TRAINDING GUIDE

Good Hygiene and Manufacturing Practices  
(GHP & GMP)
Hazard Analysis and Critical Control Points  
(HACCP)
for 
oyster mushrooms growing on cassava residues (stalks and peels)
for small and medium-sized enterprises in Ghana and Nigeria

Preface

This document is part of a series of training guides developed under the GRATITUDE project (described below). The Food Safety and Quality Management approaches described were developed and agreed in collaboration between the project partners and reflect the conditions in the target countries.

This training guide on good hygiene and manufacturing practices for mushrooms grown on substrates containing cassava residues (stalks and peels) for small and medium-sized enterprises (SME) in Ghana and Nigeria, complemented by hazards analysis and critical control points (HACCP), was developed under the European research project GRATITUDE – Gains from losses of root and tuber crops – and is in accordance with international legislation on food hygiene.

This training guide is a basic document for each food operator working in oyster mushroom farming in Ghana and Nigeria and was developed according to the process currently used in those countries.

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Acknowledgement

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Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>EAS</td>
<td>East African Standard</td>
</tr>
<tr>
<td>EUR</td>
<td>Euro (official currency of the eurozone)</td>
</tr>
<tr>
<td>GHP</td>
<td>Good hygiene practices</td>
</tr>
<tr>
<td>GMP</td>
<td>Good manufacturing practices</td>
</tr>
<tr>
<td>HACCP</td>
<td>Hazard analysis and critical control points</td>
</tr>
<tr>
<td>SME</td>
<td>Small and medium-sized enterprises</td>
</tr>
</tbody>
</table>
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1. Introduction

The purpose of the principles of Good Agriculture and Manufacturing Practice (GAP, GMP) and Good Hygiene Practices (GHP) for oyster mushroom farming on substrates containing cassava residues (peels and stalks) is to provide operators with some basic rules in order to guarantee their compliance with food safety and quality standards – and therefore guarantee the consumers’ health – as well as to minimise weight and quality losses.

The principles of GAP, GMP and GHP are based on the conditions and requirements of European Community (EC) legislative directives and laws, decrees and ordinances, and on the requirements of the African Organisation for Standardisation. They comply with the Codex Alimentarius and especially with the Regulation of the European Parliament and Council (EC) No. 178/2002 which lays down general principles and requirements of the food law, establishing the EFSA (European Food Safety Authority) and stipulating procedures concerning food safety. They also comply with the African Standard ARS 53/2012 on general principles of food hygiene.

Overview of related legislative guidelines and standards:

- **Regulation of the European Parliament and Council (EC) No. 178/2002** 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
- **Regulation of the European Parliament and Council (EC) No. 852/2004** on the hygiene of foodstuffs, establishing the rules for the implementation of the HACCP system (Hazard Analysis and Critical Control Points) and the guides to good practices development and dissemination
- **African Organisation for Standardisation (ARS) No. 53/2012** on the general principles of food hygiene, establishing a code of practice for manufacturing and hygiene of foodstuffs, and rules for the implementation of the HACCP system
2. Product description

According to the Codex Alimentarius Standard and to African Standards, the name “mushrooms” stands for the products prepared from the fresh edible bodies of macrofungi (fungi with a fruiting structure visible to the naked eye) conforming to the characteristics of any suitable cultivable varieties (cultivars), which mushrooms shall be in good condition and after cleaning and trimming shall be sound.

