Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) on the safety of foods air-dried outdoors that are produced by traditional methods and which require an adjustment of the hygiene requirements that must be fulfilled

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Abstract

The European Union recognises that traditional methods of food production are a valuable and irreplaceable heritage that must be preserved over time. Therefore, Regulation (EC) No. 852/2004 permits a degree of flexibility in its application provided food hygiene goals are not compromised.

For decades, both plant and animal-based foods have been produced in Spain which are air-dried outdoors until reaching a low water activity (a_w) that enables their preservation at room temperature. These foods include, raisins, dried apricots, dried figs, *ñora* peppers, dried fish or octopus that are at least partially air-dried, among others.

The Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) is of the opinion that the processing of naturally dried foods leads to their correct preservation, provided

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they reach an a_w that inhibits the proliferation of pathogenic microorganisms and the production of toxins in them. Some of the stages in the process may cause microbial inactivation. Above all, it is necessary to ensure the absence of the formation of toxins, with aflatoxins being the ones that have been most frequently identified. Thus, it is considered that the drying should be conducted in the least time possible, ensuring a decrease of a_w within the first 2-3 days of below 0.90 to inhibit the development of aflatoxins, and this drying should be continued until a_w levels lower than 0.70 are reached, preventing the growth of pathogenic microorganisms that cause spoilage.

It is necessary to guarantee suitable hygienic conditions during processing in order to prevent contamination by pathogens and/or toxins. Although they cannot proliferate in the stated preservation conditions, they can remain viable in the final product, therefore they may pose a risk to consumer health. Microorganisms with a low infective dose and those that have been identified in dried products (such as *S. aureus* and *Salmonella*) and microbial toxins are especially relevant. Autonomous Communities must monitor compliance with the requirements to ensure that they do not pose a risk in these products.

Although these types of products have a low a_w, within the range of 0.6 to 0.8 according to available literature, given that this information is not available for each assessed product, the level of safety reached cannot be established on an individual basis. Additionally, the diverse factors used in some of them (additives and preservatives, pasteurisation processes, etc.) require individual assessment once all the necessary information is available.

Therefore, the drying must reach a_w levels below 0.70 in the least time possible for these types of products to be considered stable, as given these conditions, there is no scientific evidence that shows that the safety and stability of the dried products are compromised, provided good hygiene practices are maintained during their preservation and storage. For final levels of a_w that are higher, correct preservation may be achieved through a combination of factors which proves that it is effective throughout the shelf life of the product, maintaining the aforementioned appropriate hygiene practices.

Key words

Dried, traditionals, water activity, a_w, preservation.

Suggested citation

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1. Introduction

1.1 Background

The European Union's regulations on food hygiene enable Member States to adjust, through national legislation, the requirements established in Annex II of Regulation (EC) No. 852/2004 (EU, 2004a) and in Annex III of Regulation (EC) No. 853/2004 (EU, 2004b) in specific circumstances, which include permitting the use of traditional methods in any of the stages of food production, processing or distribution.

The aim of this flexibility measure is to maintain and value the use of traditional methods of food preparation, as the European Union recognises them as a valuable and irreplaceable heritage that must be maintained over time. Over the years, traditional foods have undergone a series of adjustments to new market challenges such as changes in consumer trends and habits, demand for healthy products, continued rise of industrialised products, and the evolution of food safety criteria and conditions for fulfilling food safety legislation (Boncinelli et al., 2017).

Member States that seek to adopt national measures to adjust these requirements for the purposes of traditional food production must notify the European Commission and the other Member States. The notification must include a detailed description of the requirements to be adjusted and the nature of the adjustment sought; it must describe the food products and the concerned establishments, explain the reasons for the adjustment, and when applicable, also provide a summary of the hazard analysis conducted in order to ensure that the adjustment will not compromise the goals of the regulations.

For decades, both plant and animal-based foods have been produced in Spain which are air-dried outdoors until reaching a low water activity (a_w) that enables their holding at room temperature. Some noteworthy examples of these foods are raisins, dried apricots, dried figs, *ñora* peppers, dried fish or octopus that are occasionally air-dried, among others.

To prepare these traditional foods, it is necessary to adjust some requirements listed in the hygiene regulations in relation to the installations as occasionally there is no building equipped as such, in addition to the characteristics of the production surfaces as well as conditions.

The Spanish Agency for Food Safety and Nutrition (AESAN) has been requested to draft a report determining whether the production methods that are followed to prepare these foods guarantee food safety from a microbiological point of view, indicating, when necessary, the measures required to ensure that the traditional process of production does not compromise the goals of the regulations on hygiene.

