

## Good hygiene practices, HACCP and the use of natural substances for the quality of Charmout

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### Abstract

HACCP assesses hazards related to production/distribution, good manufacturing practices and critical points in the food distribution system. GMP controls hygiene parameters for personnel and facilities at the production plant. However, natural substances are used to assess quality on the one hand and the effectiveness of secondary metabolites on the other, in order to prevent microbial proliferation in the finished *charmout* product. In Chad, it is important to apply HACCP methods in the various production/manufacturing industries to control certain critical points. As a result, consumers are exposed to microbial contamination such as *E. coli*, *Salmonella*, etc. linked to meat products (*charmout*).

**Keywords:** HACCP; *Charmout*; Natural Substance; Chad

### 1. Introduction

HACCP assesses the hazards associated with production/distribution, good manufacturing practices and critical points in the system. Microbiological quality control (mandatory hygiene and commercial quality desired by both the manufacturer and the consumer) involves a series of steps ranging from the control of raw materials, during processing or in the finished food product, to good manufacturing practices, including the identification of the main critical points in the production/distribution system, most often through an HACCP approach [1]. It is a scientific approach for assessing the hazards associated with food production and establishing control systems to ensure food safety [2]. The system focuses on assessing the hazards associated with a particular food production process, identifying the stages of production where hazards occur, and designing control mechanisms [3]. The HACCP system aims to eliminate hazards whose elimination or reduction to acceptable levels is essential for the production of safe food [2,3,4]. It is a defensive system that addresses the entire food manufacturing process and considers food safety before the influence of biological, chemical and/or physical hazards [5]. An effective HACCP approach must be based on a solid foundation of prerequisite programmes, good manufacturing practices (GMP) and standard operating procedures (SOP) [6].

GMPs are procedures applied by food producers to maintain food safety, include hygiene parameters for staff, facilities, procedures and the environment throughout the manufacturing process [7]. Most HACCP plans in food processing activities, such as the production of cheese and dry meat products, are primarily considered to be bacterial agents [8,9]. Therefore, HACCP provisions in meat manufacturing are an urgent and compelling requirement. Some possible microbial threats (e.g., *E. coli* O157:H7, *Salmonella spp.*, *Staphylococcus aureus*, *Lister monocytogenes*, *Campylobacter spp.*) associated

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with meat products have been identified [10,11,12]. However, natural substances have been used since ancient times as medicines for treating human diseases [13]. Interest in these medicinal plants is booming thanks to the integration of modern techniques that make it possible to evaluate the quality, safety and efficacy of secondary metabolites and the potential role of medicines developed from these metabolites in healthcare. Indeed, plants, with their wide variety of phytochemical constituents, have significant potential in the treatment of several human and animal diseases [14,15,16,17]. These biologically active compounds can be isolated from the plant using traditional methods such as maceration, decoction, infusion, etc. [18]. This quality is ensured by compliance with the control procedures set out in the marketing authorisation (MA) dossier submitted for the marketing of the finished product. To this end, quality control and standardisation of raw materials, intermediate and finished products will ensure products of consistent and reproducible pharmaceutical quality [19].

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## 2. General overview of *charmout*

The literature shows that the consumption of *charmout* is an ancient practice in Chad [20]. This product of choice was intended for all Chadians. For Chadians, the purpose of cattle is to produce meat for consumption. Beef has given rise to various preparation and/or preservation techniques. These range from the production of *charmout* (dried strips of meat) to *varanga* (fried shredded meat) and *jaka* (meat preserved in fat) [21]. In *Sakalava* country (western Madagascar) and/or *Tsimihety* (north), *maskita*, which is more or less equivalent to *charmout*, and *kitoza* are obtained by sun-drying or smoking over an open fire [22].

### 2.1. Raw materials used and method of production of *Charmout*

*Charmout* is a product made from zebu meat that is widely consumed by the Chadian population. The ingredients are essentially meat and salt. Some producers soak the products in oil.

