International Journal of Innovation, Creativity and Change. www.ijicc.net
Special Edition: Safe Communities, 2020

Caking Mechanisms of Passion Fruit Powder During Storage

Ansar[a], **Nazaruddin**[b], **Atri Dewi Azis**[c], [a,b]Faculty of Food Technology and Agroindustries, University Mataram, Indonesia, [c]Faculty of Teacher Training and Education, University Mataram, Indonesia, Email: [a]ansar72@unram.ac.id

Dry food is generally susceptible to caking during storage. Therefore, the purpose of this study is to analyse the influence of temperature and relative humidity on mechanisms contributing to the caking of passion fruit powder during storage. The research was conducted by storing passion fruit powder in desiccators at various points of temperature (10, 20, and 30°C) and relative humidity (32.8%, 52.8%, and 75.2%). The variations in storage RH were produced by using saturated salt solutions put under the desiccators. The parameters were the evaluated extent of passion fruit powder caking during storage. The results showed that variation in storage temperature did not significantly influence caking because the storage temperature used in this study was still lower than the glass transition temperature of the samples. Water molecules in this condition become unable to carry out chemical activities that cause caking. However, RH variation has a significant influence on the caking of passion fruit powder. The high moisture content at a storage RH of 52.5 and 75.2% could trigger caking.

Keywords: *Passion fruit, Powder, Caking, Temperature, Relative Humidity*

Introduction

The passion fruits (*Passiflora* spp.), including the Passifloraceae family, consist of more than 500 species. Among them, the well-known genus is Passiflora (Pereira, Correa, & Oliveira, 2015). Spanish missionaries discovered Passiflora species in South America to be medicinal plants (Ozarowski & Thiem, 2013).

At present, Passiflora species are widely used in traditional medicine throughout the world, mainly as sedatives and anxiolytics, which are also exploited by the food, pharmacology, and cosmetics industries (Marques, et al., 2016). The most popular species in Indonesia is Passiflora edulis Sims because it can be consumed either fresh or processed (Ansar, Suhargo, & Rahardjo, 2004). Consumers prefer it because it contains nutrients such as beta-carotene, potassium, fibre, and vitamin C. Some believe it reduces blood pressure because it is beneficial to health (Lopez-Vargas, Fernandez-Lopez, Perez-Alvarez, & Viuda-Martos, 2013; Ramaiya, et al., 2013).

Passion fruit can be processed into powder as raw material for instant drinks, baby food ingredients, ice cream, bread, and snacks. However, the problem of its powder is hygroscopic, so it cakes easily (Alakali & Satimehin, 2009; Ansar, Rahardjo, Noor, & Rochmadi, 2011).

In Indonesia, powdered fruit products have not been developed widely (Hariadi, 2013; Ansar, Nazaruddin, & Azis, 2019). In other countries, fruit processing into powders has been developed with satisfactory results (Matsui et al., 2010; Pack, Kim, Pack, & Kim, 2012). The problem that always occurs in passion fruit powder is that the particles easily cake and change colour, becoming brown during storage.

The physical change caused by caking has a negative impact on consumer judgment, both in terms of taste and nutrition (Akhtar, Abbasi, & Hussain, 2010; Liu, et al., 2008). Therefore, caking can be used as an indicator of the expired shelf life of the powdered product. Caking can be overcome by anti-caking. However, consuming a lot of food containing preservatives can affect one's health (Kandandapani, Balaraman, & Ahamed, 2015; Lima, Vuolo, Batista, & Drag, 2016).

The caking process in powdered products has not been publicised widely. Therefore, it is very important to analyse the causes of caking in passion fruit powder. Based on these arguments, the purpose of this study is to analyse the influence of temperature and relative humidity on the caking of passion fruit powder during storage.

