

Drying of produce:

Guidance to minimize the microbiological risk



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Purpose of this booklet

Content overview

This booklet helps you to understand and manage the critical elements that impact microbiological food safety during drying.

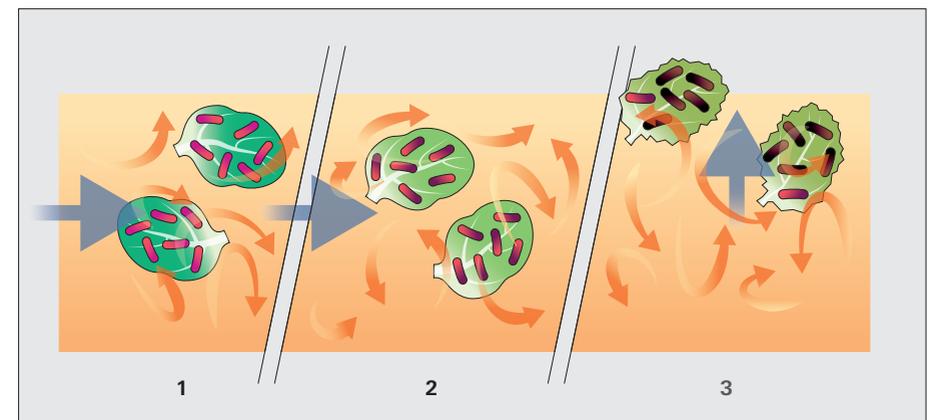
- Why is it important to manage the drying properly;
- What are the main elements to control during produce drying;
- What are the main elements to manage for an effective maintenance of equipment;
- Why is it important to validate and verify the microbial reduction for a drying process.

Microbiological food safety for produce drying

Produce (e.g. herbs, root vegetables, onions, berry fruits) can be contaminated with pathogenic microorganisms during the production in the field.

For some produce categories, drying is the only mild thermal process that can bring a microbial reduction.

During drying, the product moisture is slowly reduced to the desired final value. The dry product is stable since microbiological growth and enzymatic reactions do not take place. When microorganisms are exposed to dry environments they develop resistance to desiccation and they also become more resistant to heat. As a result, the lower the product moisture, the harder it becomes to inactivate microorganisms.



When considering a drying process with a continuous reduction of product moisture, the inactivation of microorganisms is more likely to take place in the initial part of the process, when the target product temperature is reached and before the moisture level becomes too low for any inactivation to happen. The present booklet focuses on this part of the drying process.

This booklet does not report any safe process parameters, universally applicable to every technology. This is due to the high dependence of inactivation linked to the built-in characteristics of every machine model.

Moisture versus water activity (a_w)

Moisture represents the water content of a specific food and is generally expressed in percent of weight. It is a common parameter in use in the food industry to express the total water content of a product.

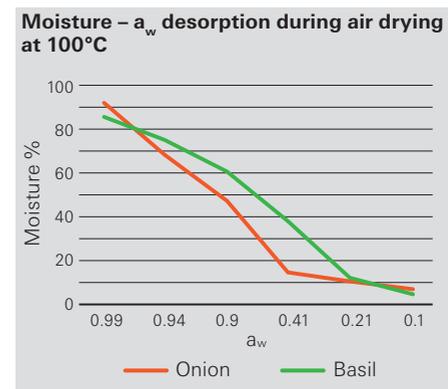
a_w represents the amount of water in the food available to microorganisms and is expressed with decimal numbers ranging from 0 (absence of water) to 1 (pure distilled water).

In microbiology, a_w is commonly used since there is a direct relationship between this parameter and conditions for growth and inactivation of microorganisms.

No fixed, direct relationship exists between moisture and a_w . In addition, no conversion factors are available because the conversion depends on the specific product considered.

Reported below are some corresponding values of moisture and a_w as well as desorption profiles for basil and onion obtained experimentally during air drying.

