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Effect of Shifting Practices on Performance of a Fixed-bed Convection Dryer for Longan

Juan Carlos González-Azcárraga[a], Marcus Nagle[a*], Sarawut Phupaichitkun[a], Busarakorn Mahayothee[b], Methinee Haewsungcharern[c], Serm Janjai[d], Hermann Leis[a], Joachim Müller[a]

[a] University of Hohenheim, Institute of Agricultural Engineering, Germany
[b] Silpakorn University, Department of Food Technology, Thailand
[c] Chiang Mai University, Department of Food Engineering, Thailand
[d] Silpakorn University, Department of Physics, Thailand

Abstract

Longan (*Dimocarpus longan* Lour) is a seasonal fruit that is grown and marketed mostly in Asia. Fresh longan has high moisture content and cannot be stored extendedly. Various post-harvest treatments have been found to prolong edibility, but longan is still mainly exported in other forms. Drying reduces the longan weight by approximately 66% and adds value to the product. However, dried longan must be undamaged and free of contaminants and have optimum color and moisture content on import. Overall, an adequate and consistent drying process is critical in achieving the standards of international markets. Thailand is currently the largest exporter of longan in the world, a third of which is dried. Production is concentrated in the north, where longan is a major component of the local economy and much of the harvest is dried for export. The most common dryer for longan in this region is the Taiwan-type fixed bed convection dryer, which is used for the bulk drying of unpeeled longan. However, it has been observed that the present drying procedures don't allow for uniform quality and techniques used to remediate this are labor-intensive and damage the product. So far, little research has characterized the shifting routine used in longan drying or suggested improvements.

Experiments were conducted in Thailand using different shifting routines compared to the conventional. Drying conditions and product quality were monitored. Results showed that air velocity and temperature distributions were heterogeneous, but patterns did not correspond. As temperature is highly influential in determining final color and moisture content of the fruits, product quality was affected. Only samples in the center positions and the side opposite the air inlet did not show significant differences when compared to a standard sample. Increased relative humidity and convective cooling of drying air caused condensation to form on top of the bulk. It was observed that one shifting scheme was superior to the others. In order to obtain a more uniform product in the Taiwan type dryer, the main issues are to create homogeneous distributions of air and temperature in the bulk and prevent condensation.

* Corresponding Author
E-mail: naglem@uni-hohenheim.de
Telephone: +49 711 / 459 23119
Telefax: +49 711 / 459 23298

Introduction

Dimocarpus longan Lour. (Sapindaceae), commonly known as longan, is a fruit native to Asia commercially cropped in Thailand, Taiwan, China, Vietnam, Australia and the United States (Diczbalis and Campbell, 2004). Due to high perishability of the fresh fruit, longan is mainly exported in processed forms, including dried, canned and frozen (Tongdee, 1997). Drying the longan reduces the weight by approximately 66% and larger amounts of dried fruit can be transported over longer distances at lower costs when compared with fresh fruit. Nonetheless, dried longan for export must arrive undamaged, uncontaminated and with uniform moisture content (Suadee, 1999). Overall, an adequate and consistent drying process is critical in achieving the quality standards of the international market.

Thailand is currently the largest exporter of longan in the world with about 70% of production exported annually. Of that amount, about 33% is export as dried product (Anupunt and Sukhvibul, 2005). In 2003, Chiang Mai was the largest producer of longan in Thailand by area, yield and productivity (Ministry of Agricultural Economics). Longan is a major contributor to the local economy in this area and much of the harvest is dried for export. So far, the most implemented dryer for longan in Thailand has been the Taiwan-type fixed bed convection dryer, used for the bulk drying of unpeeled longan. About 3,000 units of these dryers are currently used for longan drying in Thailand, but the present operation of the dryers does not produce a uniformly dried product. By convention, drying bulks are loaded into the dryer in three layers that are rotated front to back (180º) and shifted from top to bottom two to three times in a period of 36-48 hours. Rotating and shifting are performed so that each layer is dried at various levels and positions within the bulk during the drying process for more uniform MC. These practices are labor-intensive and often damage the peel of the longan fruits, but currently the only solution. In order to achieve more uniform drying, further investigation and possible improvements concerning drying of longan are required. The aim of this study was to obtain a uniformly dried product with higher quality standards by optimizing the shifting strategy without increasing labor or damage to the product.