3. Requirements for mushrooms

According to EAS 56:2010, to Codex Standard 55-1981 and to the European Regulation of food contaminants, the minimum requirements for mushrooms are that they must be:

a) free from poisonous mushrooms and other toxic ingredients  
b) firm and intact  
c) free of other species of edible mushrooms  
d) sound  
e) clean  
f) fresh in appearance  
g) free from pests and free of damages caused by pest  
h) free of abnormal external moisture  
i) free of any foreign smell/taste  
j) free of physical damage  
k) colour according to the variety  
l) shaped as typical for the species/variety  
m) firm body  
n) stem may be cut or whole
Microbiological requirements for mushrooms must be:

<table>
<thead>
<tr>
<th></th>
<th>CFU/g, maximum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escherichia coli</td>
<td>10^2</td>
<td></td>
</tr>
<tr>
<td>Listeria monocytogenes</td>
<td>25g, maximum</td>
<td>absent</td>
</tr>
<tr>
<td>Salmonella</td>
<td>25g, maximum</td>
<td>absent</td>
</tr>
<tr>
<td>Mould</td>
<td>2·10^2</td>
<td></td>
</tr>
<tr>
<td>Yersinia Enterocolica</td>
<td>25g, maximum</td>
<td>absent</td>
</tr>
</tbody>
</table>

Requirements related to contaminants for mushrooms are:

a) cyanide content max. 10 mg/kg on wet basis
b) total mycotoxins max. 10 μg/kg, aflatoxin B1 max. 5 μg/kg on wet basis
c) hazardous heavy metals content must comply with the limit 0.3 mg/kg (ppm) for lead, 0.2 mg/kg (ppm) for cadmium, 0.1 mg/kg (ppm) for mercury. Limits for lead and cadmium are set on wet basis; the limit for mercury is set for the foodstuff as sold (EU 1881/2006).
d) Pesticides must comply with the limits established by the EAS 56:2010 and by the EU 396/2005.

The **Water** requirement for mushroom farming should comply with Regulation (EC) No 183/2005 and must be:

a) Clean
b) Free of contamination
4. Production process for mushrooms

Mushroom cultivation must aim to produce a foodstuff which has beneficial properties for the consumers. The basic process involves the addition of calcium carbonate to the cassava peels, followed by pasteurisation and inoculation of substrate. Figure 1 shows the process flow of mushroom cultivation on cassava peels and stalks.

![Flowchart of mushroom cultivation process](image)

**Figure 1: Process flow for oyster mushroom cultivation**
5. Good hygiene practices (GHP) in oyster mushroom cultivation

Implementation of these practices is to ensure safety and quality of mushrooms by avoiding the presence of contaminants. According to the Codex Alimentarius:

- **A contaminant** is: any substance not intentionally added to food, which is present in such food as a result of the production, manufacture, processing, preparation, treatment, packing, transport or holding of such food, or as a result of environmental contamination.

5.1 Staff hygiene

Operators who are directly or indirectly in contact with food must maintain an adequate level of cleanliness, and behave and operate in an appropriate manner to avoid contamination of food.

People are a potential source of disease-producing microorganisms which live in parts of the body such as hair, nails, nose, mouth, throat, bowels and sores. Therefore, it is necessary to recommend the following provisions:

- An annual medical examination for every operator concerned with handling or manufacturing of foodstuffs
- The monitoring of staff for lesions caused by *Staphylococcus*, though clinical examination of arms, hands, face, throat and other exposed skin, to be carried out by a medical practitioner with appropriate food handling experience
- The monitoring of staff for potential *Salmonella* and *Staphylococcus* carriers by way of bacteriological analysis
- Medical treatment for those diagnosed positive with a microorganism

Staff who are injured or sick must not handle food and should be made to undergo medical treatment. Cover cuts and wounds with waterproof dressings. Conditions which must be reported to management should include diarrhoea, vomiting, fever, skin lesion, jaundice and discharge from the ears, eyes or nose.

Staff must **wash their hands** with soap in the following circumstances:

(i) At the start of food handling activities
(ii) Immediately after using the toilet
(iii) After handling raw material or any material which could lead to contamination of the products
In agro-food industries, clothing can be a major vector in food contamination. Work clothing must respect some specific principles:

- it must be kept in a separate compartment from personal clothing and the compartment must be kept clean
- it must include a cap which covers all the hair
- it must include shoes which are only worn in the factory

Wearing of personal effects such as jewellery, watches, hairpins, bracelets, bands etc. should be discouraged. Visitors must wear protective clothing and adhere to all personal hygiene requirements. Staff must not smoke, spit, chew gum, sneeze or cough over unprotected food. Domestic animals are not allowed in the factory. Table 1 and Figure 2 summarise the practices which are and are not allowed.