To draft this report, the Scientific Committee has been provided with information by various autonomous regions which includes a description of the production process for each specific food.

1.2 Legislative framework

Legal provisions on the food safety of traditional preparations have been included in different regulations based on the need to preserve preparation processes linked to a specific territory as well as the original preparation formula.

Specifically, Regulation (EC) No. 852/2004 mentions that "flexibility is also appropriate to enable the

continued use of traditional methods at any of the stages of production, processing or distribution of food and in relation to structural requirements for establishments" (EU, 2004a). Flexibility is particularly important for regions that are subject to special geographical constraints, including the outermost regions referred to in Article 299 (2) of the Treaty. However, flexibility should not compromise food hygiene objectives. Moreover, since all food produced in accordance with the hygiene rules will be in free circulation throughout the Community, the procedure allowing Member States to exercise flexibility should be fully transparent. It should provide, where necessary to resolve disagreements, for discussion within the Standing Committee on Food Chain and Animal Health established by Regulation (EC) No. 178/2002 (EU, 2002).

Member States may adopt national measures adapting the requirements laid down in Annex II, in accordance with paragraphs 4 to 7, without compromising achievement of the objectives of this Regulation.

a. The national measures referred to in paragraph 3 shall have the aim of:
   i) enabling the continued use of traditional methods, at any of the stages of production, processing or distribution of food; or ii) accommodating the needs of food businesses situated in regions that are subject to special geographical constraints.

b. In other cases, they shall apply only to the construction, layout and equipment of establishments.

2. Foods air-dried outdoors and produced using traditional methods

One of the traditional methods of food production is to air-dry certain animal and plant-based foods in the open air. Originally, this was done to preserve these products for long periods of time. Currently, these traditional methods also provide an added culinary value.

The following sections describe the production processes for a series of foods that are produced in Spain using this method, based on the information provided by the autonomous regions. They may be divided into sea products and plant-based products.

2.1 Types of products considered

2.1.1 Sea products

- Dried and salted fish:
  - Dried conger eel prepared in traditional open-air drying establishments.
  - Tuna jerky and flathead mullet roe with a preparatory stage where they are air-dried outdoors.
  - *Bonito*, tuna, frigate tuna and mackerel. The entire fish is used and prepared by air-drying outdoors.
  - Cod and blue whiting. After salting, they are usually air-dried outdoors.
  - Dried fish from Elasmobranchii species. The subspecies *Raja* spp., small-spotted catshark (*Scyliorhinus canicula*) and the common smooth-houndshark (*Mustelus mustelus*) are used. They are dried outdoors in the sun.

- Dried octopus:
  - Octopi of a considerable size are left in a bath of water and salt and subsequently hung outdoors and exposed to the sun.

2.1.2 Plant-based products

- Fruits dried outdoors by exposure to the sun and air:
  - Raisins or plums dried by exposure to the sun and/or air.
  - Figs dried by exposure to the sun.
  - Dried whole apricots or slices of apricot, peach, apple and pear, dried by exposure to the sun and/or air-dried outdoors.
- Vegetables dried by exposure to the sun and/or air:
  - *Ñora* peppers that are naturally dried by exposure to the sun.
  - Fresh vegetables and tomato slices exposed to the sun.

2.2 Characteristics of air-drying outdoors or by exposure to the sun

Air-drying outdoors or by exposure to the sun uses the sun's radiation to produce a temperature rise in the material in question. To do so, the foods are spread over large areas outdoors either on the ground or on trays and left to dry until reaching dehydration levels so they remain stable during storage. The food is regularly turned in order to expose its different sides and to increase the efficiency of the drying (Ekechukwu and Norton, 1999) (Saravacos and Kostaropoulos, 2002) (Belessiotis and Delyannis, 2011). This method is widely used in the case of some fruits such as grapes, figs, dates and other fruits (Hussein et al., 1986) (Ekechukwu and Norton, 1999) (Doymaz, 2005) (Belessiotis and Delyannis, 2011).

The main inconveniences of drying in the sun are the long drying periods (up to 30 days), dependent on the climate and exposure to conditions of rainfall, dust, insects and other animals (Belessiotis and Delyannis, 2011). For this reason, when sun-drying by direct exposure, the food is dried in a specific container with a transparent cover to protect it from rain, wind, dust, insects and animals. The transparent cover enables the partial passage of the sun's radiation. The moisture evaporates and is whisked away by natural air convection (Sharma et al., 2009).

