10-POINT GUIDE TO IMPROVING PRODUCTIVITY WITH HUMIDITY IN FOOD MANUFACTURING

Humidification, Dehumidification
and Evaporative Cooling

condair

MANAGE HUMIDITY, INCREASE PROFITABILITY

The water content of food is a deciding factor in its appearance, taste, shelf-life and ultimately its weight. Fruits and vegetables can be as much as 80-99% water, while foods such as meat, fish and pasta can be between 50-79% water.

For food manufacturers, managing the water content of their product is a vital strategy in maximising yield and maintaining quality. Evaporative losses and moisture gain can occur whenever the surface of the produce is exposed to the atmosphere.

The two main factors that influence the volume and speed of water movement from and into food produce are the relative humidity of the surrounding atmosphere and the duration of exposure.

This document presents an introductory 10-point guide for food manufacturers on understanding humidity and proactively managing it to enhance productivity, reduce waste and maintain product quality.

Water content %	Food item
90–99%	Strawberries, watermelon, lettuce, cabbage, celery, spinach, pickles
80–89%	Yogurt, apples, grapes, oranges, carrots, pears, pineapple, potato
70–79%	Bananas, avocados, cottage cheese, ricotta cheese, shrimp
60–69%	Legumes, salmon, ice cream, chicken breast
50–59%	Ground beef, hot dogs, feta cheese, tenderloin steak (cooked)
40–49%	Pizza
30–39%	Cheddar cheese, bagels, bread
20–29%	Pepperoni sausage, cake, biscuits
10–19%	Butter, margarine, raisins, dried pasta, wheat flour
1–9%	Walnuts, peanuts (dry roasted), chocolate chip cookies, crackers, cereals, milk powder

Source: The USDA National Nutrient Database for Standard Reference

CONTENTS

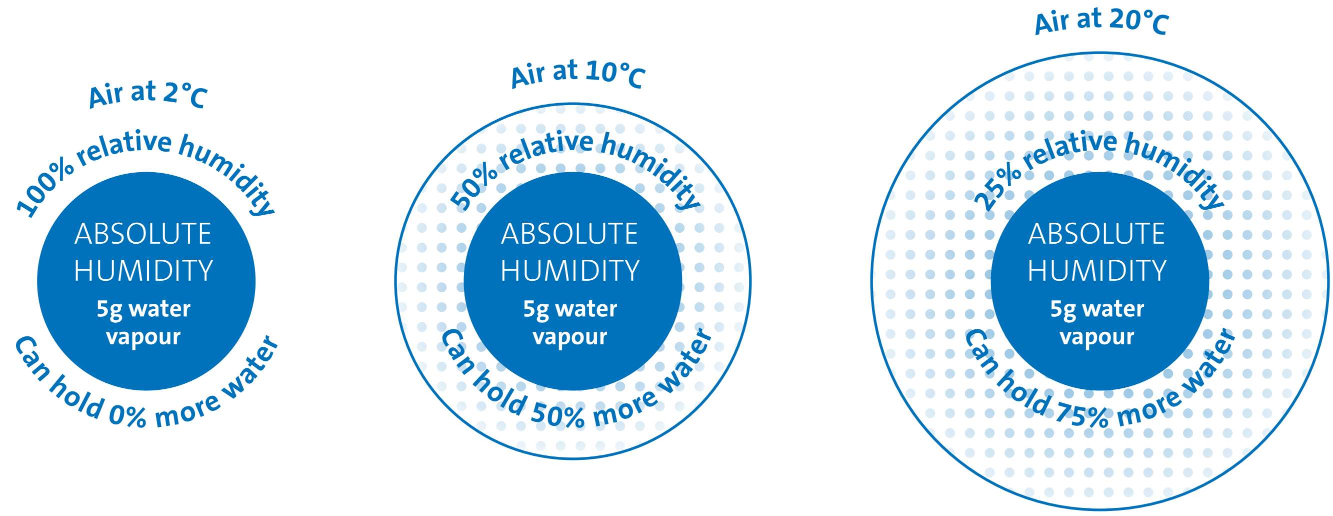
1 WHAT IS RELATIVE HUMIDITY?

