Drying and Decontamination of Almonds by Sequential Infrared and Hot Air Drying

Chandrasekar Venkitasamy[1], Caiping Zhu[1,2], Maria T. Brandl[3], Tara H. McHugh[4], Zhongli Pan[1,4]

[1]Department of Biological and Agricultural Engineering, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA
[2]College of Food Engineering and Nutrition Science, Shaanxi Normal University, Xi'an 710062, China
[3]Produce Safety and Microbiology Research Unit, USDA-ARS-WRRC, 800 Buchanan St., Albany, CA 94710, USA
[5] Healthy Processed Foods Research Unit, USDA-ARS-WRRC, 800 Buchanan St., Albany, CA 94710, USA

Abstract

The harvesting practice of shaking almonds and drying them on the ground increases the risk of contamination with enteric pathogens, such as *Salmonella*, which is a major cause of almond recalls and almond-linked outbreaks. Rain events during the harvest season may cause complete loss of crop due to increased contamination risk and lack of adequate drying technology. To develop a sequential infrared and hot air (SIRHA) drying method for almonds, wet almonds with hulls were dried using SIRHA dryer. Almonds in their hulls were inoculated with *E. faecium* and dried to evaluate the decontamination efficacy of the SIRHA method. The SIRHA drying (IR drying at 70ºC for 1h followed by HA at 70ºC) reduced the moisture content of almond kernels to 7% in 3 h, resulting in a saving of 2 h (40%) of drying time compared with HA drying. The greatest *E. faecium* population size reductions (4.69±0.71, 1.82±0.39, 1.52±0.31 log CFU/almond, on hulls, shells and kernels, respectively) were observed for SIRHA drying with tempering [2h of IR and 2h of tempering (holding) at 70ºC followed by 1h HA]. The peroxide value (PV) and free fatty acids (FFA) content of almond oil from all treatments were within the accepted level for the almond industry. The results suggested that SIRHA drying could be used for drying rain-impacted wet whole almonds, but that additional sanitization may be required to further decontaminate the shells and kernels.

Introduction

The current almond harvesting practice combined with rain events during harvest may cause complete loss of a crop due to increased contamination risk and lack of adequate drying technology. Therefore, there is an urgent need to develop a technology that can dry the almonds quickly and also reduce the microbial population of food-borne pathogens such as *Salmonella*. Our previous research showed that IR heating of pistachios to 70ºC and holding/tempering at 70ºC for 1-2 followed by hot air drying reduced the drying time of pistachios by 9.1% and the *E. faecium* cell population (surrogate of *Salmonella*) by 6.39-log CFU/g in kernels and 5.29-log CFU/g in shells. Our previous results also showed that IR pre-heating of raw almond kernels followed by tempering resulted in over 5.0-log reduction of *S. enterica* cell populations. Therefore, the SIRHA drying method was used in this study to dry wet whole almonds.

Objectives

1. To study the drying characteristics and product quality of wet almonds using SIRHA drying method
2. To evaluate the effectiveness of the SIRHA method to perform simultaneous drying and decontamination in order to produce safe and high quality almonds

Materials and Methods

Almond samples

Late season harvest variety (Monterey) almond trees at the Nickel's Soil Lab of Colusa County, CA were shaken to the ground and rain was simulated by spraying water onto the almonds on the ground for one week. The almonds then were collected and stored in the freezer at -30ºC until used for inoculation and drying.

Materials and Methods (Continued)

SIRHA drying of almonds

Frozen almond samples were thawed for 1h at ambient temperature, weighed and dried using the SIRHA dryer (Fig.1). Initial moisture content was determined with the hot air oven drying method (105ºC for 24 h) and the moisture content during drying was calculated from the moisture loss by weighing the samples at 1h interval. 15 whole almonds were placed in a single layer in each of three wire mesh cups (8 cm dia. x 4 cm height) placed on a tray that was shaken by a vibratory motor for uniform exposure of almonds to IR and hot air. The temperature of the almonds was monitored with an IR temperature sensor and maintained with an IR intensity control console. Drying was performed until the moisture content reached less than 7%, the accepted moisture level for hulling. The quality of almonds was evaluated by extracting the almond oil and determining PV and FFA content of the oil samples.