In these processes, the product's temperature depends on the intensity of the sun's radiation, ranging between 40 and 80 ºC (Ekechukwu and Norton, 1999) (Belessiotis and Delyannis, 2011).

Conversely, in indirect sun-drying, the material is not directly exposed to the sun's radiation. It uses adjacent units with solar panels to heat the drying air, thus producing a convection-based drying process (Sharma et al., 2009). This technique also depends on direct sunlight but drying times are reduced to anything between 15 to 30 hours (Belessiotis and Delyannis, 2011). Some systems include electrical energy or heaters to take the air to the desired temperature when solar energy is insufficient. The typical temperature of the drying air may be between 20 and 30 ºC above room temperature (Fudholi et al., 2010).

2.3 Factors to be considered for the open-air drying of traditional foods

The preservation technique for these types of products is based on reducing water content, reaching a low a_w. Drying by traditional methods should enable reaching an a_w that inhibits the development of pathogenic microorganisms and the production of toxins, as well as the proliferation of altering microorganisms. It is also necessary to ensure correct hygienic handling, as there are pathogens that may remain viable in these products for long periods of time, even if they are unable to multiply.

In relation to the effect of drying on the holding of these foods, it is widely accepted that products with an a_w lower than 0.83 or a pH lower than 3.9 prevents the growth or production of toxins from food-based pathogenic microorganisms (NACMCF, 2010) (EFSA, 2012). One of the most representative pathogenic bacteria in these types of products is *Staphylococcus aureus*, which can proliferate in foods with low water content (a_w levels higher than 0.85). It is considered that a_w levels below 0.60 do not permit any type of microbial proliferation. Within the interval between 0.605 and 0.690, microbial growth has only been observed in a few species, basically certain xerophilic fungi (*Aspergillus penicillioides*, *Eurotium amstelodami* (*Aspergillus amstelodami*) and *Xeromyces bisporus*), the yeast *Zygosaccharomyces rouxii* and some halophilic archaea (Tokuoka and Ishitani, 1991) (Stevenson et al., 2015) (Yakimov et al., 2015). Dried foods that have at least been air-dried outdoors for a while or have been exposed to the sun and which have reached a low a_w that makes them stable are the ones considered in this report.

2.4 Biological hazards identified with traditional air-dried foods

Some of the major biological hazards identified in these types of products are (apart from *S. aureus,* already mentioned), *Salmonella* spp., sporulated bacteria (*Bacillus cereus*, *Clostridium botulinum*) and mycotoxin producing fungi. These agents have been identified in several of these products and have been linked to different health alerts (Chen et al., 2009) (Sospedra et al., 2010) (Syamaladevi et al., 2016). The drying method was not specified in these alerts. 115 health alerts due to the presence of *Salmonella* in nuts and seeds have been detected (2005-2021). The results founded in the RASFF (Rapid Alert System for Food and Feed) portal show that the most frequently-notified pathogen of bacterial origin is *Salmonella*, followed by *Bacillus cereus*. These pathogenic microorganisms are borne by these types of foods, but they cannot proliferate in them. It has been shown that they are capable of remaining viable in them for long periods of time. The foods that are responsible for the most alerts are dried mushrooms. Nevertheless, it may be stated that the number of health alerts for foodborne pathogens are few in number, with alerts related to the presence of mycotoxins (aflatoxins and ochratoxin A) being the most frequent ones.

The toxins naturally found in foods with low water content are usually mycotoxins. It is known that they are produced by *Aspergillus*, *Fusarium*, *Alternaria* and *Penicillium*. They are classified in the fungus kingdom (Taniwaki et al., 2018), the aflatoxin B1 (AFB1) produced primarily by *Aspergillus flavus* being the most well-known and dangerous mycotoxin. Regulation (EC) No. 1881/2006 lists the maximum limits of AFB1 and total aflatoxins in tree nuts and dried fruits; of AFB1, total aflatoxins and ochratoxin A in dehydrated fruits belonging to the *Capsicum* genus; and of ochratoxin A in raisins (EU, 2006). Mycotoxin contamination of crops begins at the ripening stage in fields and

continues during the stages of harvesting, drying and storage. In order to prevent the formation of these substances, the drying process must be conducted in closed, hygienic environments with controlled humidity. Different research studies have demonstrated that an appropriate and effective drying strategy could improve food quality and prevent the proliferation of fungi and their toxins (Xing et al., 2017).

