent a straight line for Newton model. Lewis model by adding a dimensionless empirical constant (n) and used it for study the drying behavior of shelled corns [14]. For this model a log-log graph used to obtain a straight line with a positive slop.

$$\frac{M_t - M_e}{M_0 - M_e} = \exp(-kt^n)$$ ------- (11)

## Effective moisture diffusivity

Mass transfer during food drying is a complex process involving various mechanisms such as molecular penetration, movement in capillary tubes, and liquid penetration in the porous materials, penetration of vapor in air pores and hydrodynamic flow, or surface propagation. Moisture penetration is one of the most important factors controlling the drying process. When different mechanisms are effective in transmitting, it is difficult to examine each mechanism and measure the mass transfer rate in each one. Hence, in such processes, the description of $D_{eff}$ is used and its concept is described by the Fick's second law as follows (15):

$$\frac{\partial M}{\partial t} = D_{eff} \nabla^2 M$$ ----------(13)

Calculation of $D_{eff}$ using Fick's second law is a tool for describing the drying process and possible mechanisms for the transfer of moisture within food products. The analytical solution of Fick's law is as follows (16):

$$MR = \frac{M_t - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2i+1)^2} \exp\left(-\frac{(2i+1)^2 \pi^2}{4L^2} D_{eff} t\right)$$

----------- (14)

Therefore, Eq. (11) can be written in simpler form as Eq. (12):

$$MR = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff} t}{4L^2}\right)$$ ------------(15)

The coefficient $K_1$ is calculated by plotting the curve ln (*MR*) versus drying time, in accordance with Eq. (15) as follows (17):

$$D_{eff} = \frac{K r^2}{\pi^2}$$ For sphere ------------- (16)

# Results and Discussion

## Determination of physical properties of green pea

The experimental data of physical properties of Pea (KPS 10) are presented in table 1. The dimensional and geometrical parameter like $D_1$, $D_2$, $D_3$, AMD, GMD and SMD were found 9.517 mm, 9.343 mm, 7.707 mm, 8.856 mm, 8.816 mm and 15.305 mm respectively. The 1000 kernel weight, volume, bulk density and true density were found 329.501 g, 0.2 ml, 0.275 g/cm$^3$ and 0.304 g/cm$^3$ respectively. The sphericity, porosity and initial moisture content were found 24.7, 0.926%, 9.528 and 80.96% respectively.

## Drying kinetics of green pea (KPS 10)

| Dimensions | Values | ± SD |
|---|---|---|
| $D_1$ (mm) | 9.517 | ± 0.341 |
| $D_2$ (mm) | 9.343 | ± 0.406 |
| $D_3$ (mm) | 7.707 | ± 0.075 |
| AMD (mm) | 8.856 | ± 0.270 |
| GMD (mm) | 8.816 | ± 0.258 |
| SMD (mm) | 15.305 | ± 0.458 |
| Bulk Density (g/cm$^3$) | 0.275 | ± 0.002 |
| True Density (g/cm$^3$) | 0.304 | ± 0.003 |
| Porosity (%) | 9.528 | ± 0.235 |
| $TKW_{1000}$ (g) | 329.501 | ± 13.480 |
| Volume (ml) | 0.20 | ± 0.100 |
| Sphericity (%) | 0.931 | ± 0.006 |
| Moisture Content (%) | 80.96 | ± 1.985 |