*Charmout* is obtained after trimming and slicing beef into strips 2 to 4 cm thick and approximately 20 to 50 cm long. The pieces are then salted. Depending on preference, ingredients may be added to enhance the flavour and make the product more tender. At the family level, *charmout* is prepared by drying, which involves hanging the pieces on a line in the open air. This process can take 2 to 3 days, but it can continue for several weeks depending on the climate. The strips of meat, whether stored after drying in kitchens or dried in the sun, are all called *charmout* in Arabic.

### 2.2. Quality of *charmout*

#### 2.2.1. Nutritional quality of *charmout*

The nutritional quality of meat refers to its nutritional composition, which includes its energy value and its macro- and micronutrient composition (lipids, carbohydrates, vitamins, trace elements, minerals) [23].

#### 2.2.2. Hygienic quality of *charmout*

The hygienic or sanitary quality of a foodstuff is the set of properties and characteristics that guarantee its safety and security. It must guarantee total safety and, as such, protect the health of the consumer. Therefore, it must not contain any toxic residues or parasites, nor be a breeding ground for bacteria that could produce harmful elements [24].

#### 2.2.3. Organoleptic quality of *charmout*

The organoleptic quality of meat encompasses the sensory properties (colour, tenderness, juiciness, flavour) that give rise to the sensation of pleasure associated with its consumption [25]. The colour of meat is a parameter that is assessed both visually and through specific measurements. It can be determined using a sensory method that allows the pigmentation or colour alteration to be judged visually, based on more or less standardised and official colour classification grids [26].

### 2.3. Some types of dried meat found in Africa

Meat is a highly perishable product, so preserving it is important. The most common method of preserving meat in the developed world is refrigeration. The cost of installing and maintaining refrigeration infrastructure and equipment is high in Chad, hence the need to use other preservation methods such as drying. Several methods are used to prepare dried meat. The main method used in Africa is sun drying, which involves exposing lean meat to the sun, or a combination of salting followed by air drying, as in the preparation of *biltong* in South Africa. Dried meat products, such as *kilishi* in Nigeria, are prepared by partially sun-drying thin slices of high-quality beef, which are then marinated in a

mixture of various ingredients before a second period of sun-drying. The addition of preservatives enhances the quality of dried meat intended for long-term storage.

The methods used to prepare dried meat in Africa vary from region to region. Below are some examples of dried meat products in Africa [27]:

### 2.3.1. *Biltong*

It is a speciality made from dried and salted meat originating in South Africa. This product is made from different types of meat, including beef, game and even farmed ostrich fillets. Raw meat fillets are often cut into strips, seasoned with spices and dried [28].



**Figure 1** Soaked *Biltong* (U/I\_EAT\_THE\_FAT, 2019) [29].

### 2.3.2. *Kilishi*

It is a variation of *biltong*. This dish, which is very popular among the Hausa people of Nigeria, is made from boneless cuts of beef, mutton or goat. It is prepared by partially drying thin strips of high-quality meat in the sun, which are then marinated in a mixture of ingredients before undergoing a second stage of drying in the sun [30].



**Figure 2** *Kilishi* spread out to dry (Yunusa, 2023) [31]

### 2.3.3. *Guedid*

*Guedid* is a traditional salted and sun-dried meat product, well known in the Maghreb countries (Morocco, Algeria and Tunisia), most often prepared after Eid al-Adha. It can be made from all types of meat, including camel meat [32,33,34,35,36]. The parts of the carcass usually processed into *Guedid* are lamb ribs. The preparation of *Guedid* differs from one region to another and depends mainly on the ingredients used, the salting and drying techniques, and the end uses of the product. In addition, the final appearance and colour are not always the same (Figure 3). Traditionally, fresh

meat is cut into thin strips mixed with salt and possibly spices. The salted strips are then hung in the open air. Salting can be done dry or in brine, with the amount of salt visually assessed according to the amount of meat used [34]. However, frying after drying or adding spices (garlic, red chilli, coriander and mint) is mainly related to customary use in certain regions. The climatic conditions of the region where it is prepared determine the chemical, microbiological and sensory characteristics of *Guedid*. *Guedid* is generally stored in jars (sometimes with oil) or plastic bags for several months at room temperature in a dry place to prevent rehydration [37,35,36]. For consumption, it is added to traditional dishes such as couscous, legume stew, Aiche, and 'Couscous Avissar'; a dish made from wheat semolina prepared in the Kabylie region (Algeria) during the winter and for the Berber New Year every 12 January [35].