3. Requirements for the preparation of traditional dried foods

A series of points must be considered when preparing foods from this group. Although it has been demonstrated that low-moisture foods are considered stable from a microbiological point of view, they may pose risks to consumers, among other factors, due to the following aspects:

- Many microbial species, including pathogens, are able to survive in conditions of dryness for long periods of time. It has even been demonstrated that their continued presence in these types of foods may be higher than in those with higher moisture content (Beuchat et al., 2013). This is especially relevant in those microorganisms that produce toxins, or which have minimal infective doses.
- The treatments that are traditionally effective for microbial inhibition in foods with a high-water content (pasteurisation, high pressures, etc.) are not as effective when applied to low moisture foods.
- The cleaning and disinfecting procedures may be more complex, as when preparing these foods, it is necessary to maintain a low level of humidity.
- Given their long shelf lives, the storage of low moisture foods for long periods of time at room temperature by consumers may lead to the proliferation of certain sporulated bacteria, some of which produce toxins and mycotoxigenic mould and therefore may pose a health hazard.

3.1 Hygiene and safety procedures during the preparation of dried foods

The FAO (Food and Agriculture Organisation of the United Nations) has established a series of recommendations and basic hygiene and safety principles for the preparation of traditional dried foods, which include:

- Preventing cross-contamination during the preparation of these foods and the implementation of Good Hygiene Practices (GHP) and HACCP principles (Hazard Analysis and Critical Control Points).
- Storing the ingredients used to prepare traditional dried foods that are not subjected to thermal treatment, such as salt, sugar, spices or herbs, in separate compartments.
- If it is necessary to rehydrate these foods, it should be done in short periods of time, to avoid the possible growth of pathogens or alternants.
- Sampling procedures should be conducted on food and/or product contact surfaces and zones.
- The raw material used should be of good quality at its stage of physiological maturity to undergo a drying process by the sun. Furthermore, it must be correctly sanitised before drying. It is also necessary to eliminate external parts that display signs of defects or damage.

- Plant-based foods with high levels of humidity may develop browning if the drying is too intensive. It is recommended that the drying process be gradual (decrease in humidity).
- Raw materials or crops at different states of ripeness should not be mixed together as the end product would lose quality. The appearance and texture of the plant product must be suitable for drying in the sun (not irregular).
- Whenever possible, the harvesting period must be in times without rainfall so that the product does not become humid and facilitate microbial proliferation.

Likewise, the *Codex Alimentarius* has published similar recommendations for this type of products (CXC-75-2015) (Codex Alimentarius, 2015).

Preservatives such as SO_2 may be used in these foods and certain bleaching actions taken, to boost preservation and maintain their quality. They must follow the current regulations on the use of these compounds in each food category.

Generally, it is considered that the raw materials must fulfil the microbiological requirements on the absence of toxins as established in the regulations. It is also necessary to follow the recommendations on the hygiene conditions of the drying surfaces CAC/RCP 3-1969 (Codex Alimentarius, 2011).

4. Evaluation of the proposed traditional dried foods

The Scientific Committee has classified the foods to be evaluated into two categories: sea products and plant-based products.

Climate data from some autonomous regions (the Canary Islands and the Region of Valencia) has been received, demonstrating considerable interest on its relationship with a correct drying. It would be necessary to study this aspect further in order to correlate weather data with the food safety of batches of traditional products. This has been conducted under more controlled processing conditions, therefore, systematic access to this information may help to conduct studies that correlate aspects such as wind velocity, temperature, daylight hours and other weather variables with the safety and stability of these products.

4.1 Sea products

We may differentiate between air-dried products and those dried by means of exposure to salt or brine, which in turn may have a stage of air-drying. Their processing involves stages that may vary according to the product in question, such as freezing, gutting, salting and drying for periods between 2 and 30 days, depending on the steps involved and the weather conditions.

A recent study has demonstrated that dried fish has a characteristic microbiota related to the methods of preparation (Hauptmann et al., 2020).

The generic traditional process may be described as follows (Figure 1):

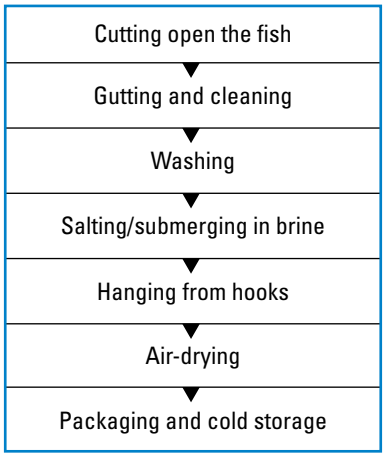

Figure 1. Drying process of sea products.