**Table 1: Staff hygiene practices: what is and what is not allowed**

<table>
<thead>
<tr>
<th>Practice</th>
<th>Allowed</th>
<th>Not allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Objects</td>
<td><img src="image1.png" alt="Eye Glasses" /></td>
<td><img src="image2.png" alt="No Jewelry" /></td>
</tr>
<tr>
<td>Shoes</td>
<td><img src="image3.png" alt="Shoes" /></td>
<td><img src="image4.png" alt="No Shoes" /></td>
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<tr>
<td>Injuries/Illness</td>
<td><img src="image5.png" alt="Bandaged Hand" /></td>
<td><img src="image6.png" alt="No Injuries/Illness" /></td>
</tr>
<tr>
<td>Clothing</td>
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<td><img src="image8.png" alt="No Clothing" /></td>
</tr>
<tr>
<td>Practice</td>
<td>Allowed</td>
<td>Not allowed</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>Eating and Drinking</td>
<td><img src="canteen.png" alt="Canteen" /></td>
<td><img src="in_the_workplace.png" alt="In the workplace" /></td>
</tr>
<tr>
<td>Behaviour</td>
<td>The habit of spitting should be never allowed, both for hygiene concerns and for a good personal image</td>
<td><img src="do_not_spit.png" alt="DO NOT SPIT" /></td>
</tr>
<tr>
<td>Smoking</td>
<td><img src="designated_smoking_area.png" alt="Designated smoking area" /></td>
<td><img src="in_the_workplace.png" alt="In the workplace" /></td>
</tr>
<tr>
<td>Animal</td>
<td><img src="animal.png" alt="Animal" /></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2: Example of personal hygiene rules panel to be placed in the working area, in an easily visible position

5.1.1 Staff hygiene facilities and toilets

Hygiene facilities shall be available to staff to ensure that the degree of personal hygiene required is maintained. The facilities shall be located close to the points where hygiene requirements apply and shall be clearly designated.

5.2 Designated eating areas

The staff canteen and designated areas for food storage and consumption shall be situated so that the potential for cross contamination of the production area is minimised.
5.3 Processing plant hygiene: maintenance, cleaning and sanitation

Cleaning and sanitation programmes should be established to ensure that food processing equipment and the work environment are maintained in hygienic conditions. The programmes should be monitored for continued suitability and effectiveness. The following conditions should be guaranteed:

a) The processing plant and equipment should be kept in appropriate conditions and state of repair
b) Facilities and equipment shall be maintained in a condition that facilitates wet or dry cleaning and/or sanitation
c) Cleaning and sanitation agents should be food grade, clearly identified, stored separately and used according to the manufacturer’s instructions.

Cleaning aids required during the preparation of mushrooms include the following: stiff brooms, soft brooms, soft brushes, hard stiff brushes, mops and mop buckets, vacuum cleaners with accessories, net sponges, mechanical scrubbers, squeegees, sweeping brushes, long handled brushes, water hoses and dusters. Cleaning chemicals may include detergents in the form of soaps, disinfectants, etc.
6. Good agriculture and manufacturing practices (GAP and GMP) in oyster mushroom cultivation

GAP and GMP are a combination of agricultural, manufacturing and quality control procedures aimed at ensuring that products are consistently manufactured according to their specifications. These practices are implemented to ensure the standardisation of the final product through specific steps, the order of which must be respected.

6.1 Mushroom farms

Mushroom farms should not be sited close to areas with high industrial pollution. Facilities must be constructed to keep out pests and permit adequate arrangement, maintenance, cleaning and functioning of equipment. The internal designs must be ideal for good hygiene practices and protect against cross contamination during operation. Structures must be built with durable materials which are easy to maintain, clean and disinfect. The design should minimise the build-up of dust during production. Walls and floors should be smooth, impervious and easy to sweep and wash. Ceilings and roofing should be well-finished to minimise the build-up of dirt, condensation and the shedding of particles. Windows should have insect-proof net screens that are easy to clean and allow proper ventilation to minimise dust.