**Figure 3** *Guedid* dried meat product (Gagoua and Boudechicha, 2018) [35,36]

#### 2.3.4. *Kourdass*

*Kourdass* is a sausage-like product made from lamb offal such as stomach, intestines, liver, lungs, spleen and fat. All the ingredients are cut into small pieces before being salted and seasoned with salt, cumin, red chilli pepper, garlic and black pepper. Pieces of stomach measuring approximately 15 × 10 cm, which have been washed and cleaned beforehand, are stuffed with the mixture to form balls with the rough side of the stomach on the outside [38,39,40]. Each ball is wrapped with intestine to seal it and dried in the sun (Figure 4). The drying time depends on the size of the ball, weather conditions and the season of preparation. Finally, *Kourdass* is consumed after boiling for 10 to 15 minutes. It is either sliced and served with couscous or eaten as a grilled sausage. *Kourdass* is usually prepared for domestic consumption during weddings and certain festivities such as Mousseem, an annual religious celebration.



**Figure 4** *Kourdass* meat product, dried (Boudechicha, 2018) [36]

### 2.3.5. Charmout

The literature shows that the consumption of *charmout* has a long history in Chad [20]. This prized product was intended for all Chadians. For Chadians, the purpose of cattle is to produce meat for consumption. Beef has given rise to various methods of preparation and/or preservation. One such method is *charmout* (meat cut into strips) [41]. In the Sakalava region (western Madagascar) and/or the Tsimihety region (north), *maskita* – which is more or less equivalent to *charmout* and *kitoza* are produced through a process of sun-drying or smoking over a hearth fire [22].



**Figure 5** Charmout meat product (Brahim, 2024)

### 2.3.6. Khlii

It is a preserved meat product, manufactured and found mainly in Morocco. It is made from lean meat cut into strips and fat from various animals, excluding pork. The meat is deboned, trimmed, cut into strips, salted, marinated, dried and sautéed. *Khlii* comes in the form of cooked meat coated with a mixture of fat and oil and packaged in airtight containers [27].

### 2.3.7. Nyirinyiri

It is a product made from camel, cattle, goat or sheep meat, dried in the sun, spiced and/or salted, and preserved in oil in small pieces. *Nyirinyiri* is mainly prepared by herders in Kenya and Somalia. It is made from lean meat cut into thin strips and sun-dried for a number of hours depending on weather conditions. It is then cut into small pieces and cooked in ghee, camel fat, vegetable oil and animal fat. *Nyirinyiri* is then preserved in fat in food-grade packaging for up to two years [27].

### 2.3.8. Segwapa

It is a speciality made from sun-dried, salted meat, primarily prepared from beef and game, which is popular throughout Botswana as a condiment and has significant export potential [27].

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## 3. Microbiological aspects of *charmout*

Microorganisms degrade food, leading to a deterioration in its organoleptic qualities: they alter the taste, smell and appearance of the product [42].

The assessment of the microbiological quality of a food product concerns two aspects:

- Hygienic quality, which characterises the risk to consumer health;
- Commercial quality, which characterises the risk of spoilage.

### 3.1. Moulds that may contaminate *charmout*

Food contamination occurs when food comes into contact with an atmosphere (smoke) containing polycyclic aromatic hydrocarbons (PAHs), for example, during the direct drying of meat with combustion gases or during the smoking or roasting of food (barbecuing, smoking meat products and fish, roasting coffee, etc.). Moulds produce reproductive structures called spores, which are invisible to the naked eye. They can also produce chemicals that may remain inside the spores, be released into the materials they colonise (e.g. enzymes, mycotoxins) or be released into the ambient air (e.g. volatile organic compounds) [43].

