Air Drying of Guava: (II) Kinetics of Vitamin C Degradation at Different Temperature

Farzana Sharmin[1], Md Syduzzaman[2*], Md Nazrul Islam[3]

[1]Department of Food Technology and Rural Industries
Bangladesh Agricultural University, Mymensingh, Bangladesh
Email- farzanas.engg@gmail.com

[2]Department of Nutrition and Food Technology
Jashore University of Science and Technology, Jashore, Bangladesh
Email- m.syduzzaman@just.edu.bd
*Corresponding author

[3] Department of Food Technology and Rural Industries
Bangladesh Agricultural University, Mymensingh, Bangladesh
Email- engr_mnislam50@yahoo.com

Abstract: ***In Bangladesh, the production of Guava (P. guajava, family: Myrtaceae) is ample and needs to be stored properly during off-seasons. Drying is one of the efficient and low-cost preservation techniques. But during the drying process, the vitamin C rich Guava lost a significant amount of vitamin C primarily due to oxidation. This study was conducted to analyze the drying behavior of guava on the stability of vitamin C during drying and storage. The drying was done by using a Cabinet dryer at a constant airflow rate and constant or variable temperature. The higher the drying temperature, the higher is the loss of vitamin C content of guava, and loss of vitamin C during 2.5 hr of drying was observed and found to be 43% to 69% of vitamin C was destroyed during drying at the temperature range of 50-60℃. The activation energy value for degradation of vitamin C was calculated as 14.73 kcal/g-mole, which is proof of temperature dependency. Activation energy values for the degradation of vitamin C could be used to optimize process variables to retain more vitamin C in the processed product. Considering short-season availability, fresh guava was stored at 30°C, 4°C, and -18°C temperature, and the effect of storage temperature on vitamin C content was determined. The rate constant were 0.13, 0.1, and 0.03 mg% day^{-1} at 30, 4, and -18°C, respectively, and the activation energy value for degradation of vitamin C was calculated to be 3.00 kcal/g-mole.***

Keywords: Vitamin C, Kinetics, Guava, Drying

1. Introduction

One of the most nutritious fruits, the guava, *Psidium guajava* L., of the myrtle family (Myrtaceae), is almost universally known by its common English name or its equivalent in other languages. In Bangladesh, it is called '*payara*'. It originated in tropical America (Mexico to Peru), where it still occurs in the wild. Guava is often called the "apple of the tropics". Guava stands fifth in production among the most important fruits of Bangladesh and can be grown all over the country. The annual production is about 45,000 m. tons in an area of about 10,000 ha[1]. Though the districts of Barisal, Pirojpur, Jhalokathi, and Chattogram are the main guava-producing areas, it is available in all areas of Bangladesh.

The guava includes about 150 species, but only a few have horticultural values. Guava fruit, usually 4 to 12 cm long, is round or oval depending on the species. Raw guavas are eaten out-of-hand but are preferred seeded and served sliced as a dessert or in salads. Bars of thick, rich guava paste and guava cheese are staple sweets, and guava jelly is almost universally marketed. Guava is rich in Vitamin C (210mg/100), carbohydrates, and protein. The red apple guava notably contains 192 mg/100g of vitamin C[2]. Vitamin C is destroyed during drying but other nutrients remain almost unchanged.

From a nutritional point of view, vitamin C is of vital importance in the body. The main functions include enhancement of the absorption of iron, involvement in the metabolism of fat and cholesterol, and antioxidant activity. The current recommended dietary allowance of vitamin C for adult non-smoking men is 90 mg/day and 75 mg/day for women. Recent scientific evidence indicates that an increased intake of vitamin C is associated with a reduced risk of chronic diseases such as cancer, cardiovascular diseases, and cataracts, probably through antioxidant mechanisms. Humans have lost the ability to synthesize vitamin C because of a mutation in the gene coding for L-gulonolactone oxidase, an enzyme required for the biosynthesis of vitamin C. Thus, vitamin C must be obtained through the diet. Deficiency of vitamin C leads to scurvy which can be prevented with only 10 mg vitamin C/day, an amount easily obtained through.