Methods

Materials

The raw materials used were passion fruit collected from a farmer in Malino, South Sulawesi, Indonesia, to be produced into passion fruit powder. The saturated salt solutions used to control relative humidity (RH) in the desiccator were $MgCl_2$ for RH 32.8%, $Mg(NO_3)_2$ for RH 52.8%, and NaCl for RH 75.2%. The equipment used in these experiments, among others, were pulpier sieve, a vacuum freeze dryer, homogeniser, freezer, and oven dryer.

Preparation of the Passion Fruit Powder

The research procedure was carried out in several steps, including drying passion fruit juice using a vacuum dryer to produce passion fruit powder with a moisture content of 14% (Moghadam & Sani, 2014). The passion fruit powder was stored in the desiccators with temperature variations at 10, 20, and 30°C. RH was 32.8%, 52.8%, and 75.2%. Storage with RH variations was carried out using saturated salt solutions (Ansar, Nazaruddin, Alamsyah, & Azis, 2018). Before being stored, the water content of passion fruit powder was determined based on the standard analysis method (AOAC, 2016).

Mathematical Model Development

The caking parameter of the passion fruit powder during storage follows the model of the first order kinetic reactions that can be expressed by the equation (Ansar, Rahardjo, Noor, & Rochmadi, 2011):

$$P = P_0 \exp(kp.\theta) \quad (1)$$

with P = caking parameter of the passion fruit powder, P_0 = initial caking value of the passion fruit powder, k_p = rate constant of caking during storage, and θ = storage duration.

If the value of k_p was a function of both temperatures (T) and relative humidity (RH), then k_p can be written as (Ansar, Rahardjo, Noor, & Rochmadi, 2011):

$$\text{kp} = \text{f(T)} - \text{f(RH} \quad (2)$$

Value k_T as a function of temperature at RH constant follows the Arrhenius equation:

$$k_T = A\exp-(Ea/RT) \quad (3)$$

While the value of k_{RH} as RH function at constant temperature is:

$$k_{RH} = B(RH)^{k_R} \quad (4)$$

Substitution of equations (3) and (4) into equation (2) results in a caking rate prediction equation where k_{RH} and k_T are combined into a single constant C:

$$k_p = C(RH)^{k_R} \exp-(Ea/RT) \quad (5)$$

Thus, equation (1) can be rewritten as:

$$P = P_0 \exp[C(RH)^{K_R} \exp-(Ea/RT)]\theta \quad (6)$$

Caking Observation

Caking observation of the passion fruit powder was conducted every week for 3 months. The passion fruit powder was called caked if the particles could not filter through sieve 10 mesh (Suyitno, 1995). Their percentage was analysed by a procedure such as was done with milk powders (Freeman, Brockbank, & Armstrong, 2015).

Statistical Analysis

The experimental data was analysed using regression analysis. A rate change constant of caking in the passion fruit powder (k_p) was a function of temperature. RH was calculated by plotting ln k_p vs inverse of absolute temperature 1/T. The line slope obtained from the equation of a straight line is Ea/R, and a line intersection k_p value was used to predict the caking rate (Ansar, Rahardjo, Noor, & Rochmadi, 2011).

Results and Discussion

The passion fruit powder had a soft texture and a light yellow colour (Figure 1).