The stages to be considered to ensure their safety are (Codex Alimentarius, 2020):

- During the salting stage, the salt penetration will depend on the lipid content of the fish, the temperature, quantity and composition of the salt, the composition of the brine, etc. It is necessary to ensure a rapid penetration of the salt which contributes to reducing water activity during the initial hours of preservation.
- When fish that may accumulate histamine is salted, the exposure to temperatures that permit the formation of bacterial toxin must be limited at each stage of the process. These species belong to the genus *Scombridae*, *Clupeidae*, *Engraulidae*, *Coryphaenidae*, *Pomatomidae*, *Scomberesocidae*. If the species subjected to drying belongs to any of these, processing conditions that control or minimise histamine synthesis must be established.
- In order to minimise the presence and proliferation of bacteria and filamentous fungi in salted and dried fish, the salt must not be reused, in order to avoid the risk of recontamination.

The main biological hazards identified in this category of products are: *S. aureus* and *Clostridium botulinum*.

The viability of *S. aureus* in dried fish products (with a_w of 0.48 in dried fish and 0.76 in squid pieces) has been assessed (Moon et al., 2017). It was observed that *S. aureus* survives for longer at 10 ºC than at 24 or 35 ºC, without synthesising staphylococcal toxin at any of the studied temperatures. Nevertheless, *S. aureus* may remain viable for up to 150 days in storage, depending on the temperature.

Although drying in the sun is a traditional and cost-effective method, it may lead to contamination if the raw material is not protected during the process. Food standards in India state that dried fish must have a humidity percentage lower than 15 % to guarantee its stability (Indian Standards, 2001) (Nagwekar et al., 2017). These authors have established the a_w of a species of dried fish, *Harpadon*

nehereus (with values of 0.60), concluding that other drying techniques (for example, drying by hot air) gave better microbiological results than drying in the sun. All of these studies indicate the need for good hygiene measures during the traditional drying process, in order to prevent contamination by pathogenic and altering microorganisms that may result in the end product having a poor microbiological quality.

4.2 Plant-based products

These may be classified as fruits (raisins, figs, apricots, etc.) and as dried vegetables (peppers).

The generic traditional process may be described as follows (Figure 2):

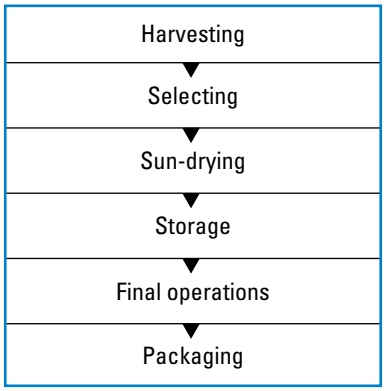

Figure 2. Drying process of plant-based products.

The stages to be considered to ensure their safety are:

Selection: drought and insect damage in the field may increase the products' level of fungal contamination. The harvested fruits and vegetables (peppers, figs, grapes, apricots, etc.) must be of good quality, and ones that display signs of damage must be excluded in order to reduce the risk of fungal contamination. In some cases, they are washed to eliminate dirt and other foreign substances. In any case, a correct visual selection will eliminate bits of mould, waste and other foreign materials that may contaminate the healthy parts of the fruits and vegetables.

Identified microbiological hazards: *Salmonella*, *Bacillus cereus* and the presence of mycotoxins.

Drying in the sun: in these products, the drying process leads to decreased humidity levels of 15-25 % (Table 1). The process may last anywhere between 1 to 2 days and 2 weeks. It must be performed within a time that prevents microbial and especially fungal proliferation. The most important factor for the growth of fungi and the formation of toxins is water activity (Magan and Aldred, 2005). The duration of the drying process in August in Spain may vary from 7 days for raisins to 15 days in the case of ñora peppers, which in September becomes 10 days for raisins and 25-30 days for ñora peppers. Daytime temperatures may be between 28 and 45 ºC and relative humidity between 50 % and 75 %.

Table 1. Example of drying parameters in traditional foods

Product	Initial humidity	Final humidity	Reference
Peppers	70-80 %	<15 %	(Aranda et al., 2017)
Figs	80-90 % 30-50 % of the soil	<24 % <0.65 a_w	(Codex Alimentarius, 2008) (Villalobos et al., 2016)
Raisins	75-80 %	18-31 % 0.6 a_w	(OIV, 2013) (Codex Alimentarius, 2019a)
Apricots	80-85 %	<25 % sulphides 0.80 a_w <20 % non-sulphides 0.70 a_w	(Codex Alimentarius, 2019b)

During conventional drying (in the sun), the fungi generally come from the air and the soil. Generally, fungal counts at the start of the drying process display values of 10^3-10^4 cfu/g. Taking into consideration the recommendations of the *Codex Alimentarius* Commission (Codex Alimentarius, 2011), the steps to prevent increased fungal burdens for different dehydrated vegetables include:

- Using drying surfaces that do not accumulate fungal burdens from previous drying processes.
- Keeping the drying surface separated from the ground.
- Keeping the drying zone free of insects and other pests.