	Moisture %	a_w
Basil	91.0	0.99
	88.9	0.98
	75.3	0.97
	34.7	0.78
	13.6	0.67
	8.6	0.55
Onion	92.1	0.99
	68.0	0.94
	47.4	0.90
	14.7	0.41
	10.9	0.21
	7.7	0.10



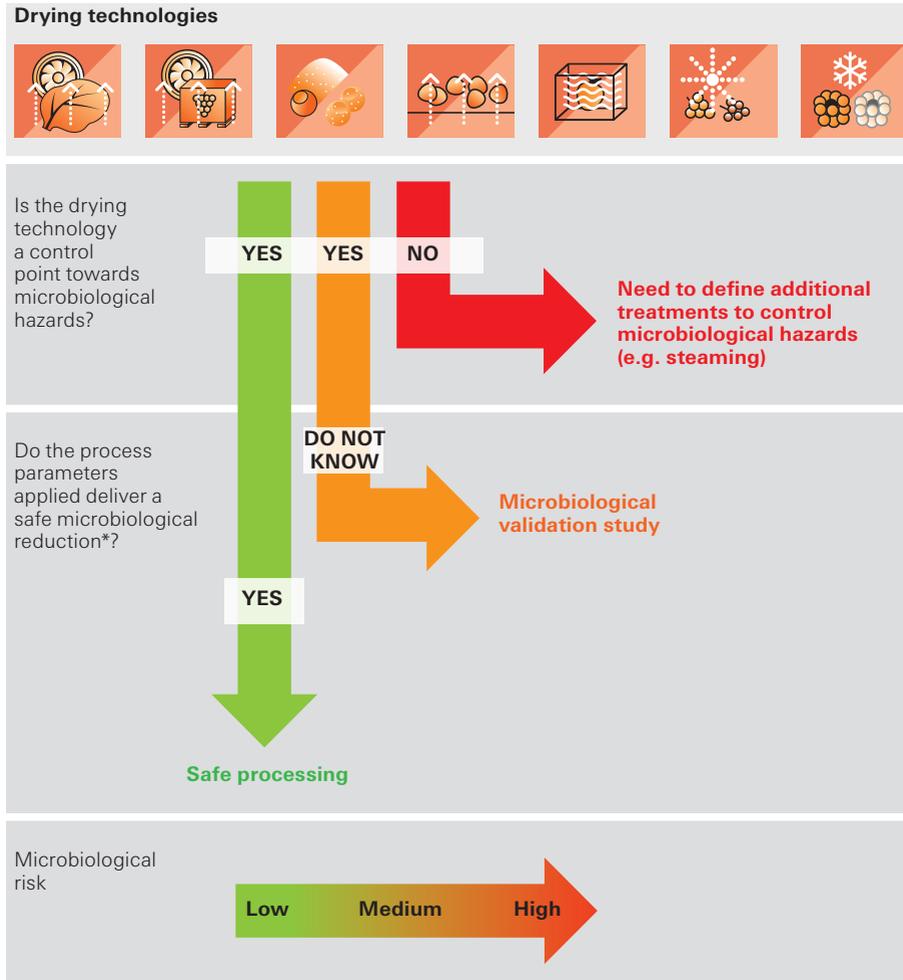
Field of application: drying technologies covered in this booklet

Drying technology		Symbol
Convective air		
In-pack pasteurization of dried fruits		
Osmotic dehydration (candying)		
Fluidized bed		
Microwave (also with vacuum)		
<p>! Sun drying and freeze-drying are common drying technologies. However, these are out of scope of this booklet since they cannot be considered critical control points for microbiological food safety. Hence, if these technologies are applied, another control step should be defined.</p>		
Sun drying		
Freeze-drying		

Decision tree for the management of the microbiological risk

The following decision tree shows different levels of control for the

microbiological risk based on the type of technology in use.