Figure 1. The passion fruit powder before (A) and after (B) storage

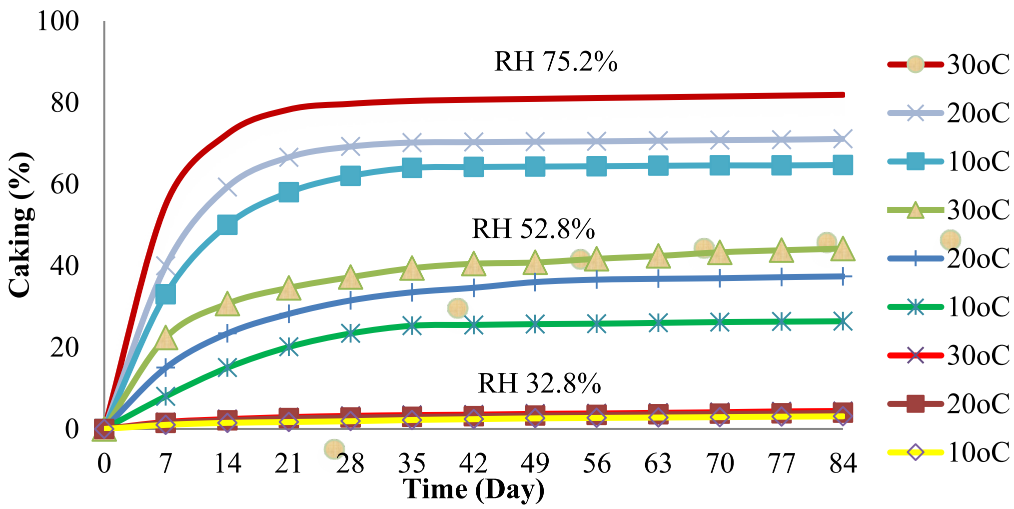
(A) (B)

Although the aroma was not as strong as the aroma of fresh passion fruit, the taste remained the same as fresh fruit. The results of measuring the water content of passion fruit powder ranged from 3.07 to 3.66% db. These results are not significantly different from other dry food products, such as pure pumpkin powder 3.99% (Dirim & Caliskan, 2012). Coconut sugar powder was 1.92-3.03% (A-sun, Thumthanaruk, Lekhavat, & Jumnong, 2016), while arenga pinnata sugar was 4.11% (Choong, Anzian, Che Wan Sapawi, & Moer Hussin, 2016).

Caking was an indicator of changes in the quality of passion fruit powder, which was most easily observed during storage. Caking occurred because there was a layer of adhesive on the surface of the particles that could solve the sugar compounds and form a sticky mass (Al-Hashemi & Al-Amoudi, 2018). During storage, there was also a process of absorption of steam on the surface of the sample, which affected caking. Caking occurs because there is an interaction between material and air humidity through a chemical process (Fitzpatrick, Podczec, & Weigl, 2010).

During storage, there was an increase in the percentage of caking in the sample (Figure 2). At 32.8% RH storage, with variations in temperatures of 10, 20, and 30ºC for three months, it was found that passion fruit powder had not clumped. When passion fruit powder was stored at RH 52.5 and 75.2% with 3 temperature variations of 10, 20 and 30ºC, caking occurred. This data shows that RH storage significantly affects the caking of passion fruit powder. The same case has been reported by Suyitno (1995): the higher the RH in storage, the more particles that cake. In his research, he showed that the percentage of acid powder caking reached 100% at 75% RH storage for three months.

Figure 2. Graphs of caking of passion fruit powder during storage at temperature and RH variations

