Study of using infrared radiation for increasing the shelf life of duku

by Gatot Priyanto

Study of using infrared radiation for increasing the shelf life of duku

L. Rahmawati[1], D. Saputra[1,a], K. Sahim[2], G. Priyanto[1] and Z. Pan[3,4]

[1]Department of Agricultural Engineering, Faculty of Agriculture, Universitas Sriwijaya, Inderalaya 30662, Indonesia; [2]Department of Mechanical Engineering, Faculty of Engineering Agriculture, Universitas Sriwijaya, Inderalaya 30662, Indonesia; [3]Department Biological and Agricultural Engineering, University of California, One Shields Ave., Davis, CA 95616, USA; [4]Healthy Processed Foods Research Unit, USDA-ARS-WRRC, 800 Buchanan St., Albany CA 94710, USA.

Abstract

Duku (*Lansium domesticum*) is an exotic tropical and non-climacteric fruit which is highly perishable after harvest. It has a short shelf life (approximately 3 days) at ambient temperature due to the browning reaction of the skin which is followed by the deterioration of the skin and flesh. As a tropical fruit, duku could not be stored at a relatively low temperature. Modified atmosphere storage coupled with medium level of temperature (10 to 18°C) could only prolong the shelf life to 12 days. The objective of this research was to investigate the feasibility of using infrared radiation coupled with the medium level of temperature to dry the skin of duku. This research showed that infrared radiation eventually created a case hardening of the skin which resembles the shell likeness. This shell would still facilitate the breathing mechanism of the duku flesh which keeps the freshness of the flesh while preventing microbial attack and lowering the metabolism. It was concluded that infrared radiation could be used to increase the shelf life of duku.

Keywords: duku, infrared radiation

INTRODUCTION

Duku (*Lansium domesticum*) is a tropical fruit and one of the most favourite fruits in Indonesia because of its unique taste and smell. The difference between duku and langsat is that duku has a thinner skin and no latex while langsat has a thicker skin that contains a milky sticky sap. There are 4 to 12 fruit per duku raceme and 15 to 25 fruit for langsat. Both fruit have five separate segments, with one to five seed in it (Paull, 2014). Duku is classified as non-climacteric fruit and is usually harvested at the full-ripe stage that can be indicated by skin color change from green to dark yellow. It starts to develop about 87 days after fruit set and the fruit can be harvested 11-17 days after that stage (Sapii et al., 2000). Its postharvest life is limited to about 3-7 days under room temperature due to deterioration of its quality such as pericarp browning, changes in texture, appearance and off-flavour after harvest (Lichanporn et al., 2009; Venkatachalam and Meenune, 2012).

Postharvest damage on duku can be controlled by several methods, chemical substance addition, low temperature storing, modified atmospheric packing, and drying. The most commonly used drying method is using hot air. This method is chosen because it is the easiest and costs the least (Diamante et al., 2010). However, these treatments cause degradation on the product's components which leads to sensorial loss of dry product. The food drying method that is commonly developed nowadays is using the low humidity-low temperature method (Ondier et al., 2010), and using high radiation frequency such as microwave, radio frequency, and infrared (Contreras et al., 2008; Kassem et al., 2011). Infrared radiation application on food processing can decrease water content, decrease energy and save process time, it has high heat transfer rate, is safe, and guarantees processed products quality (Pan et al., 2011). The unique characteristic of infrared is that it can heat up the surface of product in short period of time without increasing the core

[a]E-mail: drdsaputra@gmail.com

temperature of product (Li and Pan, 2014). In addition, infrared radiation can activate a particular enzyme (Kouzeh et al., 1982). While it can activate this enzyme, infrared radiation also can inactivate pathogens contained in the products. Infrared radiation is able to inactivate bacteria, spore, yeast, mold with few affecting parameters such as the power of infrared heater (Hamanaka et al., 2000), sample's temperature (Sawai et al., 2003), wavelength, and the width of fields of wave target (Krishnamurthy et al., 2008), sample's thickness (Sawai et al., 2000), and sample's water content (Hamanaka et al., 2006). The usage of these methods is hopefully to produce shell-dry duku. This shell would still facilitate the breathing mechanism of the duku flesh which keeps the freshness of the flesh while preventing fruit damage from microbial attack, and maintains the distinguished sweet-sour flavor of duku and prolongs shelf life.