Material and Methods

Experiments were conducted at a commercial longan drying facility located near the village of San Patong in Chiang Mai province, Thailand. The dryer used was Taiwan-type fixed bed convection dryer equipped with a Liquid Petroleum Gas (LPG) burner and blower operated by a 1 hp (0.745kW) electric motor (Fig. 1). For each treatment, the dryer was loaded with two tons of "Class B" (20-22 mm diameter). Drying air temperature was regulated manually by adjusting the supply of LPG to the burner. Temperature was maintained at 75-80º C, since this is the range at which whole unpeeled longan is conventionally dried (Phaphuangwittayakul et al., 2004). In order to determine the effect of shifting routines, four treatments were applied as shown in Fig. 2. Treatment 1 is the routine currently used by the facility operator.

Figure 1. The Taiwan-type dryer for bulk drying of unpeeled longan, loaded with three layers of fruit each 20 cm high.

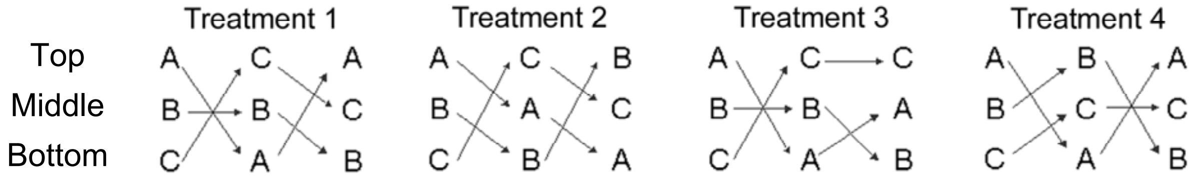

Figure 2. Schematic diagram of the shifting routine of layers (A, B, & C) for each treatment.

For each treatment, temperature was monitored using thermocouples positioned by PVC frames exposed at nine different positions through small holes in the pipes. During drying, the frames were placed on top and bottom of the bulk and between layers. Air velocity was measured periodically at nine points on top of the bulk corresponding to the thermocouples using a vane anemometer. For comparison, air velocity was also measured in an empty dryer at positions on the bottom of the drying bin corresponding to temperature. Distribution maps for temperature and air velocity were made using MATLAB. Mesh bags were filled with fruit samples and placed atop each layer during drying at five positions corresponding to temperature. Fruits were sampled at the following sequential stages of drying: beginning of drying, first shift, second shift and end of drying. A sample of 21 fruits chosen by the facility operator as “optimally dried” was also analyzed as a standard reference. Total moisture content (MC) analysis of 16 fruits per sample was determined gravimetrically by oven method at 105º C for 72h and calculated wet basis. Five fruits from each sample were evaluated for flesh color by a colorimeter. LAB coordinates were converted to hue angle values. Data was subjected to SPSS analysis including ANOVA to and Least Significant Difference (LSD) to determine differences between data points, layers and treatments and quality parameters where samples were compared to the standard.

Results

It was noticed in all treatments that air velocity was the highest at the far side of the dryer. For the empty dryer, the near side even showed negative values indicating suction. Temperature distribution was also not homogeneous during the drying process, it was more uniform on the bottom layer and became less homogenous in higher layers. Horizontally, temperatures were higher near the center and decreased towards the sides. However, distributions of temperature and air velocity did not correspond (Fig. 3). Evaporation from the fruits caused RH of the drying air to increase and temperature to drop between bottom and top layers. Low temperatures and high RH at the top of the bulk of drying caused condensation to form on the surface of the fruits during the first hours of drying.