**Table 1:** Physical properties of Pea (KPS 10).

Grean Pea with initial moisture content (411.77%, db or 80.96% wb) was dried by three drying methods viz., sun drying, solar drying and tray drying (at 50, 60 and 70$^0$C temperatures). The effect of drying methods on drying characteristics of green pea is described in different drying curves plotted between drying time vs moisture content (Figure 1), drying time vs drying rate (Figure 2) and drying time vs moisture ratio (Figure 3). The total drying time was recoded for sun drying (510 min), solar drying (420 min), and tray drying at 50$^0$C (420 min), 60$^0$C (420 min), 70$^0$C (420 min). The final moisture content was observed as follows sun drying (19.41%, db), solar drying (12.59%, db), and tray drying at 50$^0$C (14.30%, db), 60$^0$C (7.47%, db), and 70$^0$C (6.62%, db). Drying behavior of pea is shown in figure 1. It is explicit that moisture content decreased rapidly with increase in drying time at the initial stage among the all-drying methods. This was likely due to the fact that during the initial stage of drying, there was a rapid removal of surface free moisture from the product [18]. This hypothesis has been supported by earlier researcher [19]. A graph comparing drying times across different methods is plotted in figure 2. The effect of drying methods on drying rate of green pea is shown in figure 2. Results revealed that drying rate were found to be higher in tray drying at 70$^0$C temperature compared to the other drying methods and temperatures of tray drying while were lowest for sun drying. Figure 2 describes the drying rate and temperatures of drying and drying methods as function of time. This rate curve used in identifying the dominant mechanism of pea during drying. In the initial drying period, the drying air temperature is usually higher than the temperature of peas. The drying of pea by different drying methods took place during the falling rate periods as the drying process is controlled by a diffusion process. Drying usually stops when steady state equilibrium is reached [20].