MATERIAL AND METHODS

Samples of duku

Duku (*Lansium domesticum*) used in this study were obtained from a local farm in Komering, South Sumatra, Indonesia. The dukus which were free from any apparent skin damage, uniform in skin color and had uniform size (about 2.5-3.5 cm in diameter) were selected.

Infrared heating procedure

A laboratory scale of IR heating unit consisting of two ceramic emitters (245×60 mm size) which had capacity of 1000 W for each (Fincohop Ceramic Infrared Heater, Taiwan) was used as the emitter for the dryer used. The dryer was locally made as shown in Figure 1. The IR treatment was performed by letting the IR emitter reach the setting temperature for 5 min in a closed container and allowing it to remain stable at the setting temperature for one minute. After reaching the setting temperature three dukus were inserted into a metal basket which were arranged in parallel. The metal basket were placed outside the box which enclosed the IR emitter to prevent the heating of the metal basket before inserting the duku. After the temperature of the emitter was stable then dukus were inserted into the radiation chamber enclosure and simultaneously the timer was turned on.

The temperatures used in this research were 200, 300, and 400°C with infrared radiation contact for 50 and 60 s. After the fruits were treated with infrared radiation for the determined time, they were stored in controlled temperature (12-17°C). Then the physical and chemical characteristics were measured. The physico-chemical properties of the fruits that were measured periodically in this research were: weight loss, water content of the skin, texture, total sugar, titrable acidity, and browning index. Weight loss was calculated as percent of initial weight, water content using oven method, texture of skin using penetrometer, and total sugar using refractometer (Atago DBX-55A). Total titratable acidity was measured using titration against a standard base, and browning index using a spectrophotometer.

Figure 1. (a) Right side-view of infrared dryer, (b) front-view of infrared dryer.

RESULTS AND DISCUSSION

Weight loss and water content of skin

Fruits in general contains water, carbohydrates, amino acids and proteins, fat acids and lipids, vitamins, minerals, and organic acids. Water is the most essential content of fruit. Most fruit consists of more than 80% water. Actual water content is water which is used by the tissue of fruit in ripening process (Mercado et al., 2011). Chareoansiri and Kongkachuichai (2009) reported that duku contains 80.6 g water 100 g^{-1} fresh product, while the primary sugar content for fructose is 7.94%, glucose 3.58%, and sucrose 2.56% (Chareoansiri and Kongkachuichai, 2009; Venkatachalam and Meenune, 2012). In Figures 2 and 3 the fruit weight loss and water content decrease can be seen. The weight loss of duku with treatment of infrared radiation exposure at 400°C for 60 s was 0.3287%. Weight loss of fruit during the storing period was caused by fruit respiration, the water vapor that was still on the fruit was evaporated. Figure 3 shows that most of the infrared radiation treatment caused the water content to decrease on the skin of duku. Weight and water content decrease can be caused by the infrared radiation heating process, the infrared energy that was absorbed on the surface of duku could increase the temperature inside the skin. With this temperature rising, there was transfer of water vapor from the skin to the atmosphere, which caused the duku skin to be thinner and dryer.

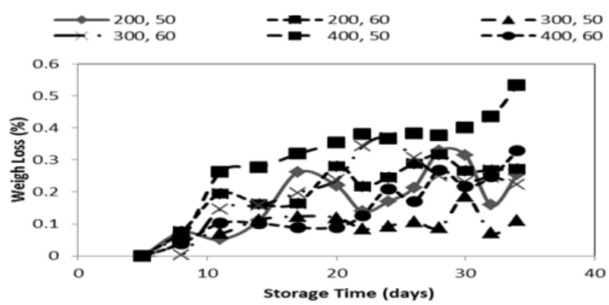

Figure 2. Changes in weight loss (%) in different storage times.

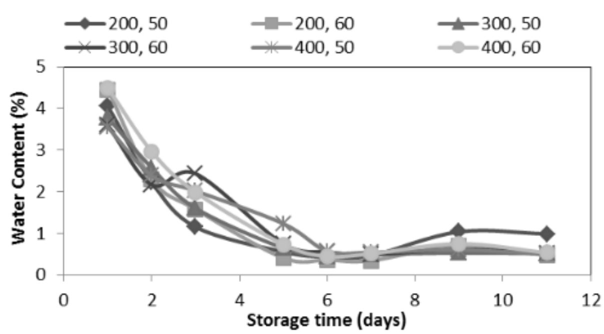

Figure 3. Changes of water content (%) in different storage times.

