Tree Nut Pasteurization, Water Activity, and Moisture Content

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Common intuition would certainly indicate that various tree nuts such as Almonds, Pistachios, etc are low moisture foods. Not surprisingly, they easily fit the FDA definition: "Low-moisture foods (LMFs) have been defined as those food products with a Water Activity (a_w) less than 0.85 and are generally considered less susceptible to microbial spoilage and the growth of foodborne pathogens" (1) This classification, however, does not by any means imply the product is inherently free of pathogenic organisms. The unfortunate reality is that certain organisms, such as salmonella, can survive on the surface of a nut for an extended period of time in a dormant state and in fact, recent studies indicate the low moisture conditions actually strengthen the heat resistance and persistence of these organisms. Hence, the application of surface pasteurization treatments for tree nuts is becoming more commonplace, and for Almonds is mandated by federal law.

One method used for pasteurization of tree nuts is the application of steam to the surface of the product. Various equipment suppliers employ different methods of steam application, but they all have one fundamental in common, the delivery of lethal heat energy to the nut surface through the condensation of steam. With condensation, a relatively large amount of energy can be transferred to the product in a short amount of time. This is due to the instantaneous release of heat that occurs when the steam changes phase from gas to liquid and transfers the Latent Heat of Vaporization to the cooler surface. Simply put, this is the extra energy the liquid water must absorb to convert to steam. When the steam condenses on the surface of the kernel, this heat is immediately transferred.

One of the practical difficulties with the real world application of a steam process is management of the condensation, liquid water, on the product surface. Obviously, a wetted nut kernel can quickly lose its appealing crunchy texture due to changes in its moisture content. Other product characteristics can also be negatively impacted such as color and skin integrity.

For potential buyers of pasteurization equipment, a good understanding of how condensation and moisture are managed by a given system will be very helpful to arrive at a sound purchase decision. In scientific terms, water content for all types of food products is expressed by two metrics, Percent Moisture (%MC) and Water Activity (a_w), where %MC expresses the total amount of water, and a_w expresses the amount of water chemically bound within the cellular structure of the product. Science has shown that water content can influence a pasteurization process, and more recently various academic studies have been undertaken with the objective of identifying and correlating the specific influence a_w and %MC to salmonella inactivation kinetics such that a mathematical model for predicting log reduction can be developed. These studies have revealed that even in lab conditions , the relationship between a_w and %MC is highly complex with multiple dynamics and interdependent relationships in play. Further, for commercial process where elevated temperature, relative humidity, and air flow rates impact the relationship between %MC and a_w, the study becomes even more complex and approaches the limitations of currently available measurement instrumentation. While academic work will certainly continue and hopefully succeed, the current state of research may best be expressed as follows: "The separate effects of a_w and %MC on the inactivation kinetics of Salmonella in LMF's remain inconclusive…" (2)

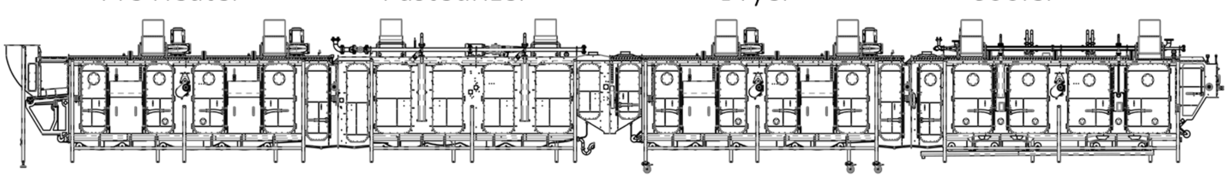
Therefore, for the potential equipment purchaser, it is not necessarily productive to focus on the complexities of either a_w or %MC when evaluating a process. Instead, an understanding of the method a given system uses to manage the overall amount of moisture involved during the process, and the flexibility of that system to respond to varying raw product conditions is key.

Of the many steam-based technologies currently available, the emerging leader in nut pasteurization is the CoolSteam System offered by Laitram Machinery. For many years, New Orleans, LA based Laitram has been a leading innovator and supplier of thermal processing systems specifically designed for delicate products. The technology combines the benefits of CoolSteam heating with the power of forced convection and excellent moisture management capability.

To define these terms for the reader, CoolSteam refers to a homogeneous mixture of air and steam at temperatures below 212 F. This mixture provides both condensational heating, and virtually simultaneous evaporation on the product surface due to the presence of air. It's an inherently gentle process, and with much less moisture than 100% saturated steam. Forced convection is a well accepted method of utilizing powerful fans to create a highly efficient environment for either heating or cooling. It has the ability to literally force heat transfer coefficients up to 1000 times higher than static conditions, but is controllable with a high degree of precision so just the right amount of heat can be applied, or removed, depending on the process objectives.

Recognizing the essential need for moisture management to preserve the raw like texture and crunch of the product in the pasteurization system, Laitram engineers adapted the benefits of forced convection in a dry heat PreHeater zone, located before the CoolSteam Pasteurization step. In operation, the Preheater increases the surface temperature of the product to just a few degrees below the temperature of the CoolSteam Pasteurization zone. This small temperature differential allows only a small, controlled amount of condensate to form on the surface of the product as it travels through the Pasteurization zone. While in theory, the system is capable of operation with zero condensate formation, such a condition is actually not desirable because condensation, especially with forced convection, is the work horse of heat transfer and essential to achieving target 4 or 5 log lethality in a short, commercially viable, time.

In actual practice during operation of the Laitram system, virtually all of the condensate on the product surface will evaporate as soon as it forms, or shortly after it exits the Pasteurization zone. For an added degree of flexibility and moisture management, the Laitram system incorporates a fully adjustable, forced convection, Drying zone after the Pasteurization zone. This gives the processor the ability to absolutely ensure the product is returned to its original %MC and a_w condition, and in some instances starts the process of removing heat from the product before the chilled air Cooling zone, also using forced convection. Since the Drying zone is downstream of the validated Pasteurization zone, the processor is free to set the Drying, and Cooling, parameters as desired, either to return product to original conditions, or to further reduce moisture as may be necessary with a slightly high moisture raw product.



Typical Laitram CoolSteam Pasteurization System with multiple forced convection zones

In total, this flexibility transforms the Laitram CoolSteam Pasteurization system into a powerful tool in the processors arsenal, capable of responding to the challenges presented by real world variability in raw product characteristics by giving the processor a degree of control in fine tuning final product moisture, always with complete assurance of achieving target lethality and food safety.

References

1 - Sánchez-Maldonado AF, Lee A, Farber JM. Methods for the Control of Foodborne Pathogens in Low-Moisture Foods. Annual Rev Food Sci Technol. 2018 Mar 25;9:177-208. doi: 10.1146/annurev-food-030117-012304. Epub 2018 Jan 12. PMID: 29328809

2 - FRANCISCO J. GARCES-VEGA ; ELLIOT T. RYSER ; BRADLEY P. MARKS , Relationships of Water Activity and Moisture Content to the Thermal Inactivation Kinetics of Salmonella in Low-Moisture Foods. Journal of Food Protection (2019) 82 (6): 963–970.