Absolute humidity

The amount of water air contains, e.g. 5g

Relative humidity

The amount of water air contains, expressed as a percentage of the maximum amount it could contain at the same temperature, e.g. 50%RH



The amount of water air can hold depends on its temperature. A volume of cold air can physically hold less water than the same volume of hot air. So heating air increases the amount of water it can hold and, vice versa, cooling air reduces its ability to hold water.

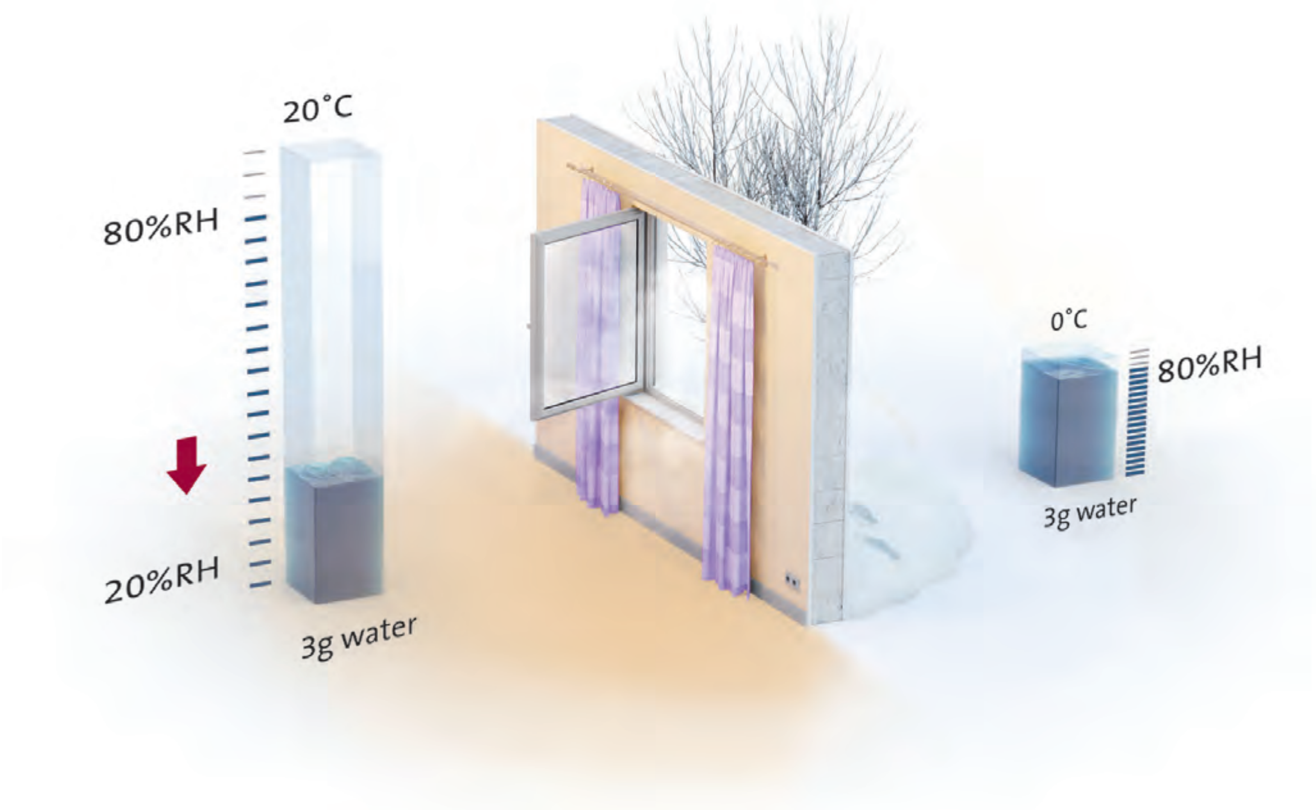
Heating air does not remove water from it. As the air temperature rises, its capacity for absorbing water increases and, unless more moisture is added, its relative humidity drops.

However, as this process happens, if the air comes into contact with anything that has a greater moisture content than itself, the air will absorb moisture from the product in question until an equilibrium is reached.

Understanding temperature's impact on air humidity and this movement of moisture is very important when considering the effects of humidity on a food production area. It also highlights the need to investigate and understand the temperature and humidity profile across the area.

“cold air can physically hold less water”

2 WHY IS INDOOR AIR DRIER IN THE WINTER?



As the outside air is cold in the winter, the amount of moisture it can physically hold is low (see point 1). Even though the amount of water vapour in the air is low, its cold temperature means the outdoor air will be at near saturation point with a high relative humidity.