Textures

In the infrared radiation exposure process with temperatures of 200 and 300°C for 50 and 60 s and controlled temperature storing, the texture of duku skin was better in comparison with the 400°C temperature. The duku with treatment of infrared radiation exposure of 400°C for 60 s had hard skin texture (Figure 4) and suffered from withered dry skin (Figure 5). This texture change in the skin can be caused by the high temperature of infrared and the duration of radiation exposure. Theoretically, the first infrared beaming would hit the skin of duku and then the heat would penetrate the inner tissue through conductive heat transfer. This thermal energy would cause sudden temperature increase. This causes cell wall damage, cell's water vapor evaporation, pectin breaks, mid lamella cell damage, and polysaccharide cell wall degradation. The higher the temperature and the longer the duration of high infrared radiation exposure the more damage is caused on the duku's skin.

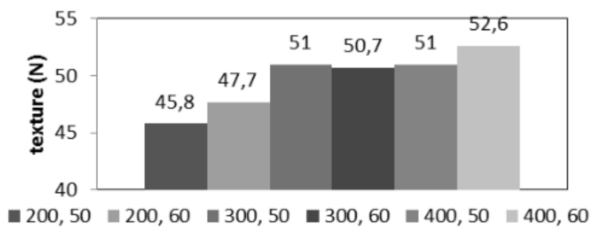

Figure 4. The texture observation result on the last day of observation.

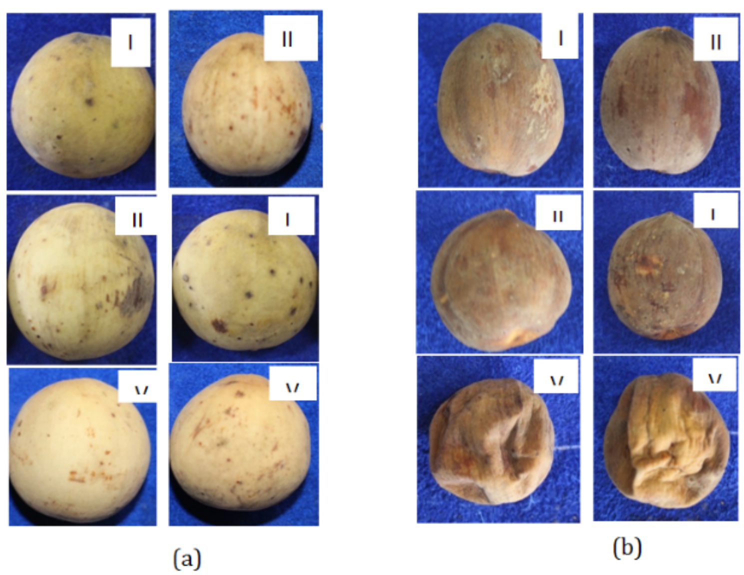

Figure 5. (a) Before heating; (b) after heating. Note: I, II, III, IV, V and VI are treatments 200°C, 50 s; 200°C, 60 s; 300°C, 50 s; 300°C, 60 s; 400°C, 50 s and 400°C, 60 s.

Total sugar and total titratable acidity

Figure 6 shows the increase of total sugar concentration before and after the treatment with temperatures of 200 and 300°C after storage for 30 days. The increase of sugar concentration after the infrared radiation exposure and storage was due to the conversion of carbohydrate to glucose. The carbohydrate conversion to glucose could be caused by the respiration in storing period. Starch can be converted back to glucose by three different enzymes namely, α-amylase, β-amylase and starch phosphorylase (Suárez-Dieguez et al., 2009). In non-climacteric fruit, the accumulation of sugar is associated with the development of optimum eating quality, although the sugar may be derived from sap imported into the fruit rather than from the fruit breakdown of starch reserves (Nascimento et al., 2006). Starch is broken down to sucrose by the action of sucrose phosphate synthetase and non-reducing sugar from sucrose by acid hydrolysis. It can be seen in Figure 7 that during the storage period, total titratable acidity decreased. The acidity of fruit generally decreases during ripening (Muler, 2005). Acids can be considered as a reserve source of energy to fruit and would therefore be expected to decline during the greater metabolic activity that occurs with ripening. In duku, maleic acid is the predominant quantity present and malic acid, citric acid, and glycolic acid are present in considerable quantities (Chairgulprasert et al., 2006).