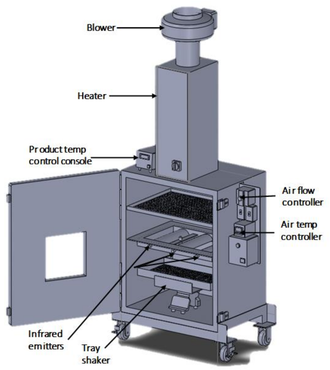

Fig.1. Sequential infrared and hot air (SIRHA) dryer

Decontamination efficacy of SIRHA drying

To determine the efficacy of decontamination, almond samples were inoculated with *E. faecium* NRRL B-2354, a surrogate accepted for microbial quality testing by the Almond Board of California. The cells were grown on TSA for 2 days at 28ºC, re-suspended in tryptone buffer at an approximate concentration of 10^{10} cfu/ml. Twenty five ml of the suspension was added to 400 g of almonds in their hulls in a bag, and the suspension and nuts were mixed by shaking. The inoculated pistachios were allowed to dry for 24 h at 28ºC and stored at 10ºC until used for treatments. The treated almonds were separated into hulls, shells and kernels. *E. faecium* cells recovered from hulls, shells and kernels in 10mM phosphate buffer in a Pulsifier were dilution plated onto tryptic soy agar (TSA) medium. *E. faecium* colony forming units (CFU) were counted after incubation at 28ºC for 2 days.

Results

The target moisture content of 7% was obtained after 3h of IR drying, 2h of IR drying followed by 1h of HA drying,1h of IR drying, and 3h of hot air drying and also by 5h of HA drying alone. Tempering for 1h and 2h at 70ºC was performed with the above drying conditions to increase the decontamination efficiency. The initial concentration of *E. faecium* in the hulls, shells and kernels were 1.78 ±0.23x10^9, 2.17±0.13x10^8 and 6.4±0.19 x10^4 per almond, respectively. As the hulls were the outer layer, they received more cells during inoculation and the kernels received the least.

Results (Continued)

a. Temperature profile and drying curves

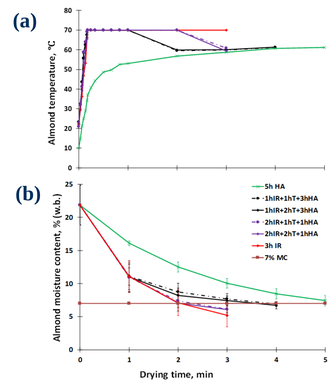

Fig. 2.(a) Temperatures and (b) moisture profiles of almonds during SIRHA drying
(Tempering time is excluded from x axis)

b. Quality of almonds

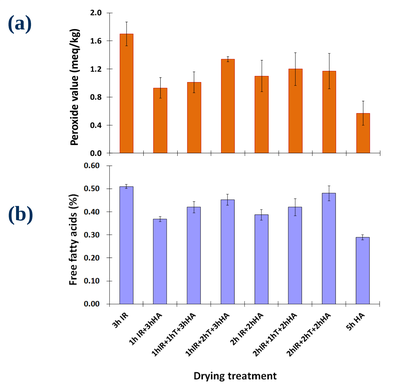

Fig. 3.(a) PV and (b) FFA content of SIRHA-dried almonds

The PV and FFA content of almond oil samples from all treatments were within the levels accepted by the almond industry.

c. Decontamination efficacy of SIRHA drying

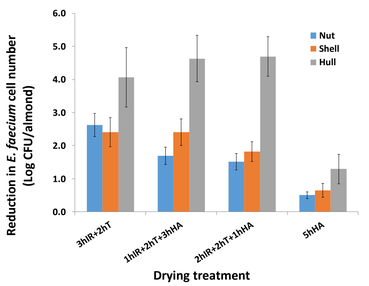

Fig.4. Effect of SIRHA drying on *E. faecium* cell reduction

Maximum *E. faecium* cell population size reductions of 4.69±0.71, 1.82±0.39, and 1.52±0.31 log CFU/almond on hulls, shells and kernels, respectively, were obtained for 2h IR drying and 2h tempering followed by 1h hot air drying. The population size reductions for treatments without tempering and with 1 h tempering were lower than for treatments with 2h tempering. Since kernels were covered by shells and hulls, they received fewer inoculum cells and were the least affected by decontamination treatments.

Conclusions

1. IR drying of almonds at 70ºC saved 40% drying time to dry almond kernels to less than 7% moisture content compared with 5h by hot air drying at 70ºC.
2. SIRHA drying with 2h IR drying and 2h tempering followed by 1 hot air reduced the *E. faecium* cell population size by 4.69, 1.82 and 1.42 log CFU/almond on hulls, shells and kernels, respectively.

Acknowledgements

1. California Department of Food and Agriculture (CDFA) for funding the research.
2. CRIS Projects 2030-42000-046-00D and 2030-41000-064-00D, USDA-ARS, Albany, CA for providing expertise, facilities and equipment for this research.

Contact: Dr. Zhongli Pan, PhD.
Healthy Processed Foods Research Unit, Western Regional Research Center,
USDA-ARS, Albany, CA, USA, zhongli.pan@ars.usda.edu