*refer to *Examples of safe processing conditions* (p. 12)

Convective air drying



Process overview

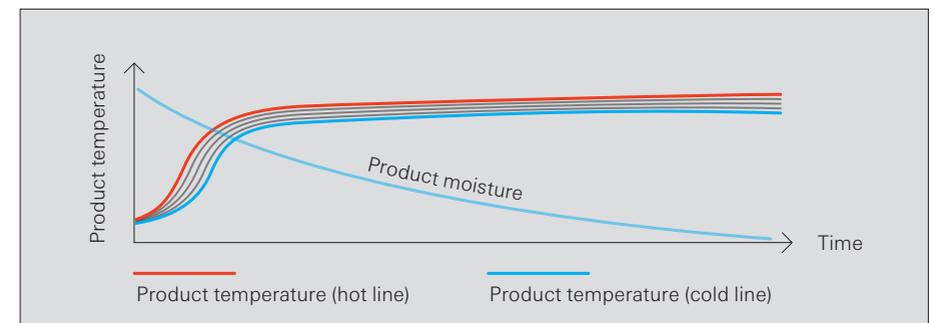
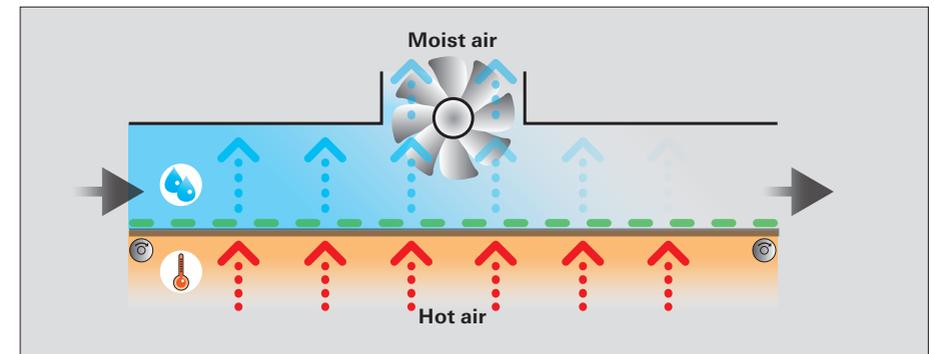
When drying fresh herbs, vegetables and fruits, convective air is the most common technology used. For this reason, this chapter is dedicated to the specifics of convective air drying.

The drawing below represents a schematic overview of the convective air drying process. Product temperature, product moisture and residence time are the main parameters to control for a good management of the process.

Management of the process

Why is it important to measure product temperature during commissioning of the process?

⚠ Product temperature is the most direct indicator of microbiological inactivation. When feasible, a temperature profile should be done on different points of the drier during commissioning using dataloggers. The temperature profile in the product bulk (volume of



Best processing practices

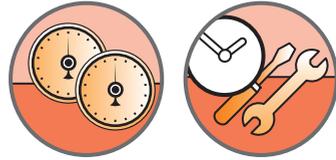
product mixed with air) is very much dependent on the type of drier, type of product and load level of the drier. Therefore, it is important to know the temperature profile for every product processed.

For continuous, convective air driers using conveyor belts each datalogger should be placed in a specific point of the product bed. When the logger moves with the product it reads a temperature line. The line that shows the lowest temperature at the beginning of the process represents the worst condition and can be referred to as "cold line". The line having the highest temperature is referred to as "hot line". A process that is well managed presents minimal difference in temperature between the two lines.

⚠ The worst parameters to be considered (see Validation and Verification) are the lowest temperature taken from the cold line and the shortest processing time.