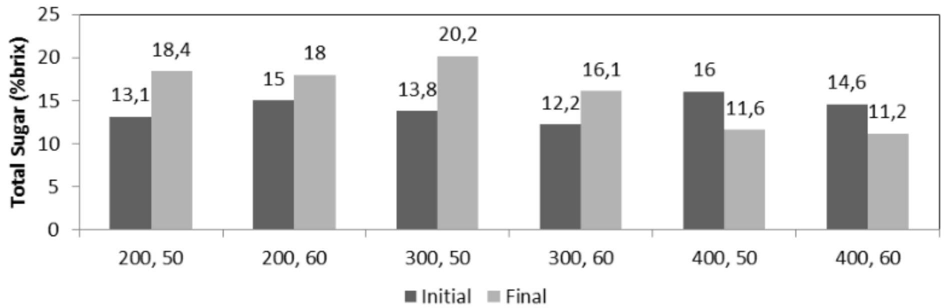

Figure 6. Comparison of initial sugar content and final sugar content after infrared radiation exposure and storage.

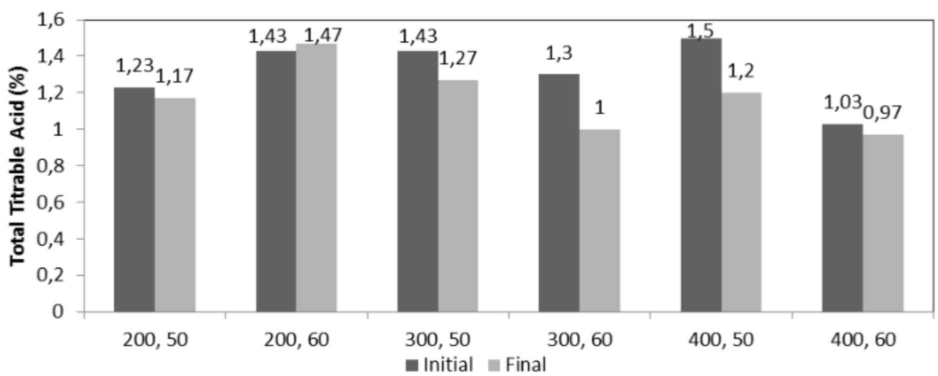

Figure 7. Comparison of initial total titratable acid and final total titratable acid after infrared radiation exposure and storage.

Browning index

Enzymatic browning reaction is one of the most devastating reactions for many exotic fruit, in particularly tropical and subtropical varieties (Quevedo et al., 2009). Figure 8 shows that browning after the infrared radiation exposure and controlled temperature storage increased. This increase happened in every treatment but the treatment which showed the least difference of browning was with 200°C temperature. Enzymatic browning was catalized by the polyphenol oxidase enzyme and peroxidase enzyme (Kincal et al., 2006; Zocca et al., 2008). Peroxidase and phenylalanine ammonia lyase could also increase the activity of browning. Browning in this experiment is expected due to the heat treatment. However, the browning of duku's skin was not a problem because the objective of the research was to make the duku's skin harden similar to lengkeng and to keep the duku's flesh fresh.

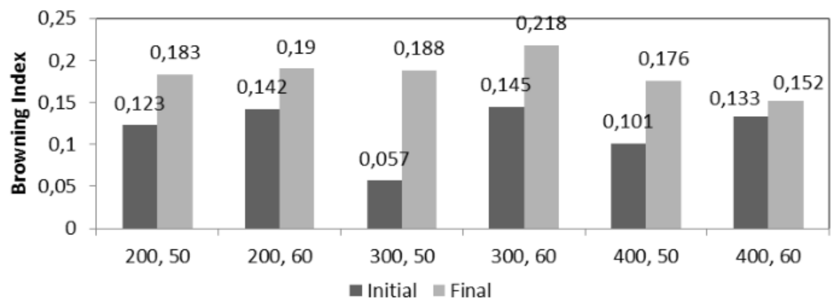

Figure 8. Comparison of initial browning index and final browning index after infrared radiation exposure and storage.