Fungal growth during the drying period must be avoided in order to indirectly prevent the production of mycotoxins, for this, the humidity, temperature and time values must be considered. Regarding pH in these fruits and vegetables, it adopts values of 5-6, which are close to the optimal value for the growth of mycotoxigenic fungi, and whose variation will have a lower impact on fungal growth.

Initial water activity in the fruits and vegetables is close to 0.98 which means that growth will be optimal unless a rapid drying process is conducted, and this involves, based on *Aspergillus flavus*:

- Ensuring reduction to 0.90 a_w within the first 2 or 3 days (Marín et al., 2012).
- Subsequently ensuring a continued reduction to a safe a_w that prevents the proliferation of foodborne pathogens, lower than the values listed in Table 1.
- The application of compounds with antimicrobial activity such as SO_2 may contribute to the safety of the process.
- Prior treatments such as for example, with hydroxides (as in the case of raisins) contribute to efficiently speeding up loss of humidity.
- Regarding temperature, keeping it at levels higher than 37 ºC slows down or even stops the growth of *A. flavus* (its optimal growth temperature is around 30 ºC) (Marín et al., 2012). Nevertheless, temperature fluctuations between day and night make this unsustainable.

In relation to bacteriological hazards, it has been shown that the pasteurisation of different dried plant-based products (apricots, raisins, macadamia nuts and other nuts) has led to various reductions in the number of pathogenic microorganisms, including *Salmonella* (Acuff et al., 2020).

Storage: this is an important stage at which to prevent increases in humidity levels which may cause microbial contamination and proliferation. In the case of nuts, peppers and figs, these must be stored in refrigerated conditions (Galván et al., 2021).

Finally, certain common recommendations are established for all the food types assessed:

- It is necessary to reduce moisture content in the first days of drying, reaching an a_w under 0.83 (which is the limit for the growth of pathogens and the synthesis of toxins). The product must then be continually dried until it reaches an a_w under 0.70 in the least time possible, which permits the biological stability of the product.
- Storage sites must have good storage conditions that avoid physiochemical changes or recontamination of the product.
- It is necessary to perform correct pest control.
- The product should be kept in structures separated from the ground.
- As far as possible, avoid temperature fluctuations.

Conclusions of the Scientific Committee

The processing of naturally dried foods leads to their correct holding, provided they reach a water activity (a_w) that inhibits the proliferation of pathogenic microorganisms and the production of toxins in them. Some of the stages in the process may cause microbial inactivation. However, it is necessary to ensure the absence of toxin formation, with aflatoxins being the ones that have been most frequently identified. Thus, it is considered that the drying should be conducted in the least time possible, ensuring decreased a_w within the first 2-3 days of under 0.90 to inhibit the development of aflatoxins, and this drying should be continued until a_w levels lower than 0.70 are reached, preventing the growth of pathogens and microorganisms that cause spoilage.

It is necessary to guarantee suitable hygienic conditions during processing in order to prevent contamination by pathogens and/or toxins. Although they cannot proliferate in the stated holding conditions, they can remain viable in the final product, therefore they may pose a risk to consumer health. Microorganisms with a low infective dose and those that have been identified in dried products (such as *S. aureus* and *Salmonella*) and microbial toxins are especially relevant. Autonomous regions must monitor compliance with the requirements to ensure that they do not pose a risk in these products.

Although these types of products have low a_w, within the range of 0.6 to 0.8 according to available literature, given that this information is not available for each assessed product, the level of safety reached cannot be established on an individual basis. Additionally, the diverse factors used in some of them (additives and preservatives, pasteurisation processes, etc.) require individual assessment.

The drying must reach a_w levels under 0.70 in the least time possible to be considered stable, as in these conditions, there is no scientific evidence that shows that the safety and stability of the dried products are compromised, provided good hygiene practices are maintained during their holding

and storage. For final levels of water activity that are higher, correct holding may be achieved through a combination of factors which proves that it is effective throughout the shelf life of the product, maintaining the aforementioned appropriate hygiene practices.