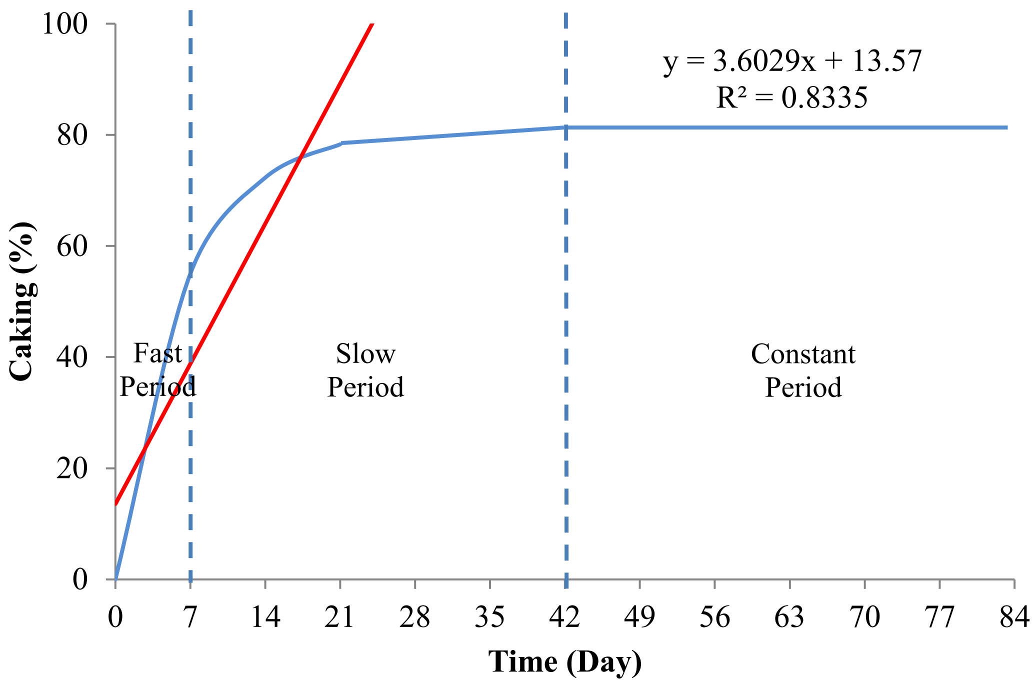


However, variations in storage temperature of 10, 20, and 30ºC do not significantly influence the caking of passion fruit powder (Figure 2). This was estimated because the storage temperature used in this study was still below the glass transition temperature of passion fruit powder of 31ºC. The same research has been reported by Roos, Karel, & Kokini (1996) and Janzantti & Monteiro (2014), who found that storing materials below the glass transition temperature can maintain product shelf life because there is no change in molecular mobility that can affect the rate of chemical reactions, enzymatic processes, and material purity.

Khalloufi, El-Maslouhi, & Ratti (2006) have also described that glass transition temperatures can be used as standard storage temperatures for powdered products.

The trigger for caking of passion fruit powder was also influenced by RH storage. The caking model of passion fruit powder during storage could be divided into three stages, namely fast, slow, and constant (Figure 3). During storage from the 1st 7th day, the caking curve tends to increase and be linear. This is a very fast caking period. On the 21st days of storage, the caking decreases (slow period), and by the 42nd day, all particles have clumped 100% (constant period).

Figure 3. The caking trend of the passion fruit powder during storage



Increased caking during storage was closely related to high humidity (52.8% and 75.2%). At low RH storage (32.8%), the moisture content was saturated, so there was no caking. The high moisture vapor contents at RH 52.8% and 75.2% can cause caking. Mariela (2014) has reported the same study results. Agudelo-Laverde, Florencia, & Pilar (2014) and Seifu, Tola, Mohammed, & Astatkie (2018) indicate that during storage with RH above 60%, there was water vapor that could function as an adhesive layer on the surface of the particles that could cause caking.

The largest percentage of caking occurred in a fast period, reaching 80%. If compared with a slow and constant period, caking that happened in a fast period could be a guideline for practical actions, such as packaging, storage, and distribution.

The mechanism of the caking process during storage began with the process of absorption of moisture on the surface of the particles, which then formed a thin layer. This thin layer caused bonding on the surface of the particle. As storage time progresses, the stickier particles then form a mass.

The results of the evaluation of k_T and k_{RH} constants, as functions of temperature and RH variations, are shown in Table 1. The table shows that with longer storage and higher temperature, the k_T value also increased. The same thing also happens in RH variation: the longer storage and the higher RH, the higher k_{RH}.