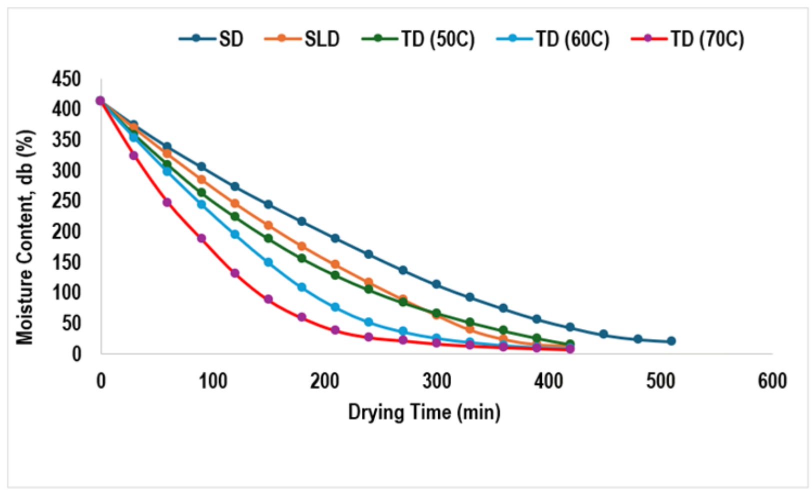


**Figure 1:** Drying curve between drying time and moisture content (db, %) of green peas.

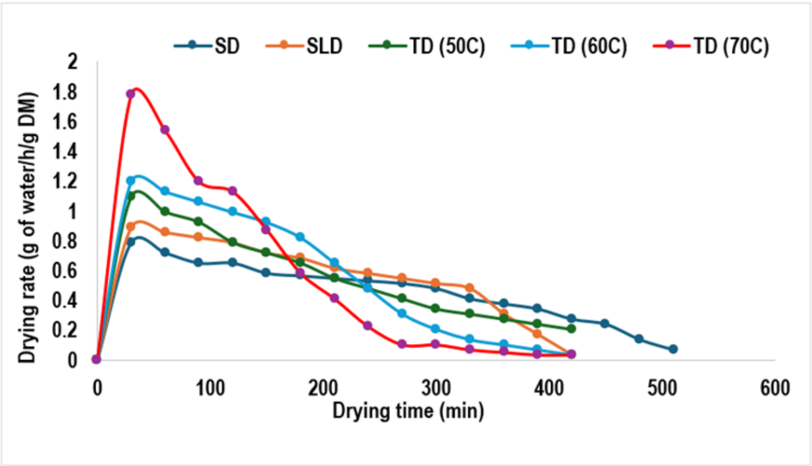


**Figure 2:** Drying curve between drying time and drying rate of green peas.

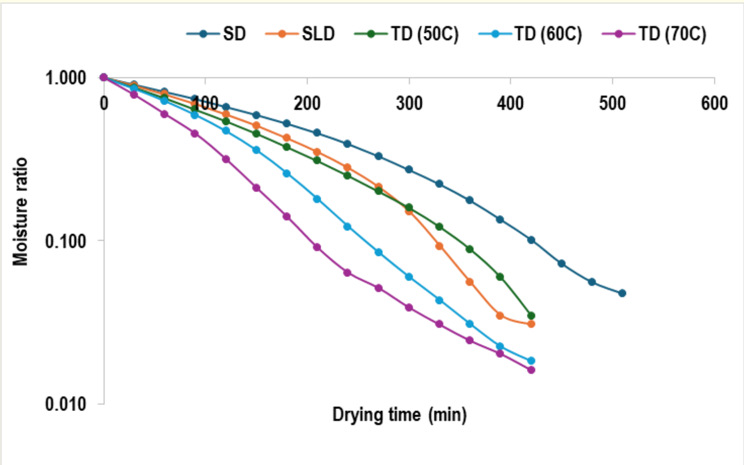


**Figure 3:** Drying curve between Drying time and moisture ratio of green peas.

| Drying methods | | Drying models | $R^2$ | K | n | $D_{eff}$ ($m^2/s$) |
|---|---|---|---|---|---|---|
| Sun drying | | Newton/Lewis model | 0.9679 | 0.0019 | - | $3.72 \times 10^{-9}$ |
| | | Page model | 0.9874 | 0.0012 | 1.2354 | $2.35 \times 10^{-9}$ |
| Solar drying | | Newton/Lewis model | 0.9675 | 0.0024 | - | $4.70 \times 10^{-9}$ |
| | | Page model | 0.9833 | 0.0010 | 1.326 | $1.96 \times 10^{-9}$ |
| Tray drying | 50$^0$C | Newton/Lewis model | 0.9427 | 0.0022 | | $4.31 \times 10^{-9}$ |
| | | Page model | 0.9934 | 0.0023 | 1.1743 | $4.50 \times 10^{-9}$ |
| | 60$^0$C | Newton/Lewis model | 0.8792 | 0.0023 | - | $4.50 \times 10^{-9}$ |
| | | Page model | 0.9965 | 0.0017 | 1.2857 | $3.33 \times 10^{-9}$ |
| | 70$^0$C | Newton/Lewis model | 0.7717 | 0.0021 | - | $4.11 \times 10^{-9}$ |
| | | Page model | 0.9934 | 0.0057 | 1.1065 | $11.17 \times 10^{-9}$ |

**Table 2:** The value of model constant during drying of pea by different drying methods.

## Mathematical modelling for prediction of drying characteristics of green peas

Newton/Lewis model and Page Model/equations were fitted to experimental data in their linearized forms using regression techniques as well as MS Excel to determine the constant of the models. In order to select the model which had better prediction and coefficient of determination ($R^2$) were considered.

- **Newton/Lewis model**: The drying constant (k) of this model [MR = exp(-kt) was obtained from the relationship of moisture ratio and drying time. A graph between drying time and moisture ratio on semi-logarithm paper was plotted and represents nearly a straight line. The drying constant was determined for all drying methods with temperatures conducted are present in Table 2. The average value of k for all the drying experiments was 0.0022. The value of $R^2$ were varied from 0.7717 to 0.9679 with an average value of 0.9058. Although Newton's model is simple but only drawback associated over predict at the early stages and under predicts at later stages of drying.
- **Page Model:** Drying constant (k and n) obtained from the equation [MR = exp(-kt$^n$)] are shown in table 2. The equation [MR = exp(-kt$^n$)] is graphically presented on log-log paper between [ln (-ln MR)] and [ln t]. It gives a straight line with a positive slope of 'n'. Thus, when experimental data are plotted in graphically by drawing straight line and determining the slope and intercept respectively [21]. This model is two constant empirical modification of Newton's exponent model. Average value of k for all experiment was 0.0024 and ranged between 0.0010 to 0.0057. The value of 'n' was determined between 1.1065 to 1.3260. The coefficient of determination ($R^2$) varied between 0.9833 to 0.9965 with an average value of 0.9908. the variation in experimental and prediction moisture ratio of green peas dried by different methods under Page's Model is shown in figure 4-8.
- **Validation of Models**: The constant of models for drying of green peas are presented in Table 2. The best model to describe drying behaviour of green peas was collected on the basis of high value of coefficient of determination ($R^2$). It is observed from Table 2 that high value of $R^2$ is indicative of good fitness of the empirical relationship to represent the variation in moisture ratio with drying time. The Page model may be assumed to represent the thin layer drying of green peas in tray dryer at 60$^0$C temperature. The Page's model was found agree with [22] for green peas.
- **Effective Moisture Diffusivity ($D_{eff}$):** Effective Moisture Diffusivity ($D_{eff}$), an important concept regarding physical and thermal properties is defined as the transport of moisture at a distant rate during the drying of foods. The values of $D_{eff}$ are calculated by the formula ($D_{eff} = K. r^2/\pi^2$) for sphere given by [17] using arithmetic mean diameter of peas (AMD = 0.0088 m) for both models. The calculated values of $D_{eff}$ are shown in table 2. The value of $D_{eff}$ for Newton's Model varied between $3.72 \times 10^{-9}$ and $4.70 \times 10^{-9}$ $m^2/s$ while for Page's model varied from $1.96 \times 10^{-9}$ to $11.17 \times 10^{-9}$ $m^2/s$ among all the experiments.