Cold winter outdoor air has very little capacity to absorb any further moisture. This is evident when you hang wet washing outside on a cold day and it takes a very long time to dry.

However, when cold winter air enters a building and is heated, its relative humidity drops because its capacity to hold moisture increases.

For instance, when a metre cube of cold outside air at 0°C and 80%RH enters a building and is heated to 20°C, its relative humidity could drop to around 20%RH. It could potentially hold 80% more moisture.

At this dry condition, the air will draw moisture from any available source it comes into contact with. In a food production environment, this includes any moist food product being processed that is exposed to the atmosphere.

Ventilating a heated production area during the winter, by leaving doors and windows open, will not raise the indoor relative humidity and solve this dry air problem. The more cold outdoor air that enters and is heated, the more moisture will be absorbed by the airflow and drawn from the food produce.

> “relative humidity drops because its capacity to hold moisture increases”

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3 WHAT ARE THE BENEFITS OF MANAGING HUMIDITY?

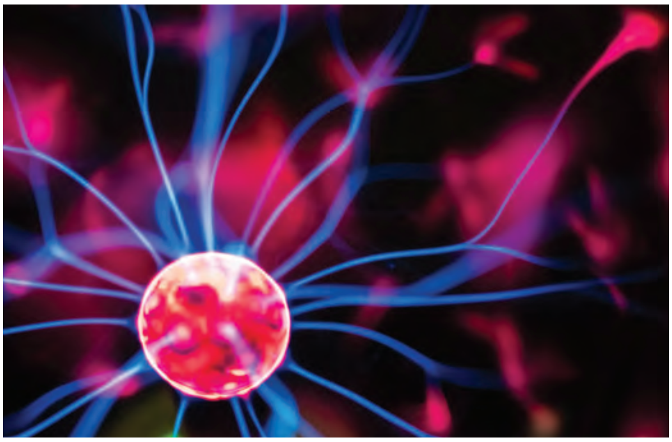
Humidity control has many benefits in food production but ultimately the objective is to improve productivity and maintain optimum product quality. Some benefits are quite specific to a production process, like using steam to stop produce sticking to its conveyor, but others are more widely employed.

Here is a selection of the most common reasons for humidity control in food production facilities, across both humidification and dehumidification.

Prevent surface drying
Moisture loss from the surface of food products can cause a skin or a crust to form. This can dull the appearance of a product. Also, if a product experiences any subsequent dimensional changes, this outer layer can split resulting in a cracked appearance. Humidification prevents this in applications such as cheese ripening, dough proofing, bread baking and biscuit production.

Prevent evaporative losses
Moisture evaporation from produce has many detrimental effects. Primarily any manufacturer selling their product by weight suffers an immediate reduction in yield if evaporative losses occur. A 1% reduction in moisture content results in a 1% drop in profits, as the manufacturer has 1% less product to sell. Alongside a reduction in yield, product quality, appearance and shelf-life can all be impaired through moisture loss. Correct humidity control prevents this in sectors such as abattoirs, fruit and vegetables, cooked fish and cheese.

Suppress airborne pollutants
Food production environments can have significant amounts of airborne contamination, such as flour or sugar. The effects of this airborne pollution can be health-related for staff, contamination on the production line or even result in a potential combustion risk. Maintaining a mid to high level humidity will cause airborne pollutants to adhere together and precipitate out of the atmosphere more readily, keeping the air cleaner.



Prevent static
Air with a humidity of 55%RH or more will act as a natural conductor for electrical charge. This is a very effective way of preventing static in food manufacturing environments. Static can cause issues for susceptible products such as wafers, or associated elements such as packaging, including plastic film, paper, card and tissue.

Provide air cooling
Cold water humidifiers will provide 680W of evaporative cooling to the air for every 1kg of evaporated water. As a humidification system can provide hundreds of kilos of moisture per hour at very low operating and energy cost, they provide an extremely economic method to cool a large production area.

Condensation control
Maintaining the correct air humidity in food production areas, which have inherently wet processes taking place, will reduce condensation forming on ceilings, walls and objects in the room. This is important not only for HACCP regulations but also for providing a safe and healthy working environment for staff.