Food contact surfaces must be easy to clean, disinfect and maintain and should be non-toxic to the products. Iron reacts with cyanide so equipment of this metal should be used with caution. Facilities should be available for handling, cleaning, waste disposal and ensuring staff hygiene. Staff should have protective clothing, nose and mouth guards, and hairnets. There should be adequate natural ventilation, good lighting, and storage facilities which are ideally separate and prevent access by and harbourage of pests.

Mushroom farms should be designed to keep the picked mushrooms away from raw compost or unpasteurised substrate. Therefore, compost storage and preparation areas are usually separate and at a sufficient distance from mushroom growing and storage areas.

Designers and constructors of mushroom farms have to take into consideration the fact that mushroom growing areas are exposed to:

a) Relatively high temperatures (70°C) and humidity (> 90%)

b) The corrosive impact of water, used continuously during the entire cultivation process

c) Chemicals
Temperature and humidity parameters depend on the cultivation stage, so the mushroom growing area is exposed to changing temperature and humidity.

One indoor cultivation cycle, from substrate composting to cleaning of the facility can take from 60–64 days. Air humidity varies, depending on the cultivation stage, between 75% and 95%; during some stages, e.g. the fructification stage, the walls and floor are sprinkled with water in order to keep high humidity in the chamber.

It is important to mention the concentration of carbon dioxide (CO₂) which occurs during the mushroom cultivation process. Normally CO₂ condensation in the atmosphere reaches about 350 ppm (0.035%), whereas in the indoor mushroom growing room it is much higher, e.g. during the vegetative growth (colonisation of substrate) in the incubation stage, this concentration exceeds 5000 ppm (0.5%) whilst during the production of mushrooms, the CO₂ concentration will vary between 800 and 1200 ppm. As the CO₂ concentration might rise to a level which could cause people to faint, the time they spend in the room during the incubation period must be kept to a minimum.

![Figure 3: An example of a good layout for efficient operation in mushroom cultivation](MushWord, 2004)

### 6.2 Walls, floors, Windows and Roofs

Brooms and brushes must be used to scrub and clean walls and floor and dirt hosed away down drains. Smooth floors may be dried using rubber squeegees. Rubber strips of squeegees must be pressed in close contact with floor by applying pressure on the handle and pushing them along floor. Walls and floors must be scrubbed with detergent solution, rinsed and dried. However, for warehouse and storage room
floors, floors must be vacuum cleaned to remove dust or spilled dried materials. Roof girders must be cleaned before the floors are cleaned. The order of cleaning must be planned so that dirt is washed down onto a surface to be cleaned and not one that has already been cleaned. Cleaning must start from the ceiling down to the floor. Scrubbing and mopping of floors, cleaning of windows and window screens must be done using clean water or a vacuum cleaner.

6.3 Cleaning and maintenance

Equipment should be well maintained to facilitate sanitation procedures, function as intended and prevent contamination. Physical and chemical cleaning as well as disinfection should be carried out regularly. Drains should be cleaned regularly to remove any organic matter that can support growth of fungi or bacteria. The drains should contain a water lock to prevent insects entering the growing room through these drains. Waste from the plant must be disposed of promptly to avoid the attraction of pests. Responsible personnel should be put in charge of sanitation to monitor and check effectiveness of cleaning and maintenance, keep records of cleaning regimes and conduct regular auditing of premises for sanitation and hygiene.

6.4 Water quality

Water is used for the preparation of substrate, cleaning and sanitising of equipment and food contact surfaces, irrigation, pesticide use, generation of steam, hand washing, and drinking. However, it can also be a vehicle for the spread of pathogenic microorganisms and chemical contaminants. It is, therefore, important to be aware of the source and quality of water used throughout the mushroom farm. Water that comes into contact with mushrooms or with food contact surfaces must be safe to use (see requirement section) and potable drinking water must be available for employees.