CONCLUSION

Duku's skin which was exposed to infrared with 200-300°C temperature for 50-60 s and stored in controlled temperature (12-17°C) created a case hardening of the skin which resembles the shell likeness. Shell likeness was caused by water content decrease of flesh and skin of duku. Case hardening which was created after infrared radiation exposure and controlled temperature storage can prevent microbial attack and lower the metabolism of duku. In addition, duku which has shell likeness texture of skin can maintain flavor (sugar content increase by 20.2%, and titrable acidity content decrease by 0.3%). So, this infrared radiation exposure method can be used in postharvest process of duku.

ACKNOWLEDGEMENTS

This research was funded by Kementrian Riset, Teknologi, dan Pendidikan Tinggi, Indonesia, through the PMDSU Project and advised by Prof. Zongli Pan from The Department Biological and Agricultural Engineering, University of California at Davis, USA.

Literature cited

Chairgulprasert, V., Krisornpornsan, B., and Hamad, A. (2006). Chemical constituents of the essential oil and organic acids from longkong (*Aglaia dookkoo* Griff.) fruits. Songklanakarin J. Sci. Technol. *28* (*2*), 321–326.

Chareoansiri, R., and Kongkachuichai, R. (2009). Sugar profiles and soluble and insoluble dietary fiber contents of fruits in Thailand markets. Int J Food Sci Nutr *60* (*Suppl. 4*), 126–139 https://doi.org/10.1080/09637480802609376. PubMed

Contreras, C., Martín-Esparza, M.E., Chiralt, A., and Martínez-Navarrete, N. (2008). Influence of microwave application on convective drying: effects on drying kinetics, and optical and mechanical properties of apple and strawberry. J. Food Eng. *88* (*1*), 55–64 https://doi.org/10.1016/j.jfoodeng.2008.01.014.

Diamante, L.M., Ihns, R., Savage, G.P., and Vanhanen, L. (2010). Short communication. A new mathematical model for thin layer drying of fruits. Int. J. Food Sci. Technol. *45* (*9*), 1956–1962 https://doi.org/10.1111/j.1365-2621.2010.02345.x.

Hamanaka, D., Dokan, S., Yasunaga, E., Kuroki, S., Uchino, T., and Akimoto, K. (2000). The sterilization effects of infrared ray on the agricultural products spoilage microorganisms (part I). Paper no. 006090. Presented at: ASAE Annual Meeting(Milwaukee, USA).

Hamanaka, D., Uchino, T., Furuse, N., Han, W., and Tanaka, S. (2006). Effect of the wavelength of infrared heaters on the inactivation of bacterial spores at various water activities. Int. J. Food Microbiol. *108* (*2*), 281–285 https://doi.org/10.1016/j.ijfoodmicro.2005.11.019. PubMed

Kassem, A.S., Shokr, A.Z., El-Mahdy, A.R., Aboukarima, A.M., and Hamed, E.Y. (2011). Comparison of drying characteristics of Thompson seedless grapes using combined microwave oven and hot air drying. J. Saudi Soc. Agric. Sci. *10* (*1*), 33–40 https://doi.org/10.1016/j.jssas.2010.05.001.

Kincal, D., Hill, W.S., Balaban, M., Portier, K.M., Sims, C.A., Wei, C.I., and Marshall, M.R. (2006). A continuous high-pressure carbon dioxide system for cloud and quality retention in orange juice. J. Food Sci. *71* (*6*), C338–344 https://doi.org/10.1111/j.1750-3841.2006.00087.x.

Kouzeh, K.M., van Zuilichem, D.J., Roozen, J.P., and Pilnik, W. (1982). A modified procedure for low temperature infrared radiation of soybeans. II. Inactivation of lipoxygenase and keeping quality of full fat flour. Lebensm. Wiss. Technol. *15* (*3*), 139–142.

Krishnamurthy, K., Jun, S., Irudayaraj, J., and Demirci, A. (2008). Efficacy of infrared heat treatment for inactivation of *Staphylococcus aureus* in milk. J. Food Process Eng. *31* (*6*), 798–816 https://doi.org/10.1111/j.1745-4530.2007.00191.x.

Li, X., and Pan, Z. (2014). Dry-skinning of tomato by infrared radiative heating: Part I. Model development. J. Food and Bioprocess Technol. *7* (*7*), 1996–2004 https://doi.org/10.1007/s11947-013-1203-8.