Table 1. The evaluation results of k_T and k_{RH} constants as functions of temperature and RH variations

No.	Treatments		k_T	k_{RH}
	Temperature (ºC)	RH (%)		
1	10	32.8	0.0043	0.0012
2	20	32.8	0.0046	0.0021
3	30	32.8	0.0047	0.0032
4	10	52.8	0.0024	0.0016
5	20	52.8	0.0029	0.0026
6	30	52.8	0.0036	0.0036
7	10	75.2	0.0012	0.0018
8	20	75.2	0.0023	0.0029
9	30	75.2	0.0027	0.0045

The influence of temperature on the caking rate constant (k_T) during storage can be known from the determination coefficient value (R^2) of 0.941. This value indicates there was a close relationship between temperature and k_T during storage.

The plot between ln k_T and 1/T was obtained with a line equation whose slope was the Ea/R-value and the line intersection was the k_T value, written as:

$$\ln k_T = -6.4628(1/T) + 0.0241 \tag{7}$$

Equation (7) obtained the value of Ea at 72,237 kJ/mol, and k_P was 4.172E+10. These values indicate that the energy required for the caking activation process of the passion fruit powder during storage was very large.

The influence of RH on the caking rate constant (k_{RH}) of the passion fruit powder during storage could be known from the determination coefficient value (R^2), which was 0.965. This value showed there was a close relationship between RH and k_{RH} during storage.

A plot between ln k_{RH} and storage RH obtained a line equation:

$$\ln k_{RH} = 3\exp{-05}(RH) + 0.0021 \quad (8)$$

The values of k_T and k_{RH} showed the caking rate of the passion fruit powder during storage. The larger the values of k_T and k_{RH}, the faster the caking rate. The results of this study are in line with the opinion's of Shimoni & Labuza (2000): large constant values indicate changes in high food quality.

Conclusion

Storage temperature variation did not significantly influence the caking because the storage temperatures used in this research were still lower than the glass transition temperature of passion fruit powder. This condition caused the water molecules to be unable to perform such chemical activity that caused caking. However, storage RH variation significantly influenced the caking of the passion fruit powder. The high moisture content at a storage RH of 52.5% or 75.2% could trigger caking. The mechanisms of the caking process during storage begin with the process of absorption of moisture on the surface of the particles, forming a thin layer. This thin layer causes bonding on the surface of the particles. As storage time progresses, the stickier particles then form a mass. Therefore, storage at a temperature of 10°C and RH 32.8% are recommended to prevent caking during storage.

Nomenclature

θ : Storage duration
Ea : Energy activation
k_p : Rate constant of caking
k_{RH} : Relative humidity constant
k_T : Temperature constant
P : Caking parameter
P_0 : Initial caking value
RH : Relative humidity (%)
R^2 : Coefficient of determination
T : Temperature (°C)

Acknowledgments

The authors gratefully acknowledge the Ministry of Research, Technology, and Higher Education, the Republic of Indonesia, for financial support. We are also thankful to the Faculty of Food and Agroindustries Technology, University of Mataram, for all facilities support in this work.

REFERENCES

Akhtar, A., Abbasi, N. A., & Hussain, A. (2010). Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. *Pakistan Journal of Botany, 42*(1), 181–188.

Alakali, J. S., & Satimehin, A. A. (2009). Moisture adsorption characteristics of ginger (Zingiber officinale) powders. *Agricultural Engineering International, 16*(4), 1286-1291.

Al-Hashemi, H. B., & Al-Amoudi, O. B. (2018). A review on the angle of repose of granular materials. *Powder Technology, 330*, 397-417. doi:10.1016/j.powtec.2018.02.003

Ansar, Nazaruddin, & Azis, A. D. (2019). Effect of vacuum freeze-drying condition and maltodextrin on the physical and sensory characteristics of passion fruit (Passiflora edulis sims) extract. *IOP Conference Series: Earth and Environmental Science* (pp. 1-12). Makassar: IOP Publishing. doi:10.1088/1755-1315/355/1/012067

Ansar, Nazaruddin, Alamsyah, A., & Azis, A. D. (2018). An Analysis of Correlation between Diameter Size and Shape of Particle Surface with Strawberry Granule Flow Rate. *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem, 6*(2), 125-130. doi:10.29303/jrpb.v6i2.85

Ansar, Rahardjo, B., Noor, Z., & Rochmadi. (2011). Influence of temperature and relative humidity on the quality of fruit juice effervescent tablet during storage. *Journal of Food Technology and Industry, 22*(1), 73-77.