Guava is one of the richest sources of dietary fiber, both in the flesh and the seeds; these help to regulate high blood pressure by helping the body regulate how quickly it absorbs sugar in the blood. It helps promote a healthy bowel through regular excretion. Moreover, folic acid and the dietary minerals, potassium, copper, and manganese are contained in guava[2]. Guava has high levels of vitamin A, B, and potassium which is thought to help improve skin tone and texture with their anti-oxidant and detoxifying properties. The beautiful astringents are thought to tighten up loose skin and leave it glowing.

Guavas contain both carotenoids and polyphenols like gallocatechin, guaijaverin, leucocyanidin, and amritoside – the major classes of antioxidant pigments – giving them relatively high potential antioxidant value among plant foods. As these pigments produce the fruit skin and flesh color, guavas that are red-orange have more pigment content as polyphenol, carotenoid, and pro-vitamin A, retinoid sources than yellow-green ones.

Guavas have astringent properties which can cure cough and cold symptoms; this is supported by a high vitamin C. It reduces mucus, loosening the cough and disinfecting the respiratory tract. Guavas can help support weight loss by helping the body feel full for longer.

As the production is very high, a considerable amount is spoiled every year because of improper storage facilities in our country. If we can store guava then it can be used for further processing. The best way of preserving fruits is drying or dehydration. This process costs less than other preserving methods and requires simple instruments. The sun-dried vegetables had inferior color, texture, and acceptability compared to the vegetables dried in the cabinet dryer.

In the mechanical dryer, desired temperature and airflow could be maintained. Compared to sun/solar drying, higher airflow and temperature can be used in mechanical drying. This leads to high production rates and improved quality products due to shorter drying time and reduction of the risk of insect infestation and microbial spoilage as well as minimum nutrient loss. Since mechanical drying is not dependent on sunlight, therefore it can be done as and when necessary. The effect of heat during the mechanical drying may affect differently with different temperatures and thicknesses. The drying kinetics of guava in different temperatures and thickness has already been published by the current authors [3].

2. Materials and Methods

Cabinet dryer, Model OV-165 (Gallen Kamp Company) was used for dehydration of guava. The dryer consists of a chamber in which trays of products were placed. Air was blown by a fan past a heater and then across the trays of products being dried. The velocity of air was recorded (0.6m/s) by an anemometer.

For determining the effect of temperature on the vitamin C degradation of guava, guavas were cut into slices. Freshly sliced guavas of a constant thickness of known weight and dried at a constant air velocity (0.6 m/s) at various air dry bulb temperatures (50°C, 55°C, and 60°C). Weight loss was used as a measure of the extent of drying. To determine the effect of temperature on the rate degradation of vitamin C, samples were obtained from identical trays containing samples for the determination of drying kinetics [3]. In addition, raw guava was stored at different storage temperatures (-18°C, 4°C, and 30°C) to compare the Vitamin C degradation for two weeks.

According to Heldman [4], any reaction which is typical in nature will occur at a rate dependent upon several factors, whether the reaction is the conversion of sucrose to glucose and fructose or the rate at which some component (such as vitamin C or thiamin) of a food is reduced in concentration by heat. The rate of the reaction is indicated by a rate constant (K) and can be described by the following general equation:

$$\frac{dc}{dt} = KC^m \qquad (1)$$

Although many reactions may be of zero-order, the first-order reaction is common to describe many reactions occurring in food products. The equation is written as:

$$\frac{dc}{dt} = KC \qquad (2)$$

In this particular type of reaction, the reaction rate is directly proportional to the concentration of the reacting substance (C). The application of a first-order reaction equation is more evident if equation 2 is solved and expressed in the following form:

$$\frac{C_t}{C_o} = Kt$$

$$\Rightarrow lnC_t = lnC_o - Kt \qquad (3)$$

Where,

C_t=Vitamin C concentration at any time, t.