Meat and smoked/dried fish are staple foods for human consumption in Chad. Therefore, studying the contamination of these foods by moulds that can produce dangerous mycotoxins is very important [44].

#### 3.1.1. *Genus aspergillus*

*Aspergillus* is one of the most common fungi and has a structure characterised by conidiophore stalks, foot cells, vesicles, metules, phialides and spores or conidia. The spores have a diameter of 3.0 to 5.4  $\mu\text{m}$  and a subglobular shape with rough walls.

During their saprophytic growth, they produce millions of very small (1 to 5  $\mu\text{m}$  depending on the species) highly volatile spores which, carried by the air and inhaled by all individuals, are the source of contamination [45]. This genus comprises around 300 species, some of which cause:

- Food poisoning or mycotoxicosis through the accumulation of toxins they secrete in plants consumed by humans or animals [46].
- Opportunistic infections called aspergillosis, with a predominance of respiratory aspergillosis, which can be explained by the habitual and constant presence of *Aspergillus* spores in the atmosphere [47]. Once inside the body, *Aspergillus* can colonise all organs and systems of the human or animal body. *Aspergillus* colonisation can therefore extend from the skin to the meninges, via the lungs and sinuses [48,49]. The fungal species most commonly involved are *Aspergillus fumigatus*, *Aspergillus flavus*, *Aspergillus niger* and *Aspergillus terreus* [50].

#### 3.1.2. *Aspergillus fumigatus*

*Aspergillus fumigatus* is a fast-growing thallus fungus with powdery colonies that are white to blue-green in colour, turning grey to blackish grey with age. It has a fairly large, single-rowed columnar aspergillum head (approximately 100  $\mu\text{m}$  long) with phialides directly carried by the hemispherical vesicle. *Aspergillus fumigatus* is characterised by a wide range of thermotolerance, high sporulation capacity and no specific nutritional requirements. Its small conidia (2-3 microns) enable it to penetrate the respiratory tract down to the pulmonary alveoli. *Aspergillus fumigatus* is the most pathogenic species, responsible for approximately 80 to 90% of human aspergillosis cases [46].

#### 3.1.3. *Aspergillus flavus*

Macroscopically, identification is based on the morphology of colonies on culture media. After inoculation and incubation of *A. flavus* at the appropriate temperature (25°C to 28°C), the colour of the colony changes from white to olive green after 3 days on PDA [51,52]. In general, all colonies have velvety or fluffy textures with fluffy centres. AFPA, DRBC and PDA are particularly useful for supporting the growth and sporulation of *A. flavus*, and allow for both macroscopic and microscopic examination [51]. Microscopically, the conidiophore, or stalk, of *A. flavus* is non-septate, rough, and hyaline, with a thick-walled branch. The conidiophore is unbranched; it rises from the foot cell, extends through the stipe and ends in the conidial head [53,54].

#### 3.1.4. *Aspergillus niger*

The colony grows upwards and is powdery to granular in texture, with a blackish colour. The reverse side is colourless to yellow. The biserial aspergilliform head, black when mature, has phialides (small in size compared to the metules) inserted on the globular terminal vesicle via metules arranged around its entire circumference. The colourless to brown conidiophores are smooth, long (1 to 3 mm), wide (15 to 20  $\mu\text{m}$ ) and thick-walled. The phialospores are globular or elliptical, echinulate and measure 3.5 to 5  $\mu\text{m}$ . When *Aspergillus niger* spores are inhaled in large quantities, they cause ear infections with pain, hypoacusis, and damage to the ear canal and eardrum in non-immunocompromised individuals [55], as well as aspergillomas and even sinusitis.