ACTIONS	RECOMMENDATIONS	APPLICABLE TO				
						
Running of temperature profiling in the product bulk during commissioning and after reassembly of the line	Temperature profiling must take into account the worst processing conditions. These are represented by the highest product bed depth, processing on half load mode, the beginning (start-up) and the end (shut-down) of the process. In these conditions, the amount of air spaces is higher and there is less contact between the product and the hot air leading to a lower heat transfer to the product.	✓	✓ For air pasteurization of packed dried fruits, the temperature profile should identify the cold point/s in the room.	✗	✗	✗
Continuous recording of air and product temperature during every production	The coldest line (for convective air) or the coldest point (for in-pack pasteurization) should be continuously monitored and recorded by using commercially available Recording Temperature Devices (RTD) or dataloggers. Some driers are equipped with RTD (e.g. Bühler). If the RTD is not fitted on the drier, it should be installed taking into consideration the hygiene / cleaning design requirements. The air temperature should also be continuously recorded.	✓	✓	✓	✗	✗
Continuous recording of air velocity and bed depth during every production	For air drying, the product bed depth and the air velocity are important elements that directly affect the product temperature. They should be continuously monitored and recorded.	✓	✗	✗	✓	✗
Continuous recording of residence time during every production	Residence time is one of the key parameters for microbiological inactivation. It should be continuously monitored through recording of belt motion and electrical engine rotation.	✓	✓	✓	✓	✓
Management of start-up and shut-down	During the start-up the product must not start the drying before the target air temperature is reached. During shut-down the product must not be treated because the temperature is decreasing below the set point.	✓	✓	✗	✓	✓
Management of process deviations	In case of a process deviating from the set parameters, a clear procedure must be present to regulate the rework or disposal of the product.	✓	✓	✓	✓	✓
Product pH verification	The level of acidity has a high impact on the total inactivation. For some technologies, pH is a critical element that should be kept under control.	✗	✓	✓	✗	✗

Maintenance of equipment



Why are appropriate calibration and maintenance important?

Calibration programs for temperature probes



All recording devices should be calibrated at regular frequency. This should be done at least every six months. For temperature probes an accuracy of $\pm 0.5^\circ\text{C}$ is recommended*.

Verification of the power output of microwave generators



To know the exact microwave power transmitted to the food it is necessary to continuously monitor the forward power (as generated from magnetrons) and the backward power (reflected back from the drier). The difference between the two values is the real power transmitted to the food.

Verification plan after reassembly of the line



Critical operational parameters should be checked after reassembly of the line. The most common parameters to consider are: temperature, time, air speed above and below the belt, air dumpers (when present), side guides and microwave power generators.

Any additional element that can be critical to the food safety of the process should be considered.

Verification procedure for effectiveness of cleaning

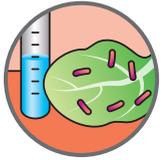


Cleaning is a critical activity for controlling the hygiene of the machine and maintaining good operational conditions. In the case of air drying, air flows must be fluent thus conveyor belts must be free from product clogging.

A procedure should be in place based on the technology considered to assess the effectiveness of cleaning. This is usually done as visual inspection on specific critical points.

* "Guidelines for the Safe Production of Heat Preserved Foods," Department of Health, UK; Industry Handbook for Safe Processing of Nuts, GMA (2010)

Validation



⚠ Why is validation so important?

A deep understanding of the process parameters and the inactivation achieved during drying is key to understand the efficacy of the process.

Microbiological validation study

- A microbiological validation study is needed if the processing conditions applied are milder (shorter time, lower temperature, lower air speed or both) than the ones reported as guidance in "Examples of safe processing reference conditions", or if another product is used. The outcome of the validation should be used as baseline to establish critical limits for processing.

- When a microbiological validation is needed a surrogate microorganism must be identified. For air drying, internal research has shown that *Escherichia coli* P1 (ATCC BAA1427) has a similar heat resistance to the target pathogen (*Salmonella* spp) and can be considered a suitable surrogate for this process. Other microorganisms can be used as surrogate if there is scientific evidence that the dry heat resistance specific to the technology considered is similar to the one of the target pathogen.

- ⚠ The results of a validation study are valid exclusively for the process parameters applied to a specific product. Only if this connection is established is it possible to safely apply the process parameters on a daily basis.

Validation

Microbiological reduction targets

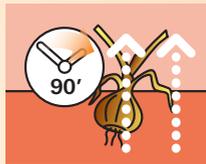
A 4 log₁₀ reduction of pathogenic bacteria like *Salmonella* is a generally recognized safe target for validation of pasteurization processes on low moisture foods*. In the absence of an official standard for drying, we thus recommend to target the same reduction for drying of fresh produce.

⚠ If safe reference processing conditions are available, validation studies will not be necessary. If no reference processing conditions are available, a validation study is needed.