Improved coating and drying
Production processes that involve product drying, cooling or coating can all be affected by the humidity of the air. Maintaining the optimum environment will improve the speed of these processes and reduce waste, no matter what the season.

“improve productivity and maintain optimum product quality”

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4 WHAT IS THE IDEAL HUMIDITY LEVEL?

The ideal air humidity for any food production area will depend on the objectives of the manufacturing application and the moisture content of the product.

For instance, if the objective is to prevent evaporative losses from a product and maintain its weight, the air's humidity level is determined based upon the product's ideal internal moisture content.

An equilibrium needs to be maintained between the product and the atmosphere, at a level that prevents moisture being transferred from product to air or vice versa. A graph called a sorption isotherm shows for any product, what the air humidity should be to maintain a specific internal moisture content (see fig 1).

This internal moisture content is often referred to as the equilibrium moisture content (EMC).

Beside from preventing evaporative losses, many food production processing require a specific humidity level to facilitate a reaction or effect in the produce. For instance in bread production, humidity control during dough proofing will prevent a skin from forming on the dough. While at a later stage in the production, humidity control during oven baking slows moisture evaporation to maintain an optimum baking time, as well as determining the properties of the crust.

Table 1 gives some examples of typical humidity levels in a variety of food production applications.

"equilibrium needs to be maintained"

Application	Typical humidity level	Humidity control objective
Soft roll baking: - Dough proofing - Oven	 80%RH 90%RH	Prevent skin forming on dough. Optimise baking time and produce ideal crust.
Crop storage: - Apples - Carrots - Potatoes - Onions - Pumpkins	 90-95%RH 90-95%RH 90-95%RH 65-75%RH 65-70%RH	Prevent evaporative losses to maintain product weight, maximise storage life and maintain product quality.
Carcass chilling	94%RH	Inhibit evaporative losses during initial cooling of carcasses and maintain product weight.
Cheese ripening: - Camembert - Cheddar - Gouda - Stilton	 94%RH 75%RH 75-80%RH 95%RH	Prevent evaporative losses to maintain product weight, and manage the correct formation of moulds for flavour and character.
Banana ripening	90-95%RH	Maintain product weight & quality.
Chocolate: - Coating - Cooling	 40-45%RH 70-85%RH	Avoid sugar bloom (surface crystallisation of sugars).

Table 1 - typical humidity levels for processing of different food products

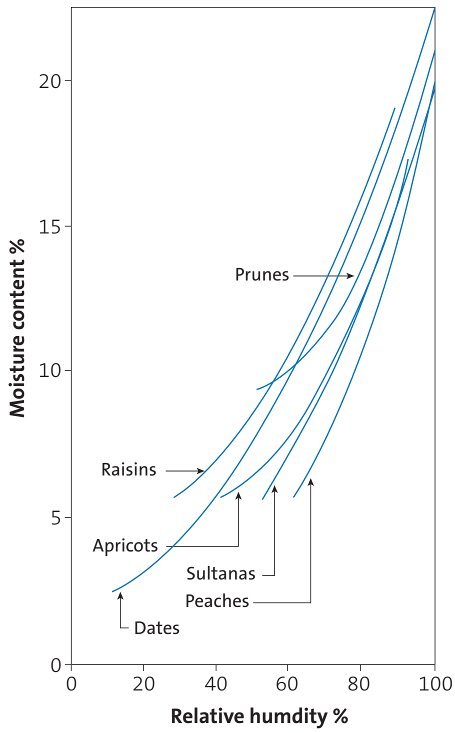
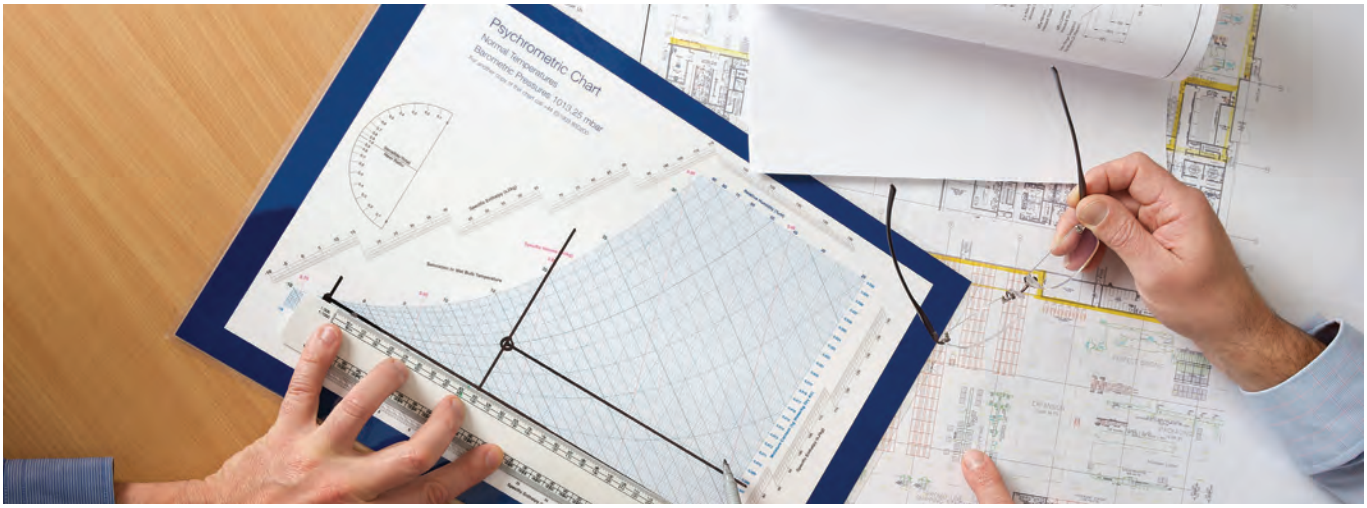