### 3.1.5. Genus *Penicillium*

The genus *Penicillium* comprises between 150 and 300 species, divided into four subgenera belonging to the Deuteromycetes division, which contaminate various organic substrates such as cereals, peanuts and fruit, but are also widely present in soil and the environment [56,57]. These species have characteristics similar to those of the genus *Aspergillus*: they are saprophytes considered to be food contaminants (they can become parasites in the presence of moisture during storage); or used as agents for synthesis, fermentation and antibiotic production (penicillin, griseofulvin). *Penicillium* are the dominant organisms in the 'blue and green moulds' associated with food spoilage, particularly in fruit and vegetables. Species belonging to the *Penicillium* genus produce a number of mycotoxins such as patulin, penicillic acid, citrinin, roquefortine C, PR toxin, isofumigaclavine, mycophenolic acid and ochratoxin A.

### 3.1.6. *Penicillium digitatum*

*P. digitatum* colonies are greenish-brown in colour with a colourless or dull bronze underside. The mycelium consists of branched hyphae with a diameter of 3 to 17 µm. The conidiophores are short, 30 to 100 µm long and 4 to 5 µm in diameter. At their tips, they resolve into a number of penicillae that are generally parallel in orientation.

The conidiophores often have a single stage of branching and end in phialides [58]. The latter are cylindrical in shape, ranging in size from 15 to 28 µm in length and 3 to 5 µm in diameter, with a small, distinct collar. These phialides bear a chain of conidia up to 160 µm in length, giving the whole structure a brush-like appearance.

## 4. Hygiene practices during the production process

Contamination can be agonistic (during slaughter) and post mortem. The exogenous origin of contamination renders ineffective the hygiene rules that must govern meat processing. In addition, the preparation of cattle, sheep, etc. is conducive to contamination from humans and animals, as well as from water.

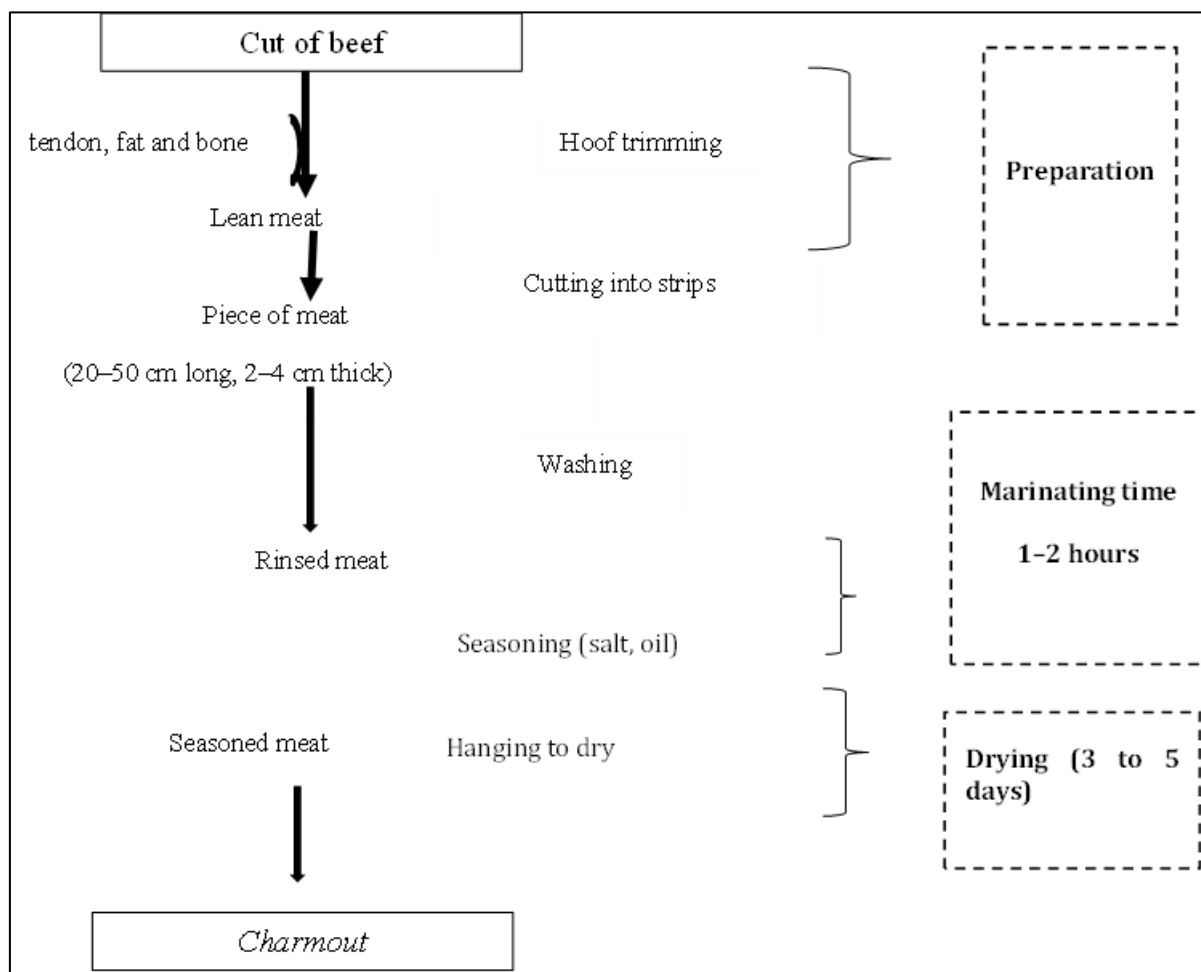
With regard to cleaning utensils, a minimum of three washes is recommended (one with soapy water and two rinses) [59].