Ansar, Suhargo, & Rahardjo, B. (2004). Study on the behavior of fruit juice drying with cuncurrent spray dryer. *Journal Agritech UGM, 24*(3), 155-159.

AOAC. (2016). *Official Methods of Analysis. 20th ed.*. Washington: Association of Official Analytical Chemists.

A-sun, K., Thumthanaruk, B., Lekhavat, S., & Jumnong, R. (2016). Effect of spray drying condition on physical characteristic of coconut sugar powder. *International Food Research Journal, 23*(3), 1315-1319.

Choong, C. C., Anzian, A., Che Wan Sapawi, C. W., & Moer Hussin, A. S. (2016). Characterization of sugar from arenga pinnata and saccharum officinarum sugars. *International Food Research Journal, 23*, 1642-1652.

Dirim, S., & Caliskan, G. (2012). Determination of the effect of freeze drying process on the production of pumpkin (Cucurbita Moschata) pure powder and the powder properties. *The Journal of Food, 37*(1), 203-210.

Fitzpatrick, J., Podczec, B. C., & Weigl, C. (2010). Comparing the caking behaviors of skim milk powder, amorphous maltodextrin, and crystalline common salt. *Powder Technology, 20*(1), 131-137. https://doi.org/10.1016/j.powtec.2010.07.029

Freeman, T., Brockbank, K., & Armstrong, B. (2015). Measurement and quantification of caking in powders. *Procedia Engineering, 102*(1), 35-44. doi:10.1016/j.proeng.2015.01.104

Hariadi, P. (2013). Freeze drying technology: for better quality and flavor of dry products. *Food Review, 8*, 52-57.

Janzantti, N. S., & Monteiro, M. (2014). Changes in the aroma of organic passion fruit (Passiflora edulis Sims f. flavicarpa) during ripeness. *Food Science and Technology, 59*, 612-620. https://doi.org/10.1016/j.lwt.2014.07.044

Kandandapani, S., Balaraman, A. K., & Ahamed, H. N. (2015). Extracts of passion fruit peel and seed of Passiflora edulis (Passifloraceae) attenuate oxidative stress in diabetic rats. *Chinese Journal of Natural Medicines, 13*, 680-686. https://doi.org/10.1016/S1875-5364(15)30066-2

Khalloufi, S., El-Maslouhi, Y., & Ratti, C. (2006). Mathematical model for prediction of glass transition temperature of fruit powders. *Journal of Food Science, 65*(4), 842-847. doi:10.1111/j.1365-2621.2000.tb13598.x

Lima, G. C., Vuolo, M. M., Batista, A. G., & Drag, N. R. (2016). Passiflora edulis peel intake improves insulin sensitivity, increasing incretions and hypothalamic satietogenic neuropeptide in rats on a high-fat diet. *Nutrition, 32*(1), 863-870. doi:10.1016/j.nut.2016.01.014

Liu, S., Yang, F., Li, J., Zhang, C., Ji, H., & Hong, P. (2008). Physical and chemical analysis of Passiflora seeds and seed oil from China. *International Journal of Food Sciences and Nutrition, 59*(2), 706-715. doi:10.1080/09637480801931128

Lopez-Vargas, J. H., Fernandez-Lopez, J., Perez-Alvarez, J. A., & Viuda-Martos, M. (2013). Chemical, physico-chemical, technological, antibacterial and antioxidant properties of dietary fiber powder obtained from yellow passion fruit (Passiflora edulis var. flavicarpa) co-products. *Food Research International, 51*(2), 756-763. https://doi.org/10.1016/j.foodres.2013.01.055