C_o=Initial vitamin C concentration

K =Reaction rate constant

2.1 The reaction rate constant and activation energy

It has been shown that diffusion coefficient (D_e) is a function of inverse absolute temperature (T_{abs}). Similarly, it has been shown that the reaction rate constant (K) is also influenced by the same principle and is represented by the Arrhenius type equation and the diffusion coefficient is replaced by the reaction rate constant[4]. The equation is written as:

$$\frac{d(lnK)}{dTabs} = \frac{E_a}{RT_{abs}^{\ 2}}$$

$$=> \int dlnK = \frac{E_a}{R}\left(\frac{dT_{abs}}{T_{abs}^{2}}\right)$$

$$=> lnK = lnB - \frac{E_a}{R}\frac{1}{T_{abs}} \qquad (4)$$

T_{abs}=Absolute Temperature, K
R =1.987 cal/g-mole
E_a=activation energy (Kcal/g-mole)
B=Constant of integration

3. Results and Discussion

3.1 Effect of drying temperature on vitamin C content of Guava

Fresh Guava was dried at three different temperatures (50°C, 55°C, and 60°C) in a mechanical dryer, having a constant thickness. To observe the effect of temperature on vitamin C concentration ratio ($\frac{C_t}{C_o}$), versus time (hour) was plotted on a semi-log coordinate as per Equation 3 (Figure 1), and the following regression equations were obtained:

$$\frac{C_t}{C_o} = 1.02e^{-0.24t} \text{ (t=time in hr, for 50°C)} \qquad (5)$$

$$\frac{C_t}{C_o} = 1.05e^{-0.35t} \text{ (t=time in hr for 55°C)} \qquad (6)$$

$$\frac{C_t}{C_o} = 1.02e^{-0.47t} \text{ (t=time in hr for 60°C)} \qquad (7)$$

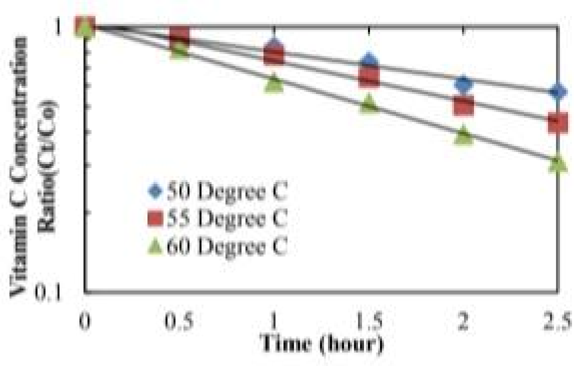

Figure 1: Effect of temperature on Vitamin C concentration ratio

It is found from Figure 1 and equations 5, 6, and 7; the *K* value (reaction rate constant, hr^{-1}) is lowest at 50°C ($0.24hr^{-1}$) among the treatments, and as the temperature increases the *K* value increases. The highest loss of vitamin C was observed at 60°C at any given time. The rate of degradation of vitamin C is much higher at the Hendel [5] observed that about half of the ascorbic acid is usually lost during drying. But wide variations are to be expected. However, the drying conditions may have been responsible for a part of the differences among these values, and it seems likely that retention of ascorbic acid could be improved by the selection of optimum conditions [6]. In addition to this, oxygen and heat, among other things, have a significant influence on the degradation of vitamin C [7] and its protection is particularly difficult to

Where,
K= Reaction rate constant, hr^{-1}

beginning of processing and the rate falls as process time progresses. This behavior is attributed to exponential decay [4].

Table 1: Percent retention of vitamin C during drying of guava in a mechanical dryer at different temperatures and time intervals.

Time (hr)	vitamin C retention (Percent retention) at different temperature		
	50° C	55° C	60° C
0.0	100	100	100
0.5	89.50	90.38	82.74
1.0	84.16	78.29	62.05
1.5	73.50	64.44	51.71
2.0	60.37	50.52	39.30
2.5	56.87	43.46	31.02

Table 1 indicates that the higher the drying temperature the higher is the vitamin C loss for a given time. However, it should be noted that at high temperatures drying rate is also higher, which may offset the losses of vitamin C. Thus, comparing activation energy values for the diffusion of water and degradation of vitamin C, one can optimize the drying process to retain a higher amount of vitamin C in guava.