**Table 1** Identification of sources of danger and various causes in the *Charmout* production unit in N'Djamena

At the industrial level (slaughterhouse)		During transport		At the production unit	
Potential risks	The reasons for these dangers	Potential risks	The reasons for these dangers	Potential risks	The reasons for these dangers
Faecal contamination (enterobacteria)	Transmission of bacteria by the workforce	The climate during transport (temperature)	The increase in temperature could promote microbial proliferation.	Contamination by faecal flora, staphylococcus, etc.	Handling of raw materials by staff
Contamination by environmental germs	Contamination of the animal during slaughter	Exposure of meat (inadequate packaging)	Meat is susceptible to contamination by microorganisms in the open air.	Contamination of equipment	Washing utensils with plain water
Mould contamination	Humidity in industry	The climate promotes contamination		Environmental contamination ( <i>Aspergillus niger</i> , <i>Penicillium</i> , <i>Aspergillus Flavius</i> , etc.)	The polluted processing environment

#### 4.1. Charmout production diagram

The meat is first cut into strips and then washed. During the cutting process, tendons, bones and fat are removed. Next, the ingredients (salt and oil) are added and mixed in. To ensure that the meat is well marinated, it must be left to marinate for 1 to 2 hours. The strips of meat are then hung on a wire to dry, usually for 3 to 5 days depending on the climate and the producer. The *charmout* produced in this way can be kept for several weeks or even months if it is properly dried.



**Figure 6** Charmout production diagram

## 5. Medicinal plants

### 5.1. Definition, History and Importance

Medicinal plants include plant species that have been used since ancient times for their medicinal properties, which are usually pleasant. These plants are often studied jointly in ethnobotany because of their importance in various fields [60].

They are widespread throughout the world, with high diversity in South and Southeast Asia, America, Europe, Africa and Australia. Africa has more than 5,000 listed medicinal species [60].

The pharmacological efficacy of these medicinal plants is based on the presence of secondary metabolites, such as alkaloids, glycosides, essential oils and other bioactive substances. These compounds are influenced by environmental factors such as light, temperature, rainfall and soil properties, leading to chemical variations within the same species depending on its habitat [61].