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References

Acuff, J.C., Wu, J., Marik, C., Waterman, K., Gallagher, D., Huang, H., Williams, R.C. and Ponder, M.A. (2020). Thermal inactivation of *Salmonella*, Shiga toxin-producing *Escherichia coli*, *Listeria monocytogenes*, and a surrogate (*Pediococcus acidilactici*) on raisins, apricot halves, and macadamia nuts using vacuum-steam pasteurization. *International Journal of Food Microbiology*, 333, pp: 108814.

Aranda, E., Casquete, R., Hernández, A. and Martín, A. (2017). Influencia del proceso de secado del pimiento en las características del Pimentón de La Vera. In book: *La agricultura y la ganadería extremeñas 2016*. Fundación CB. Badajoz, pp: 153-166.

Belessiotis, V. and Delyannis, E. (2011). Solar drying. *Solar Energy*, 85, pp: 1665-1691.

Beuchat, L.R., Komitopoulou, E., Beckers, H., Betts, R.P., Bourdichon, F., Fanning, S., Joosten, H.M. and ter Kuile, B.H. (2013). Low-water activity foods: increased concern as vehicles of foodborne pathogens. *Journal of Food Protection*, 76 (1), pp: 150-172.

Boncinelli, F., Contini, C., Romano, C., Scozzafava, G. and Casini, L. (2017). Territory, environment, and healthiness in traditional food choices: insights into consumer heterogeneity. *International Food and Agribusiness Management Review*, 20, pp: 143-157.

Chen, Y., Freier, T., Keuhem, J., Moorman, M., Scott, J., Meyer, J., Morille-Hinds, T., Post, L., Smoot, L., Hood, S., Shebuski, J. and Banks, J. (2009). Controll of *Salmonella* in Low-Moisture Food. Grocery Manufacturers Association, Washington.

Codex Alimentarius (2008). Code of Practice for the Prevention and Reduction of Aflatoxin Contamination in Dried Figs. CAC-RCP 65-2008.

Codex Alimentarius (2011). Code of hygienic practice for dried fruits. CXC 3-1969.

Codex Alimentarius (2015). Code of hygienic practice for low-moisture foods. CXC 75-2015.

Codex Alimentarius (2019a). Standard for raisins. CXS 67-1981.

Codex Alimentarius (2019b). Standard for dried apricots. CXS 130-1981.

Codex Alimentarius (2020). Code of practice for fish and fishery products. Rome. Available at: https://doi.org/10.4060/cb0658en [accessed: 21-07-21].

Doymaz, I. (2005). Sun drying of figs: an experimental study. *Journal of Food Engineering,* 71 (4), pp: 403-407.

EFSA (2012). European Food Safety Authority. EFSA Panel on Biological Hazards. Scientific Opinion on Public health risks represented by certain composite products containing food of animal origin. *EFSA Journal*, 10 (5): 2662, pp: 132.

Ekechukwu, O.V. and Norton, B. (1999). Review of solar-energy drying systems II: an overview of solar drying technology. *Energy Conversion & Management*, 40 (6), pp: 615-655.

EU (2002). Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31 of 1 February 2002, pp: 1-42.

EU (2004a). Regulation (EC) No. 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139 of 30 April 2004, pp: 1-54.

EU (2004b). Regulation (EC) No. 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. OJ L 139 of 30 April 2004, pp: 55-205.

EU (2006). Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. OJ L 364 of 20 December 2006, pp: 5-24.

Fudholi, A., Sopian, K., Ruslan, M.H., Alghoul, M.A. and Sulaiman, M.Y. (2010). Review of solar dryers for agricultural and marine products. *Renewable and Sustainable Energy Reviews,* 14 (1), pp: 1-30.

Galván, A.I., Rodríguez, A., Martín, A., Serradilla, M.J., Martínez-Dorado, A. and Córdoba, M.G. (2021). Effect of Temperature during Drying and Storage of Dried Figs on Growth, Gene Expression and Aflatoxin Production. *Toxins*, 13 (2): 134, pp: 1-14.

Hauptmann, A.L., Paulova, P., Castro-Mejía, J.L., Hansen, L.H., Sicheritz-Pontén, T., Mulvad, G. and Nielsen, D.S. (2020). The microbial composition of dried fish prepared according to Greenlandic Inuit traditions and industrial counterparts. *Food Microbiology*, 85, pp: 103305.

Hussein, A.M., Sommer, N.F. and Fortlage, R.J. (1986). Suppression of *Aspergillus flavus* in raisins by solar heating during sun drying. *American Phytopathological Society*, 76 (3), pp: 335-338.