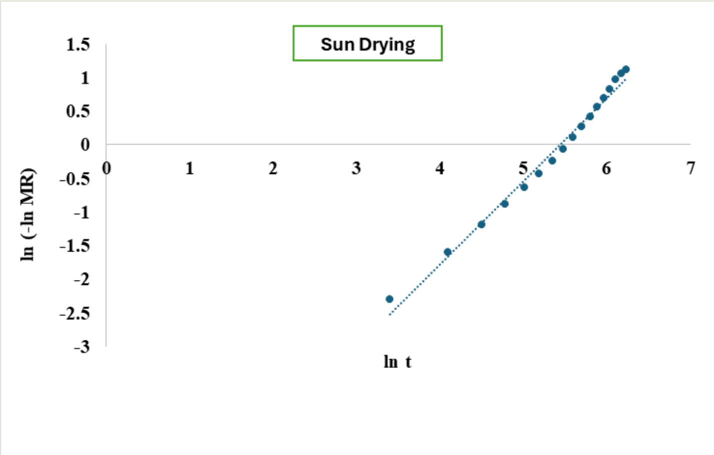


**Figure 4:** Variation in experimental and prediction moisture ratio of Sun dried green peas under Page's Model.

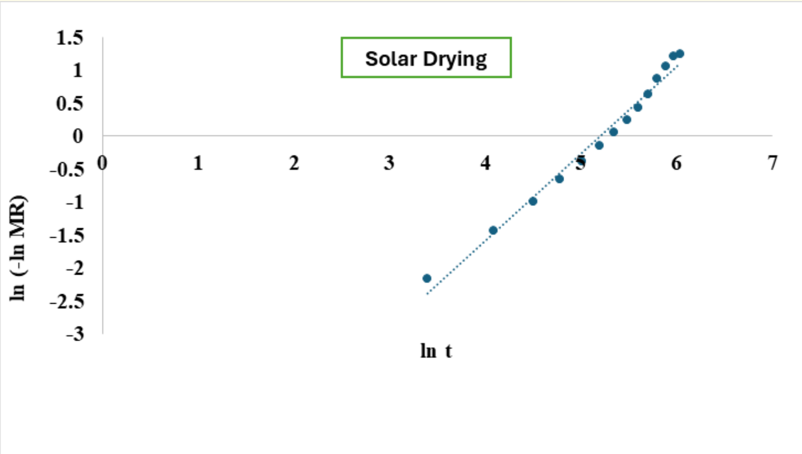


**Figure 5:** Variation in experimental and prediction moisture ratio of solar dried green peas under Page's Model.

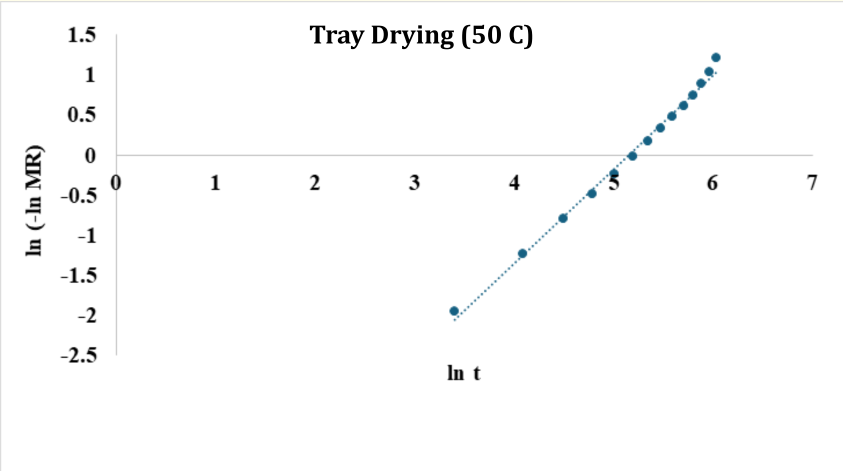


**Figure 6:** Variation in experimental and prediction moisture ratio of tray dried (50 C) green peas under Page's Model.