## 5.2. Plants used in the preservation/conservation of *charmout* quality

### 5.2.1. *Xylopi aethiopica*

*Xylopi aethiopica* (Annonaceae), commonly known as black pepper, African pepper, Guinea pepper and spice tree, is an aromatic evergreen tree that grows to a height of 15-30 m. It is native to low-altitude rainforests and marginal wet forests.

It is native to low-altitude rainforests and wet forests in savannah areas and coastal regions of Africa.

Folk medicine attributes abortive and emetic properties to it, as well as its use in the treatment of diarrhoea and dysentery, gastric disorders, menstrual disorders, nasopharyngeal infections, arthritis, rheumatism and infections, among others [62].



**Figure 7** Seeds of *Xylopi aethiopica*

### Antimicrobial activity of *Xylopi Aethiopica*

The study by [63] showed that the fresh and dried fruits, leaves, stem bark, and root bark of *Xylopi aethiopica* produced varying degrees of activity against fungi.

### 5.2.2. *Cymbopogon citratus*

The Poaceae, or grasses, are a family of monocotyledonous plants in the order Poales, which includes approximately 12,000 species grouped into 780 genera, with a cosmopolitan distribution. In terms of number of species, it is the fifth largest family of flowering plants, after the Asteraceae, Orchidaceae, Fabaceae and Rubiaceae. It includes most species commonly referred to as grasses and cereals. They are generally herbaceous plants, more rarely woody (bamboo), which share morphological characteristics that clearly distinguish them from other plant families: cylindrical stems (culms) with hollow internodes, alternate leaves arranged in two rows, with linear blades and parallel veins, and a sheath that envelops the stem, elementary inflorescence in spikelets, flowers reduced to sexual organs (stamens and ovary), fruits with a pericarp fused to the seed (caryopses).

This is the most economically important plant family, providing an essential part of the basic diet directly through domesticated species such as cereals (wheat, rice, maize, barley and millet), sugar cane, and indirectly through fodder plants, not to mention materials useful to industry and crafts such as bamboo, straw, thatch and biomass (ethanol). Grasses are also cultivated for ornamental purposes, particularly for lawns and sports fields (golf courses), and to combat soil erosion (marram grass). The family also includes numerous weed species that affect crops, with five species of Poaceae (*Cynodon dactylon*, *Echinochloa colona*, *Eleusine indica*, *Sorghum halepense*, *Imperata cylindrica*) among the ten 'worst' weeds worldwide [64].



**Figure 8** *Cymbopogon citratus*

#### Antifungal activity of *Cymbopogon citratus*

*C. citratus* essential oil has antifungal activity against *Candida albicans*, *Candida pseudotropicalis*, *Mycosporum gypseum*, *Botrytis cinerea*, *Aspergillus niger*, and *Beauveria bassina*. It is also effective against fungi of the dermatophyte group, such as *Trichophyton rubrum*, *Microsporum gypseum*, *Aspergillus fumigatus*, *Cladosporium trichoides*, *Trichophyton mentagrophytes*, *Epidermophyton floccosum*, *Botrytis cinera*, and *Aspergillus nidulans* [65,66,67].

The essential oil shows statistically significant activity against *Aspergillus niger* and *Aspergillus fumigatus* at a concentration of 5 $\mu$ L/0.4 L of air. The results obtained by Sulaiman (2013) [68] also confirm the strong activity of the volatile substances obtained from the essential oil against the maturation of spores of the two species mentioned above

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## 6. Conclusion

The HACCP system has identified the hazards that could potentially contaminate dried meat and affect consumer health or the quality of finished products as a result of poor meat production or storage. Natural substances, such as extracts of *Xylopiya aethiopica* and essential oil of *Cymbopogon citratus*, are essential factors in meat quality, preventing the development of mould mycelium through their high volatile substance activity. Keeping meat at a temperature of 4 °C during this stage preserves its original qualities and is the most effective approach to ensuring its proper preservation.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors report no conflicts of interest.

### *Authors' contribution*

All the authors contributed to the drafting of this review

### *Submission statement*

This manuscript is original and has not been submitted.

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