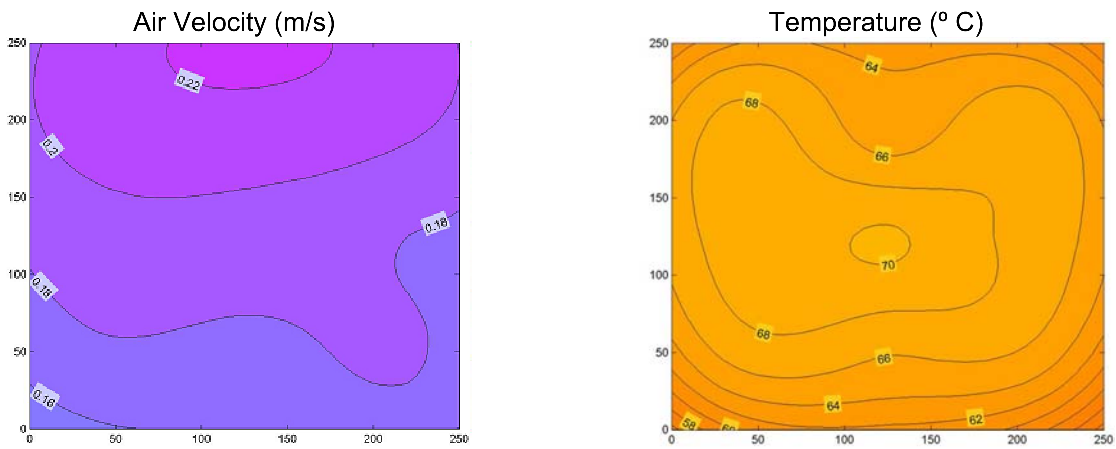

Figure 3. Temperature and air velocity distribution during Treatment 3. Dimensions in cm.

Distribution of final MC of the samples was more uniform than the initial MC. Standard samples were found to have a MC of 14.7%. Layer C samples did not show significant differences in MC as well as those from middle positions and those exposed twice to the far side of the dryer. For flesh color, a threshold hue angle of 60º was defined from analysis of standard samples. Similarities were found for samples from positions corresponding to MC. In all treatments, Layer C had significant differences from Layers A and B. Layer C had the lowest MC and hue angle value, which were closest to the standard sample. In Treatments 1, 2 and 4, layers were significantly different in terms of MC and color of the final product. In Treatment 3, no significant differences between layers were found, indicating a more homogeneous color of the final product. Overall, Treatment 3 showed average values closest to the standard and the smallest variability indicating the best uniformity (Table 1).

Table 1. Mean values for final moisture content (M_f) and hue angle (Hue) and variability of final quality as indicated by standard deviation

Treatment	M_f (%)	Hue (°)
1	$19.53^{a*} \pm 6.04$	$71.04^{a} \pm 7.68$
2	$16.93^{b} \pm 4.81$	$68.06^{b} \pm 6.69$
3	$\mathbf{14.71^{c} \pm 2.79}$	$\mathbf{63.77^{c} \pm 5.41}$
4	$17.04^{b} \pm 5.04$	$65.28^{c} \pm 6.91$
Standard	$\mathbf{14.70^{c} \pm 1.15}$	$\mathbf{59.42^{c} \pm 6.24}$

Discussion

Condensation on top of the bulk at the beginning of the drying process is perceived as a significant problem due to increased hydration of the fruits. A possible solution may be to increase air velocity during the first stage of drying to accelerate the airflow rate and lower the RH. Another solution would be to lower the bulk height since the change in sensible heat of drying air moving through the bulk is a function of the thickness of the bulk (Pabis et al., 1998). Similar air velocity distribution was previously found for this type of dryer, however absolute values did not correspond. This was most likely due to differences in bulk height. Furthermore, no suction was found in the assessment of an empty dryer (Janjai et al., 2006). Non-uniform air velocity had an impact on temperature distribution due to its influence on heat exchange rate. Although previous studies stated that air velocity does not have a big influence in single layer drying (Phupaichitkun et al. 2005), in bulk drying different air velocity influenced the temperature distribution and thus impacted the drying rate. The use of air deflectors in the plenum to compensate for uneven distribution has been tested with a reportedly high degree of success (Janjai et al., 2006). Unfortunately, such features are not yet normally installed for the Taiwan dryer type.