Fig. 1 - Moisture sorption data (median values between wetting and drying) in atmospheres of various relative humidities

5 DO I NEED TO HUMIDIFY OR DEHUMIDIFY AND BY HOW MUCH?



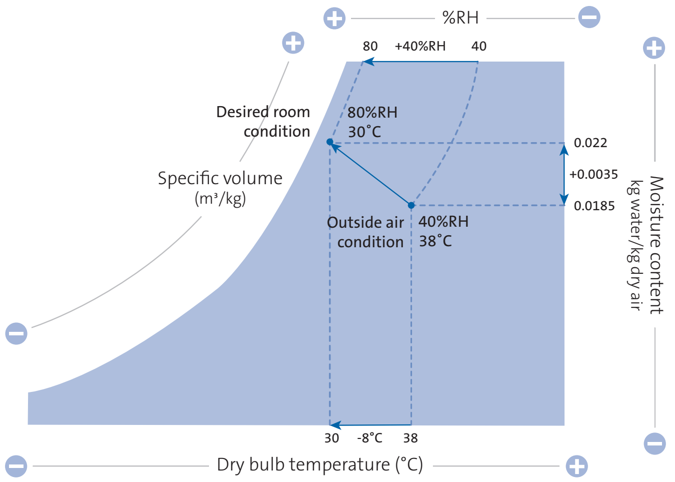
Once an ideal air humidity level has been determined for a specific process or area, it is necessary to calculate whether you need to add moisture (humidify) or remove moisture (dehumidify) to maintain this level.

This may seem obvious for an open area like a warehouse, but for more enclosed or extreme conditions, it may not be so clear. For instance, 15%RH may seem like a low humidity but to maintain this level inside an oven would normally require the addition of moisture due to the high temperature.

A psychrometric calculation must be performed that determines the difference in air moisture content from a starting temperature and relative humidity condition to the desired condition.

This calculation will take into account the volume of air involved, the start and end air conditions and all external factors that influence the air. These external factors could include the number of air exchanges an area experiences, the outside air's temperature and humidity, and any existing available sources of moisture in the area.

This calculation should be carried out by a humidity control professional. It will result in a volume of moisture per hour that needs to be added or removed from the atmosphere. This then determines the size of the humidifier or dehumidifier that must be employed to achieve the perfect environment.



Example psychrometric calculation

> a psychrometric calculation must be performed

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6

DOES PRODUCT TEMPERATURE AFFECT AIR HUMIDITY?