From Table 1, it is apparent that the losses of vitamin C were highest at 60°C and lowest at 50°C for a given time. Yet, near about 10% of vitamin C was lost at 50°C and 55°C after 30 minutes of drying but at 60°C the loss was about 20% during the same period. It is also observed that after 2.5 hours of processing for 50°C, vitamin C retention was 60% but for 55°C and 60°C, the retention of vitamin C was 43% and 31% respectively for the same drying time.

It is obvious that during drying, % loss of vitamin C is accelerated by air and heat. The more heat transfer the more vitamin C is lost. Nevertheless, prolonged drying also increases vitamin C degradation and results in lower retention, though the retention or loss of vitamin C may vary from one product to another due to its variation in composition.

achieve. Other notable factors that influence the degradation of this vitamin include water content or moisture content, pH, and metal traces, especially copper and iron in the food material [8].

3.2 Effect of drying temperature on reaction rate constant of vitamin C

For process optimization and to compare the effect of drying temperature on reaction rate constant of vitamin C content of Guava, reaction rate constant (K) value versus inverse absolute temperature (T_{abs}^{-1}) were plotted on a semi-log co-ordinate and regression lines were drawn (Figure 2). The following regression equation was developed:

Reaction rate constant = 2×109e^{-74t} (t= T_{abs}^{-1}) (8)

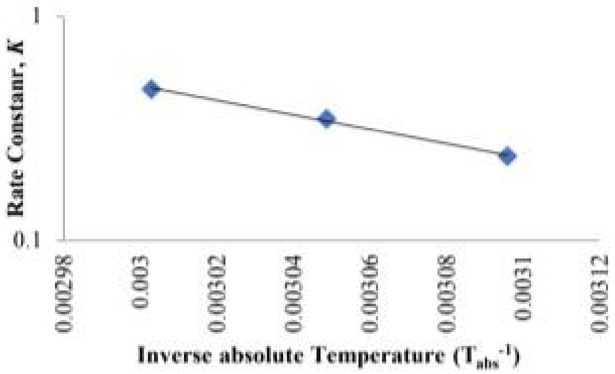

Figure 2: Effect of temperature on rate constant, *K*.

There is a relationship between drying rate constant and thickness of products and the relationship can be expressed as a power-law equation[9]. The exponent of the power-law equation, n=0.85 to 1, instead of 2 as predicted by Fick's 2nd law indicates the presence of significant external mass transfer resistance. Influence of temperature on drying rate constant and thus also diffusion coefficient indicates an Arrhenius type of relationship between diffusion coefficient and absolute temperature. From this analysis, the activation energy of diffusion of water from slices was calculated and found equal to 26.8 Kcal/g-mole which is quite high. To dry a heat-sensitive material and achieve good product quality, a bed of inert particles may be used. This would help form a wet coating thus providing a favorable condition for heat and mass transfer [10], [11].

Thin-layer drying characteristics of guava was significantly affected by the temperature and thickness of slices, and most of the drying took place during the falling rate period. Over the temperature range examined, it is obvious that with the increase of temperature, the reaction rate constant of vitamin C is increased. The activation energy (E_a) for degradation of vitamin C was calculated as 14.73 kcal/g-mole. This means that vitamin C content in guava showed high temperature dependence[11]–[14]. The activation energy is varied for similar products and differences in activation energy for ascorbic acid degradation may be attributed to the temperature range used and product characteristics (including pH, enzyme systems, etc.) reaction mechanism [8].

3.3 Effect of storage temperature

The fresh Guava sample was divided into three parts and kept in three different storage conditions (room temperature, 30°C; refrigeration temperature, 4°C and freezing temperature, -18°C); and the effect on vitamin C content was observed. The data obtained from the experiment were analyzed by Equation 3 and plots of vitamin C content (mg/100g) versus the time (day) were made on a semi-log coordinate (Figure 3) and the following regression equations were obtained:

For -18°C temperature:
mg % of vitamin C =107.89e$^{-0.03t}$ (where t= time in day) (9)
For 4°C temperature:
mg % of vitamin C = 111.35e$^{-0.1t}$ (where t= time in day) (10)
For 30°C temperature:
mg % of vitamin C =111.06e$^{-0.13t}$ (where t= time in day) (11)