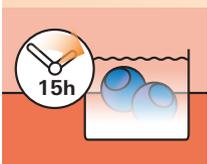
Examples of safe processing reference conditions



Convective air drying of basil at 100°C (product temperature), with an air speed of 1 m/s, delivers >4log₁₀ reduction of *Salmonella* after a time of 70 minutes.



Convective air drying of onion at 100°C (product temperature), with an air speed of 1 m/s, delivers >4 log₁₀ reduction of *Salmonella* after a time of 90 minutes.



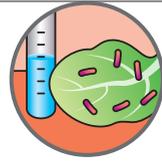
Osmotic dehydration (candying) of frozen blueberries at pH 3.0 using a 75% sucrose solution at a temperature of 40°C for a time of 15 hours is sufficient to reduce *Salmonella* and STEC by >6.0 log₁₀.



In-pack pasteurization of dried raisin (moisture 12–16%, pH 3.7–4.2) delivers >6 log₁₀ reduction of *Salmonella* after a time of 2 hours at 62°C (product temperature).

* "Guidelines for Using *Enterococcus faecium* NRRL B-2354 as a Surrogate Microorganism in Almond Process Validation." Almond Board of California.

Verification



Why is verification so important?

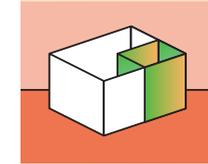
- Verification should be done at an appropriate frequency on the finished product.
- *Enterobacteriaceae* as representatives of pathogenic bacteria such as *Salmonella* and Shiga Toxin Producing *Escherichia coli* (STEC) and target pathogens should be used for finished product testing.
- Analytical data should be collected over a defined period of time. This allows to do trend analysis and better control the process.

Good Manufacturing Practices (GMPs)

Why is it important to have GMPs in place?

GMPs (as defined by CODEX - General Principles of Food Hygiene) are a collection of generally recognized rules, procedures and practices that together provide guidelines stating what is and what is not acceptable in the food industry. GMPs must be preventive in their approach. They ensure that food quality and food safety objectives are consistently met.

Zoning



Zoning is the separation of areas with different hygiene levels. It can be applied to prevent spreading of microorganisms from a specific

highly contaminated area to other more critical processing zones. As an example, raw material reception should be separated from the packing area of the clean dried product.

Cleaning



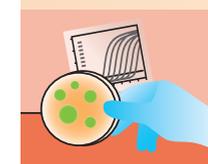
Cleaning must be considered as a process step, preparing the line for production. The equipment and the process environment must be clean and

hygienically designed so they are not a source of contamination to products.

Cleaning is a mandatory action to keep the hygiene of the equipment and process facilities under control.

For areas where the dried product is present it is important to reduce the use of water to a minimum (e.g. avoid wet cleaning and condensation). Effectiveness of cleaning should be verified at regular frequency (e.g. visual inspection, ATP analysis).

Environmental monitoring



Environmental monitoring is the testing at pre-determined frequency of appropriate sampling sites (environment and product contact

surfaces) identified based on risk. Appropriate combinations of relevant pathogens and/or hygiene indicators should be analysed. The results provide the necessary information to keep the microbiological population in the processing area under control and to detect any cross contamination.

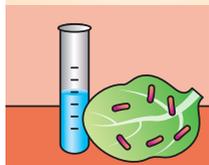
Record keeping

Why is it important to store records?

⚠ Records show evidence that a specific mitigation/control/preventive action has been taken at a specific time. Therefore, it is important to collect them in a timely manner (e.g. every 10 seconds for continuous recording or once for every batch

for manual recording) and keep them over time. A person should be responsible to do so.

The following are examples of records that should be collected and kept because of their importance to ensure the safety of the dried products:

	Temperature profiles of new machines during commissioning and new products		Visual inspection sheet showing effectiveness of cleaning
	Temperature profile of air and product, bed depth and residence time on every production batch		Validation and verification data
	Verification parameters measured after line reassembly		Environmental monitoring data
	Corrective actions report in case of process deviations and critical limits are not met (e.g. decision about product, cleaning to be done etc.)		



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