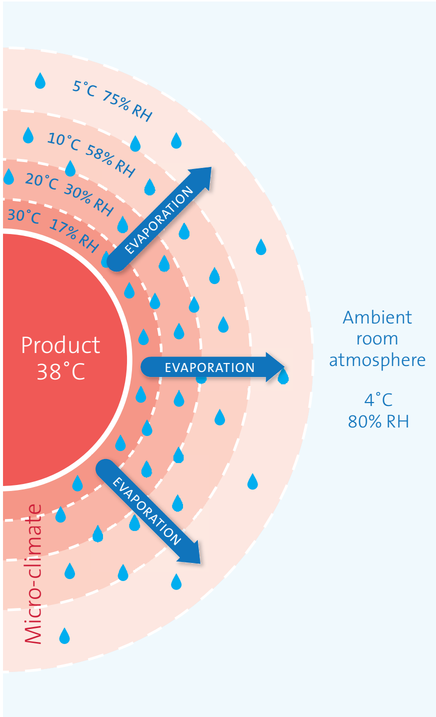
If an object's temperature is different from the ambient room temperature, then the air coming into contact with the object will be affected. It will either be warmed or cooled, with subsequent effects on the air's relative humidity and potentially the object.

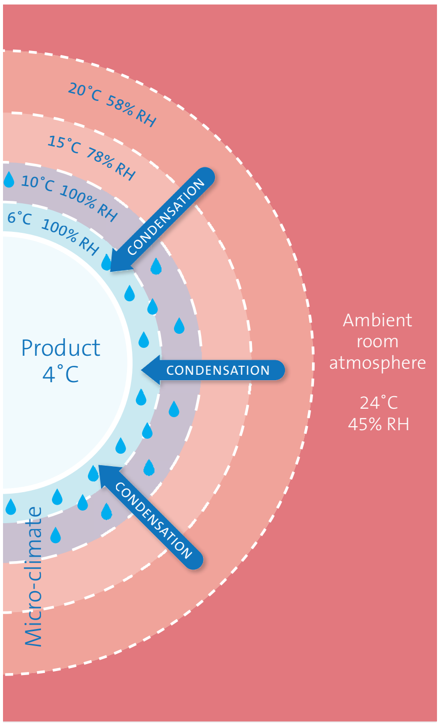
For instance, a cold item will lower the temperature of the air that comes into direct contact with it. As cool thermal energy passes from the object to the air, a cold micro-climate results. The conditions in this micro-climate will be different from the ambient conditions of the room. Along with a lower temperature, a higher relative humidity will occur.

We see this effect on a cold glass on a summer's day. As the air next to the glass cools, its relative humidity rises to saturation point. The water the air contains can no longer be accommodated by the cold air. As the relative humidity rises to dew point, the air's moisture condenses on to the glass' surface, making the glass wet.

Likewise an item that is warmer than its environment will create a warm micro-climate with a lower relative humidity than the ambient atmosphere. This can cause a product to dry, as moisture is drawn from its surface.

So even when a production area's humidity level is at a supposedly optimum condition, a temperature difference between produce and air can cause production issues with either evaporative losses or moisture gain. The greater any temperature difference is, the greater this negative effect.





> “Evaporative loss and condensation issues due to temperature difference can typically be solved by adjusting the room’s humidity”

This micro-climate effect is prevalent in food production environments, where refrigeration or cooking can cause significant differences between produce and air. Warm crops brought in from a summer’s field to be refrigerated, freshly slaughtered carcasses being chilled or any cooked product prior to packaging all have a significantly different temperature to the ambient atmosphere to which they are exposed.

Evaporative loss and condensation issues due to temperature difference can typically be solved by adjusting the room’s humidity level, finding a way to acclimatise the food product to the production area or managing the production area’s temperature differently.

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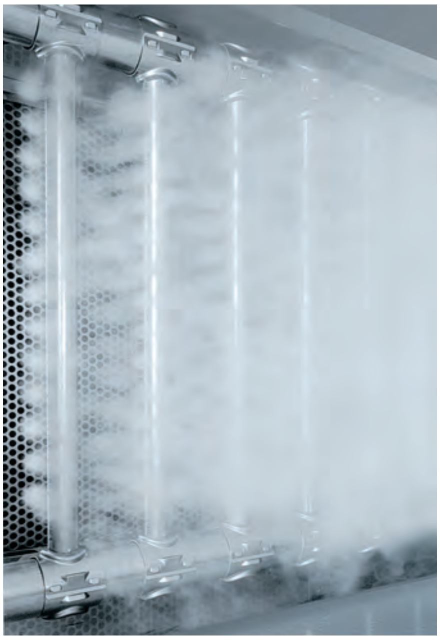
7 WHAT HUMIDIFIER OPTIONS ARE THERE?