6.5 Control of microbiological contamination

Microbiological contamination is the most important concern in mushroom cultivation.

Mushrooms are contaminated with microorganisms mainly:

- a) from their growing substrate; sterilisation can drastically reduce the risk
- b) from spawn
- c) from rodent droppings and insects
- d) from spawn (liquid culture)
- e) from humans, during harvest
Significant microbiological hazards in mushrooms are:

a) *Clostridium botulinum*

b) *Enteric bacterial pathogen* (from the growth medium)

c) *Staphylococcus aureus* (mainly from humans)

Among less hazardous causes of spoilage, *Pseudomonas spp.*, *yeast* and *mould* are the most frequent and their growth is accelerated when mushrooms are stored aerobically at ambient temperature. The option of storing mushrooms in a dried form could help in controlling microbial growth.

Tables, conveyors and screen must be cleaned before a new growth.

*Bacilli* are very frequently found in the grain spawn jar. Their endospores can survive sterilisation and contaminate the substrates and therefore the mushrooms. The most practical method to eliminate endospores is soaking the grain in water for 12–24 hours prior to sterilisation.

The procedure for mushroom cultivation should comply with microbiological criteria established in accordance with Codex Standard CAC/GL 21 – 1997.

6.6 Pest Control

❖ Insects

Fungus gnat and Phorid fly are the most hazardous insects for mushrooms. Adult fungus gnats are small (1/8 inch long), fragile, greyish to black flies with long, slender legs and thread-like antennae. Their wings are clear or smoky-coloured with no pattern and few distinct veins. Larvae are clear to creamy-white and can grow to about 1/4 inch long. They have shiny black head capsules.

![Fungus gnat](image1.png) ![Phorid fly](image2.png)

a) Fungus gnat  b) Phorid fly
c) Mushroom fly

Flies are attracted to the mushroom crop and their larvae feed directly on mycelium, swarm over the mushroom and tunnel into the developing or developed mushroom. Tissues that have been physically damaged by flies often become colonised by bacteria which cause soft rot, thereby accentuating the problem. Controls include strict sanitation and general farm hygiene. For example, the grow room must be air tight. Fresh air that is used is filtered. Even a small crack will serve as an entry for the flies. Most farms use adhesive tape or some other method that allows monitoring of populations. Biocontrol using nematodes offers effective control when populations of flies are low. In addition to the damage that fly larvae cause by eating mushroom mycelium or by killing pins, the adults also carry diseases such as *Verticillium*, *Mycogone* and Cobweb.

Besides flies, mites are also commonly found in straw (and manure); most species are beneficial to mushroom growing as they feed on eelworms and other mites, although some can cause damage. Mites, like fly larvae, may feed on mushroom mycelium and on the mushrooms, where they can cause surface discoloration. They may also live on other fungi (weeds and indicator moulds) found in mushroom culture. One example is the red pepper or pygmy mite (*Pynehphorus* spp.). These mites are commonly associated with *Penicillium* and *Trichoderma* moulds, upon which they feed. These mites have the ability to change into an intermediate stage called a hypopus, wherein they develop flattened bodies and a sucker plate with which they attach to moving objects, like flies. Mites at this stage swarm on top of mushrooms.

Regular spraying of the work environment with insecticides and the use of screen netting must be ensured to eliminate insects, cockroaches, houseflies etc. Insecticides must not be used on the production floor during production and must not be sprayed directly over food-contact surfaces and equipment that comes into direct contact with food. Dark cabinets and drawers must be regularly checked for eggs of cockroaches.
and thoroughly cleaned and sprayed with insecticides. Ultra-violet lamps can be used to eliminate flying insects (Fletcher and Gaze, 2008).