Lichanporn, I., Srilaong, V., Wongs-Aree, C., and Kanlayanarat, S. (2009). Postharvest physiology and browning of longkong (*Aglaia dookkoo* Griff.) fruit under ambient conditions. Postharvest Biol. Technol. *52* (*3*), 294–299 https://doi.org/10.1016/j.postharvbio.2009.01.003.

Mercado, J.A., Pliego-Alfaro, F., and Quesada, M.A. (2011). Fruit shelf life and potential for its genetic improvement. In Breeding for Fruit Quality, M.A. Jenks, and P.J. Bebeli, eds. (USA: John Wiley and Sons).

Muler, I. (2005). Relationships between preharvest soybean oil application and postharvest behaviour of apples. Ph.D. thesis (USA: Washington State University).

Nascimento, J.R.O., Júnior, A.V., Bassinello, P.Z., Cordenunsi, B.R., Mainardi, J.A., Purgatto, E., and Lajolo, F.M. (2006). Beta-amylase expression and starch degradation during banana ripening. Postharvest Biol. Technol. *40* (*1*), 41–47 https://doi.org/10.1016/j.postharvbio.2005.11.008.

Ondier, G.O., Siebenmorgen, T.J., and Mauromoustakos, A. (2010). Low-temperature, low-relative humidity drying of rough rice. J. Food Eng. *100* (*3*), 545–550 https://doi.org/10.1016/j.jfoodeng.2010.05.004.

Pan, Z., Li, X., Yong, W., and Atungulu, G. (2011). Development of infrared heating technology for tomato skinning. p.3–8, http://www.icef11.org/content/papers/nfp/nfp1213.pdf.

Paull, R.E. (2014). Longkong, Duku, and Langsat: Postharvest Quality-Maintenance Guidelines (Department of Tropical Plant and Soil Sciences, College of Tropical Agriculture and Human Resources, University of Hawai'i at Mānoa).

Quevedo, R., Jaramillo, M., Díaz, O., Pedreschi, F., and Aguilera, J.M. (2009). Quantification of enzymatic browning in apple slices applying the fractal texture Fourier image. J. Food Eng. *95* (*2*), 285–290 https://doi.org/10.1016/j.jfoodeng.2009.05.007.

Sapii, A.T., Yunus, N., Muda, P., and Lin, T.S. (2000). Postharvest quality changes in dokong (*Lansium domesticum* Corr.) harvested at different stages of ripeness. Paper presented at: The Australian Centre for International Agricultural Research.

Sawai, J., Sagara, K., Kasai, S., Igarashi, H., Hashimoto, A., Kokugan, T., Shimizu, M., and Kojima, H. (2000). Far-infrared irradiation-induced injuries to *Escherichia coli* at below the lethal temperature. J. Ind. Microbiol. Biotechnol. *24* (*1*), 19–24 https://doi.org/10.1038/sj.jim.2900772.

Sawai, J., Sagara, K., Hashimoto, A., Igarashi, H., and Shimizu, M. (2003). Inactivation characteristics shown by enzymes and bacteria treated with far-infrared radiative heating. Int. J. Food Sci. Technol. *38* (*6*), 661–667 https://doi.org/10.1046/j.1365-2621.2003.00717.x.

Suárez-Dieguez, T., Soriano-García, M., Anaya-Sosa, I., and Cruz y Victoria, M.T. (2009). Comparative studies of two α-amylases acting on two sorghum hybrids starches (Montecillos hybrid 2 and 3) and their significant differences in their catalytic activities. Carbohydr. Polym. *75* (*3*), 538–540 https://doi.org/10.1016/j.carbpol.2008.09.015.

Venkatachalam, K., and Meenune, M. (2012). Physical and chemical quality changes of longkong (*Aglaia dookkoo* Griff.) during passive modified atmospheric storage. Int. Food Res. J. *19* (*3*), 795–800.

Zocca, F., Lomolino, G., and Lante, A. (2008). 3,4-Dihydroxyphenylalanine gel diffusion assay for polyphenol oxidase quantification. Anal. Biochem. *383* (*2*), 335–336 https://doi.org/10.1016/j.ab.2008.09.001. PubMed

Study of using infrared radiation for increasing the shelf life of duku

ORIGINALITY REPORT

10%	7%	5%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

2%

★ fruitandvegetable.ucdavis.edu

Internet Source

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		