Humidification systems can introduce moisture directly to a room or into a central air handling unit (AHU). To introduce water to the air it can be boiled and released as steam, evaporated from a wet surface, or turned into an aerosol.

Steam humidifiers generate their own steam by using electricity or gas to boil water. Alternatively, they can use a building's existing supply of steam to provide sterile humidification. Steam can be supplied directly from the humidifier to the room via a fan unit, or into a central AHU with steam pipes.

Steam humidifiers are frequently used for small or medium sized facilities, if particularly close humidity control is required or for specific applications, such as ovens, where a steam pipe provides a more practical solution.

Evaporative humidifiers are typically used in AHUs and offer high output and low energy operation. Air passing through the AHU travels through a moist evaporative cassette, absorbing water is it does so.

Spray humidifiers are often used in larger commercial or refrigerated areas. Spray systems can either pressurise the water with a pump to create an aerosol, which is released from a series of nozzles, or combine it with a compressed air supply to atomise the water.

Ultrasonic humidifiers use a rapidly oscillating diaphragm submerged in water to create a mist. This is dispersed into the air with a fan. These types of humidifiers are frequently used in refrigerated displays or cold areas, as the mist has a very small droplet size that is readily absorbed by the cold air.

> "introduce moisture directly to a room or into a central air handling unit"

8 WHAT DEHUMIDIFIER OPTIONS ARE THERE?

To remove moisture from an atmosphere it can either be condensed out on a cold surface or absorbed by a desiccating substance. Commercial dehumidifiers use one of these two strategies to lower an atmosphere's humidity level.

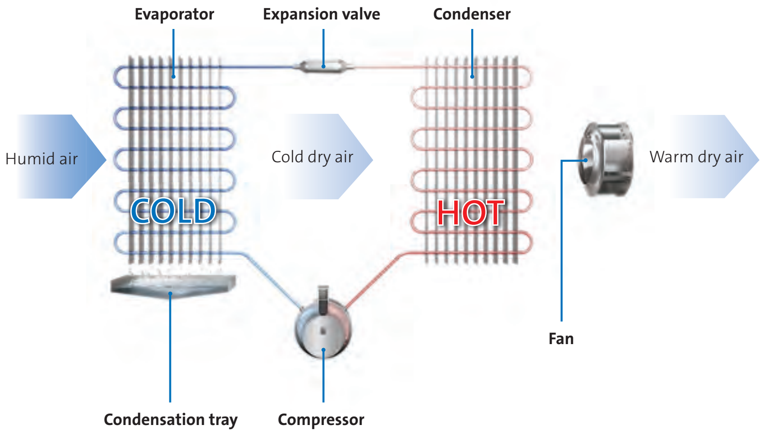
In deciding which technology is most appropriate for a food manufacturing application, it is important to consider the required humidity level and the room temperature. Condensing dehumidifiers are ideal for areas that require a humidity of 50%RH or more and ambient temperatures of above 15°C. Below these levels desiccant systems are often more effective.

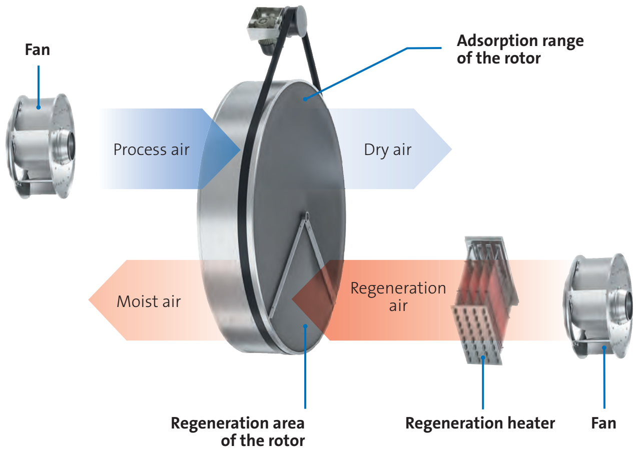
Both systems can be employed as direct room dryers or connected to a building's central air handling system.

Condensing dehumidifier process

A condensing dehumidifier uses the same type of refrigerant circuit found in split air conditioners or refrigerators. Through the expansion of refrigerant gas, a cold coil is created over which room air is passed. Moisture condenses on the cold surface and drips into a tray, where it is either collected in a water tank or sent directly to drain.