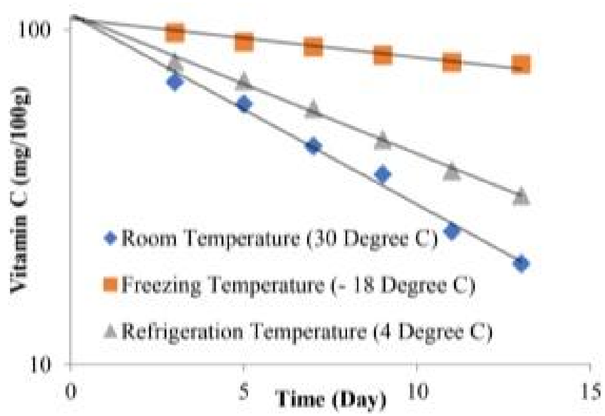

Figure 3: Effect of storage condition on guava

It is evident that the nature of the above equations is first-order type or exponential type. From Figure 3 it is clearly seen that the vitamin C reduces rapidly initially but the rate of vitamin C reduction or loss is decreasing as the time of storage increases.

From equations no. 9, 10, and 11, it is also found that the reaction rate constant (K) is highest for room temperature (30°C) i.e., 0.13 mg% day^{-1} and lowest for freezing temperature (-18°C) i.e., 0.03 mg% day^{-1}. Similar degradation of vitamin C also reported for bean, tomato, and pea with a minor variation which is influenced by the composition of the reported produces.

It is observed that up to the first week of storage about 50% vitamin C is retained but after 2 weeks of storage (13th day) about 70% vitamin C is lost during storage at refrigeration temperature. It is also observed that on the 13th day the quality degraded with changing the color in guava. During storage at freezing temperature, 79.58% vitamin C is retained after 7 days but after 13 days vitamin C retention is 70.54% which is higher than that at refrigeration temperature. On the other hand, during storage at room temperature after 1-week vitamin C retention is 40.57% and after 13 days vitamin C retention is 18%, which is higher than that at both freezing and refrigeration temperature. However, the lower the storage time, the higher the percent retention of vitamin C.

The reaction rate constants (K) found from equations 9, 10, and 11 were plotted against inverse absolute temperature and from Figure 4. It is observed that with the increase of temperature, the reaction rate constant of vitamin C is increased. The activation energy for degradation of vitamin C was calculated as 3.0 kcal/g-mole.

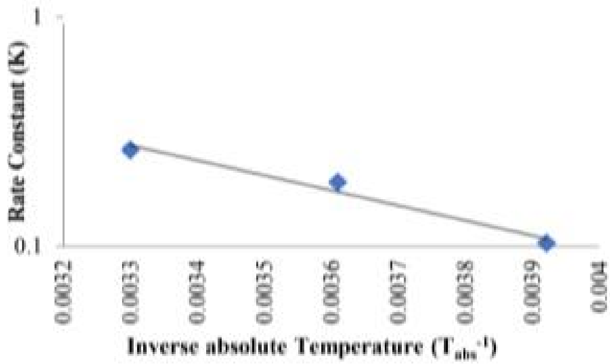

Figure 4: Effect of temperature on rate constant (K) of vitamin C during storage

This means that vitamin C content in guava showed temperature dependence. This value is quite lower than that (14.73 kcal/g-mole) found for degradation of vitamin C during drying at a temperature range 50-60℃. As noted earlier, temperature range has a profound effect on the activation energy for degradation of vitamin C. Villota and Hawkes [8] noted that changes in reaction mechanism might occur for a large temperature range, and mechanism of deterioration changes below freezing point due to concentration effect, while at the high-temperature physical state of the same compound might occur.

4. Conclusion

The drying temperature and thickness influence the activation energy. The activation energy is important to manipulate optimum drying time and temperature as well to minimize losses of vitamin C and other nutrients present in the fruit. Thus, high-quality dehydrated guava could be developed with high nutrient content, and spoilage of guava can be prevented during peak season benefiting the farmers as well as the country.

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