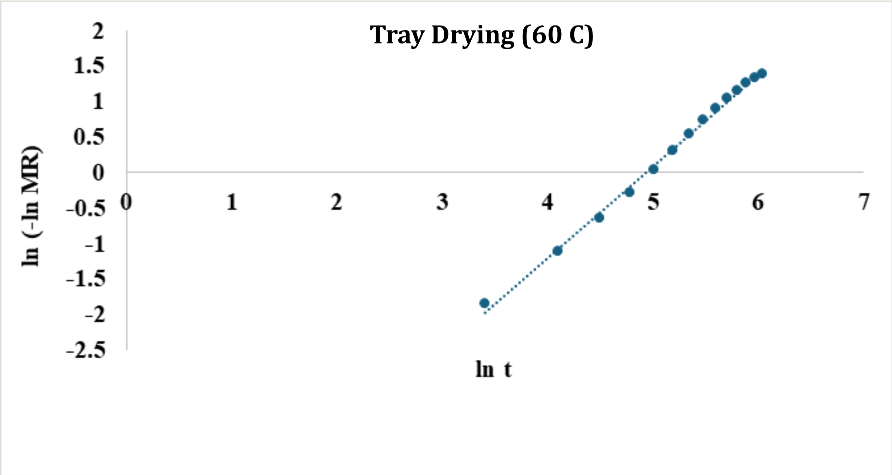


**Figure 7:** Variation in experimental and prediction moisture ratio of tray dried (60 C) green peas under Page's Model.

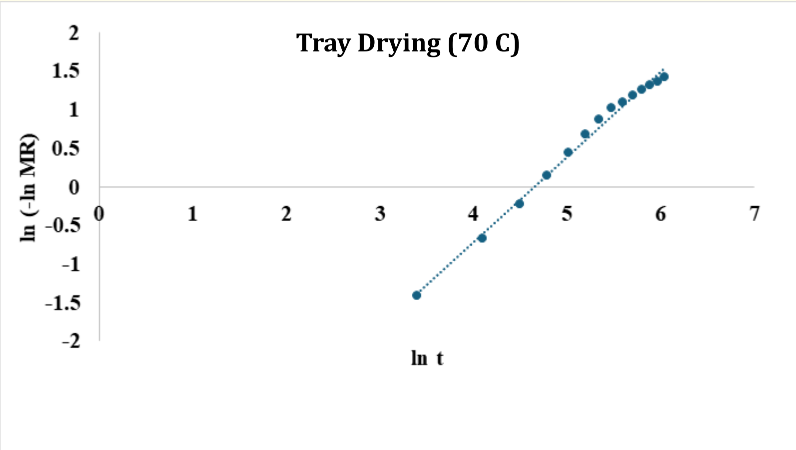


**Figure 8:** Variation in experimental and prediction moisture ratio of tray dried (70 C) green peas under Page's Model.

## Conclusion

This study was undertaken to examine the physical parameters and drying kinetics of green field peas, specifically the KPS 10 variety. The initial moisture content of green pea KPS 10 was determined to be 80.96%. Statistical analysis revealed that Page's model provided a reliable prediction for the drying characteristics of the sample across various drying methods and temperatures employed. The observed drying process proved to be efficient, predominantly occurring during the falling rate period-a finding that is in agreement with several existing reports on the drying behavior of biological materials. It is suggested that the Page model accurately represents the thin-layer drying behavior of green peas at a temperature of 60°C in a tray dryer. The effective diffusivity ($D_{eff}$) values for Newton's Model ranged between $3.72 \times 10^{-9}$ and $4.70 \times 10^{-9}$ $m^2/s$ while for Page's model, they varied from $1.96 \times 10^{-9}$ to $11.17 \times 10^{-9}$ $m^2/s$ among all the experiments conducted.

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