**Rodents**

A staff member must be responsible for monitoring the farm for rodent infestation and for their elimination. Their assignment should include baiting and making recommendations for repairs that are necessary to keep out rodents. Access to processing and storage facilities by rodents must be completely avoided. Cracks must be sealed and holes filled once observed. Containers for storing food must be rodent proof. Traps with bait must be placed along rodent pathways. Anticoagulant rodenticides may be used to kill rodents.

**Birds, reptiles and domestic animals**

These must be continuously monitored and controlled by appropriate means to avoid product contamination.

### 6.7 Control of chemical contamination

Mushrooms tend to concentrate heavy metals and pesticides from substrates. To minimise the probability of contamination above the allowed limits (see the requirement section) substrate should not contain such chemicals, or the amount should be as little as possible.

### 6.8 Control of operations

All medium- to large-scale processing enterprises should implement a HACCP programme to guarantee the safety of their products. Monitoring procedures must check against chemical, microbiological and physical contamination of products. Packaging of food products should permit adequate protection from damage, contamination and allow adequate labelling and must not react chemically with the product.

Records of processing, production and distribution, if kept, will enhance the credibility of the food safety systems. Staff must have the requisite skills and training in food hygiene principles and practices, be able to predict potential risks, and take appropriate preventive and corrective actions. Products revealed to be hazardous to health should be recalled from markets and not sold for human consumption.

### 6.9 Transportation

During the transportation of food products, avoid the contamination of products and packaging materials. Clean and disinfect vehicles where necessary. Maintain ideal temperatures, humidity and avoid dust and water from coming into contact with products.
6.10 Product Information and Consumer Awareness

Practice the First-in First-out (FIFO) principle of stocking. Mark product containers for lot identification and traceability. Products for the consumer market must bear adequate information for handling, storage, preparation and for safe and correct use of the product.
7. Training

The training is targeted at mushroom cultivators at household or SME level, either for domestic or commercial use. The following instructions are based on the GHP, GAP and GMP reported in previous pages.

7.1 Training Needs

The trainee must have a checklist which contains the following:

**MATERIALS**

1. Raw materials: substrates, spawn, calcium carbonate, gypsum
2. Clean bags
3. Clean stainless steel knives for cutting mushrooms
4. Packaging materials for finished product

**EQUIPMENT/AREAS**

1. Mushroom growing rooms with all necessary facilities and a corridor
2. Sterilisation room
3. Packaging room
4. Cold room
5. Rest and refreshment rooms
6. Packaging storage area
7. Settling and septic tanks

**CLEANING and PROTECTIVE TOOLS**

1. Detergent
2. Disinfectant
3. Gloves
4. Overalls
7.2 Stages of oyster mushroom production

❖ Cassava peels and stalks
Cassava peels and stalks must be clean; content of cyanide, heavy metals and pesticides must be as low as possible, since mushrooms are able to concentrate these chemicals with serious risk for human health.

❖ Soaking in water of cassava peels and stalks (cassava substrate)
Cassava peels and stalks are mixed in the ratio 3:1 w/w and are soaked in water.

❖ Addition of rice bran and calcium carbonate and fermentation (or composting)
Mushrooms grow and perform well at a pH near neutral or slightly below neutral. Lime, or chalk (calcium carbonate, CaCO₃) is an important constituent of mushroom substrates.

Addition of CaCO₃ increases the number and weight of mushrooms. The final percentage of CaCO₃ in the substrates is commonly between 0.2 and 10%. Rice bran is added as a source of carbon. The substrate is then allowed to ferment at 43–45°C for 11 days, or is composted for 28 days with regular turning every 4 days.

❖ Addition of gypsum (eventual)
Gypsum is added to minimize the greasiness the substrates normally tends to have. It is added in the case of composting. Gypsum increases the flocculation of certain chemicals in the compost, and they adhere to the peels and stalks rather than filling the pores (holes) between the peels and stalks. A side benefit of this phenomenon is that air can permeate the pile more readily, and air is essential to the composting process. The exclusion of air results in an airless (anaerobic) environment in which deleterious chemical compounds are formed which detract from the selectivity of mushroom compost for growing mushrooms. Gypsum is added at the outset of composting at 20–22kg per ton of peels and stalks.