It is believed that the heterogeneity of end product quality found in this study was caused by the non-uniform distribution of temperature, as temperature has been reported to be the determining factor influencing the quality of dried longan (Mahayothee et al., 2006). Accordingly, the distribution of final MC and color of the samples most closely resembled temperature distribution. In all treatments, samples having the most desirable MC and hue angle were those from the positions in the bulk that experienced the highest and most consistent temperatures, specifically in the center of the bulk and those expose twice to the far side of the dryer. End product samples from Layer C of each treatment and samples from Treatment 3 seemed to be the best in terms of quality. This is believed to be due to the rapid temperature increase experienced in Layer C, and in Treatment 3, with subsequent heat application to Layers A and B while Layer C remained on top.

Conclusions

Evaporative cooling, differences in air velocity and heat distribution created non-uniform drying of the product. During the first shift, condensation occurred on the surfaces of fruits on the top layer. Drying temperature was found as the greatest factor influencing end product quality in terms of MC and color. Shifting was found to influence product quality as end products were found to be most uniform in Treatment 3. To obtain a uniform product using the Taiwan-type dryer, the main issues are to create a homogenous air velocity and temperature distribution in the bulk. Possible solutions include: increased air velocity during the first drying stage, reduction of bulk height and installation of air deflectors in the plenum.

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References

Anupunt, P., and N. Sukhvibul. 2005. Lychee and longan production in Thailand. Acta Horticulturae 665:53-59.

Janjai, S., P. Intawee, C. Chaichoet, B. Mahayothee, M. Heawsungcharern, and J. Müller. 2006. Improvement of the air flow and temperature distribution in a conventional longan dryer. International Symposium Towards Sustainable Livelihoods and Ecosystems in Mountainous Regions, Chiang Mai, Thailand. 7-9 March.

Mahayothee, B., Wongtom, R., Keowmaneechai, E., Phupaichitkun, S., Haewsungcharern, M., Janjai, S. & Müller, J. 2006. Influence of drying on browning and sensory characteristics of dried whole longan. In: Proceedings of the15th International Drying Symposium (IDS 2006) (edited by I. Farkas). Budapest, Hungary. Pp. 1562-1566.

Pabis, S., D.S. Jayas, and S. Cenkowski. 1998. Grain Drying: Theory and Practice John Wiley & Sons, New York.

Phaphuangwittayakul, P., S. Limpiti, and Z. Alikhani. 2004. A batch dryer for un-peeled longan drying. Agricultural Mechanization in Asia, Africa and Latin America 35:41-44.

Phupaichitkun, S., B. Mahayothee, M. Heawsungcharern, S. Janjai, and J. Müller. 2005. Single-layer drying behavior of longan (*Dimocarpus longan* Lour.). Deutscher Tropentag 2005, Stuttgart-Hohenheim, Germany. 11-13 October.

Suadee, W. 1999. Drying process and export of dried longan in Chiang Mai and Lamphun provinces. M.Sc. Thesis. Department of Agricultural Extension, Chiang Mai University, Chiang Mai, Thailand.

Tongdee, S. 1997. Longan, p. 335-345, In: Postharvest physiology and storage of tropical and subtropical fruits (edited by S. Mitra). CAB International, Oxon, UK.

Tongdee, S. 2004. Horticultural crop production and marketing decision influencing postharvest technology. Extension Bulletin 545. Food & Fertilizer Technology Center, Taipei, Taiwan.