The cold air is then heated by the compression of the refrigerant gas and reintroduced to the room at a low humidity.





Desiccant dehumidifier process

Desiccant dehumidifiers draw in moist ambient air and pass it through an absorbent desiccant wheel. Water is absorbed by the desiccant material and the dry air is passed back into the room. In order to remove the moisture from the wheel, hot air is continually passed through a small portion of it. This hot air absorbs the moisture, dries the wheel as it slowly rotates, and is then exhausted either outside or to an appropriate area.

As this hot regenerating airflow heats the wheel, some of this heat is passed back into the room as the hot section of the wheel rotates back into the process airflow.

Desiccant dehumidifiers require the waste air to be vented somewhere. Condensing dehumidifiers simply require a drain, as the moisture is removed in a liquid state rather than in a gaseous form. Both types can add heat to a room but can be fitted with cooling or heating modules to manage the supply air temperature as well as humidity, if required.

> "commercial dehumidifiers use one of these two strategies"

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9 WHAT HYGIENE MEASURES ARE REQUIRED?

The hygienic operation of any food production environment is paramount. Any humidity control system employed must be capable of maintaining exceptionally high hygiene standards.

Beside concerns around the physical construction of the unit, and ensuring the materials are food grade, the main hygiene consideration is associated with the potential for bacterial build-up in any water system.

As most commercial dehumidifiers send their waste water directly to drain or vent it outside, the potential for microbial growth, and subsequent release into the atmosphere, is minimal. As humidifiers are introducing potentially inhalable droplets into an atmosphere, the risk associated with these systems should be considered.

Steam humidifiers boil water and produce sterile steam for humidification, so they present minimal hygiene risk. Evaporative humidifiers are typically located in an air handling unit (AHU) and do not produce respirable aerosols, so also present little risk to health. Although, it is worthwhile considering whether airborne pollutants, returning from the manufacturing area to the AHU, could be a potential source of nutrients on the surface of the evaporative media and cause unhygienic operation.

Spray and ultrasonic humidifiers should always be run on a potable water supply and include water filters to prevent contaminants from entering the system. Alongside a fresh filtered water supply, the humidifier must incorporate automated flush and drain cycles to ensure water entering the humidifier cannot remain static in pipework during periods of non-operation.

Additionally water treatment systems can be employed to treat the water, either with silver ion or ultraviolet sterilisation. This kills or inactivates any remaining microorganisms.

Any humidification or dehumidification system operated in a commercial premises must be regularly serviced in line with the manufacturer's recommendations. This should include disinfection of any wetted surface.

When installed, operated and maintained correctly, humidity control systems create a healthier environment for staff.

> "exceptionally high hygiene standards"

10 WHAT'S THE PAYBACK OF A HUMIDITY CONTROL SYSTEM?

Many food manufacturers experience financial losses by not understanding and proactively managing their factory's humidity levels. Losses from production issues are simply accepted as an unavoidable part of the manufacturing process. Investing in humidity control systems can provide rapid return on investment but before setting out on a project, it's helpful to fully explore the benefits and costs.

Financial benefit will obviously come from the primary objective for the humidity control system. If this is to prevent evaporative losses the calculation can be relatively simple, based upon the expected improvement in yield.

It is important to consider whether the improvement in yield is based upon the sales value of the final product or the value of the primary ingredient/s needed to make up the loss.

Alongside, the enhanced yield, is there any improvement in the energy or labour costs required as a result of this improved productivity? For instance, machine downtime to correct a problem or having to waste a percentage of a production run, can all take its toll on the overall efficiency of a manufacturing operation.

When reviewing the cost of a humidity control system, it is important to consider not just the initial purchase price but also the energy consumption, installation cost, commissioning (if required), routine servicing and whether any consumable components are regularly needed.

"rapid return on investment"

Condair offers free expert ROI projections for humidity control systems

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As well as benefiting from the most advanced humidity control technology available, clients are supported by local specialist engineering teams, which can offer installation, commissioning, maintenance and spares support.

The company has been serving the global food industry for many years and helps manufacturers achieve rapid return on the investment in their humidity control systems through improved productivity.

Contact us today for a free expert assessment of your manufacturing environment and discover how improved humidity can enhance your profitability.

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