Indian Standard (2001). Fish-Dried and Dry-salted – Specification. IS 14950:2001, Bureau of Indian Standards, New Delhi.

Magan, N. and Aldred, D. (2005). Conditions of formation of ochratoxin A in drying, transport and in different commodities. *Food Additives and Contaminants*, 22, pp: 10-16.

Marín, S., Ramos, A.J. and Sanchis, V. (2012). Modelling *Aspergillus flavus* growth and aflatoxins production in pistachio nuts. *Food Microbiology*, 32 (2), pp: 378-388.

Moon, H.J., Min, K.J., Park, N.Y. and Park, H.J. (2017). Survival of *Staphylococcus aureus* in dried fish products as a function of temperature. *Food Science and Biotechnology*, 26, pp: 823-828.

NACMCF (2010). National Advisory Committee on Microbiological Criteria for Foods (NACMCF). Parameters for determining inoculated pack/challenge study protocols. *Journal of Food Protection*, 73, pp: 140-202.

Nagwekar, N., Tidke, V. and Thorat, B.N. (2017). Microbial and biochemical analysis of dried fish and comparative study using different drying methods. *Drying Technology*, 35, pp: 1481-1491.

OIV (2013). Organización Internacional de la Viña y el Vino (OIV). Recomendaciones de la OIV respecto de la producción de uvas pasas. OIV-VITI 493-2013.

Saravacos, G.D. and Kostaropoulos, A.E. (2002). Food dehydration equipment. In book: *Handbook of food processing equipment*. Saravacos, G.D. and Kostaropoulos, A.E. editors. 1st Ed. USA: Springer, pp: 331-382.

Sharma, A., Chen, C.R. and Vu Lan, N. (2009). Solar-energy drying systems: a review. *Renewable and Sustainable Energy Reviews*, 13 (6-7), pp: 1185-1210.

Sospedra, I., Soriano, J.M. and Mañes, J. (2010). Assessment of the microbiological safety of dried spices and herbs commercialized in Spain. *Plant Foods for Human Nutrition,* 65, pp: 364-368.

Stevenson, A., Burkhardt, J., Cockell, C.S., Cray, J.A., Dijksterhuis, J., Fox-Powell, M., Kee, T.P., Kminek, G., Mcgenity, T.J., Kenneth, N., Timmis, K.N., Timson, D.J., Voytek, M.A., Westall, F., Yakimov, M.M. and Hallsworth, J.E. (2015). Multiplication of microbes below 0.690 water activity: implications for terrestrial and extraterrestrial life. *Environmental Microbiol*ogy, 17 (2), pp: 257-277.

Syamaladevi, R.M., Tang, J., Villa-Rojas, R., Sablani, S., Carter, B. and Campbell, G. (2016). Influence of water activity on thermal resistance of microorganisms in low-moisture foods: a review. *Comprehensive Reviews in Food Science and Food Safety,* 15 (3), pp: 353-370.

Taniwaki, M.H., Pitt, J.I. and Magan, N. (2018). *Aspergillus* species and mycotoxins: occurrence and importance in major food commodities. *Current Opinion in Food Science*, 23, pp: 38-43.

Tokuoka, K. and Ishitani, T. (1991). Minimum water activities for the growth of yeasts isolated from high-sugar

foods. *Journal of General and Applied Microbiology,* 37, pp: 111-119.

Villalobos, M.C., Córdoba, M.G., Serradilla, M.J. and Martín, A. (2016). Sistemas de secado alternativos al secado al sol en higos. In book: *La agricultura y la ganadería extremeñas 2015*. Fundación CB. Badajoz, pp: 177-192.

Xing, F., Liu, X., Wang, L., Selvaraj, J.N., Jin, N., Wang, Y., Zhao, Y. and Liu, Y. (2017). Distribution and variation of fungi and major mycotoxins in pre- and post-nature drying maize in North China Plain. *Food Control*, 80, pp: 244-251.

Yakimov, M.M., Lo Cono, V., La Spada, G., Bortoluzzi, G., Messina, E., Smedile, F., Arcadi, E, Borghini, M., Ferrer, M., Schmitt-Kopplin, P., Hertkorn, N., Cray, J.A. and Hallsworth, J.E. (2015). Microbial community of the Deep-sea brine Lake Kryos is active below the chaotropicity limit of life as revealed by recovery of mRNA. *Environmental Microbiol*ogy, 17, pp: 364-382.