Mariela, C. B., Agudelo-Laverde, M. L., Florencia, M., & Pilar, B. (2014). The relationship between anti browning, anti-radical and reducing capacity of Brassica and Allium powders. *International Journal of Food Studies, 3*(1), 82-92. https://doi.org/10.7455/ijfs/3.1.2014.a8

Marques, S. F., Libonati, R. F., Sabaa-Srur, R. L., Luo, R., Shejwalkar, P., Hara, K., & Smith, R. E. (2016). Evaluation of the effects of passion fruit peels flour (Passiflora edulis fo. flavicarpa) on metabolic metabolic changes in HIV patients with lipodystrophy syndrome secondary to antiretroviral therapy. *26*, 420–426. doi:10.1016/j.bjp.2016.03.002

Matsui, Y., Sugiyama, K., Kamei, M., Takahashi, T., Suzuki, T., & Katagata, Y. (2010). Powder of passion fruit (Passiflora edulis) seed containing high amounts of piceatannol inhibits melanogenesis and promotes collagen synthesis. *Journal of Agricultural and Food Chemistry, 58*(5), 11112-11118. doi:10.1021/jf102650d

Mirhosseini, H., & Amid, B. T. (2013). Effect of different drying techniques on flow ability characteristics and chemical properties of natural carbohydrate-protein gum from durian fruit seed. *Chemistry Central Journal, 7*(1), 1-14. https://doi.org/10.1186/1752-153X-7-1

Moghadam, M. M., & Sani, A. M. (2014). Optimization of spray drying parameters in production of malt extract powder. *Current Nutrition & Food Science, 10*(1), 77-85. https://doi.org/10.2174/157340131130999990002

Ozarowski, M., & Thiem, B. (2013). Progress in micro propagation of Passiflora spp. to produce medicinal plants: A mini-review. *Revista Brasileira Farmacognosia, 23*(1), 937-947. doi:10.1590/S0102-695X2013000600011

Pack, C. U., Kim, Y. S., Pack, K. J., & Kim, B. K. (2012). Changes in physicochemical characteristic of rice during storage at different temperatures. *Journal of Stored Products Research, 48*(1), 25-29. doi:10.1016/j.jspr.2011.08.005

Pereira, A. D., Correa, R. X., & Oliveira, A. C. (2015). Molecular genetic diversity and differentiation of populations of 'somnus' passion fruit trees (Passiflora setacea DC): Implications for conservation and pre-breeding. *Biochemical Systematics and Ecology, 59*(2), 12-21. doi:10.1016/j.bse.2014.12.020

Ramaiya, D. S., Bujang, J. S., Zakaria, M. H., King, W. S., Sahrir, S., & Arif, M. (2013). Sugars, ascorbic acid, total phenolic content and total antioxidant activity in passion fruit (Passiflora) cultivars. *Journal of the Science of Food and Agriculture, 93*, 1198-1205. doi:10.1002/jsfa.5876

Roos, Y. H., Karel, M., & Kokini, J. L. (1996). Water and molecule weight effects on glass transition in amorphous carbohydrate solution. *Journal of Food Science, 56*, 1676-1681. doi:10.1111/j.1365-2621.1991.tb08669.x

Seifu, M., Tola, Y. B., Mohammed, A., & Astatkie, T. (2018). Effect of variety and drying temperature on physicochemical quality, functional property, and sensory acceptability of dried onion powder. *Food Sci and Nutr, 6*, 1641-1649. doi:10.1002/fsn3.707

Shimoni, E., & Labuza, T. P. (2000). Degassing kinetics and sorption equilibrium of carbon dioxide in fresh roasted and ground coffee. *Journal of Food Process Engineering, 23*(2), 419-436. doi:10.1111/j.1745-4530.2000.tb00524.x

Suyitno. (1995). Dietary fiber and water activity and behavior of fruit powder. *Journal Agritech FTP UGM, 12*(1), 25-33.