❖ Filling of bag with cassava substrate
Bag filling can be done manually or mechanically by specific machines. In both cases (a) and (b), operators should be careful not to contaminate the substrates with extraneous matter containing metals or chemicals.
Mushrooms
GHP, GMP, HACCP

Gratitude – FP7 WP5 – Food Safety, Quality and Compliance

a) Manual bag filling

b) Mechanical bag filling

❖ Pasteurisation (or sterilisation) of bags

Substrates must be sterilised to reduce the amount of microbial competitors for the substrate. This gives the mycelium an advantage over harmful organisms, allowing it to take over the substrate and eventually produce mushrooms.

Sterilising leaves the substrate quite susceptible to contaminants. Without the beneficial bacteria to guard against foreign competitors, the substrate becomes a free for all for anything to grow. Pasteurisation reduces the amount of harmful competing organisms. When the process is over, there is still some micro-activity going on in the substrate, usually in the form of beneficial bacteria.
Cooling

Bags should be cooled down to ambient temperature before inoculation. Slow cooling is advisable as condensation occurs when hot bags are abruptly exposed to cool air. This is why some mushroom operations have a pre-cooling room that is used before the cooling room.

Inoculation with spawn

After sterilisation/pasteurisation, substrate has to be cooled to room temperature in a clean environment. Bags are opened in a clean room or inoculation cabinet and spawn (grain based) is mixed with the top layer of substrate. Bags are closed with a plastic ring containing a greasy wool or cotton plug to prevent infection and allow air exchange. As an alternative, wooden sticks can be used that are colonised with a pure culture of mushroom mycelium and are pushed into the substrate from an opening at the top in the same way as grain based spawn is applied.

Incubation

Inoculated bags are then incubated in a suitable room, where temperature and humidity are maintained at 24–28°C and 65–70%, respectively. The spawn run is strain-dependent, but usually takes 20–25 days. Ventilation time and frequency vary largely
depending on room temperature, humidity and the number of growing units (bags or bottles). It would be important if growers could determine ventilation time and frequency by measuring the CO$_2$ concentration. The maximum upper limit of CO$_2$ concentration for mycelia growth is 3000ppm. During incubation, it is critical to perform a close examination of the bags and look for any contamination. When unnoticed, contaminated bottles can ruin the product and render useless all the hard work involved in substrate preparation, inoculation, and incubation.

**Fruiting of mushrooms**

When almost all of the substrate in the bags is colonised, they are brought to a growing room or exposed to a lower temperature (such as when incubating and growing mushrooms in the same place). Fruiting is induced by low temperature or high humidity as the mycelia shift from vegetative growth into reproductive growth. Mushroom initials develop after rhizomorphs have formed in the bags. The initials are extremely small but can be seen as outgrowths on a rhizomorph. Once an initial quadruples in size, the structure is a ‘pin’. In the phase of pre-fruiting, preventive measures with insecticides and fungicides are usually carried out to prevent insect and fungus proliferation.

Pins continue to expand and grow larger through the button stage, and ultimately a button enlarges to a mushroom. Harvestable mushrooms appear within 18–21 days. Pins develop when the carbon dioxide content of room air is lowered to 0.08 percent or lower, depending on the cultivar, by introducing fresh air into the growing room. Outside air has a carbon dioxide content of about 0.04 percent.

The timing of fresh air introduction is very important and is something learned only through experience. Generally, it is best to ventilate as little as possible until the mycelium has begun to show at the surface of the casing, and to stop watering at the time when pin initials are forming. Pinning affects both the potential yield and quality of a crop and is a significant step in the production cycle.

**7.3 Hazard analysis and critical control point (HACCP) for mushroom cultivation**

Mushrooms to be marketed should respect the HACCP principles, which are derived from GHP and GMP. The objective of the HACCP system is to identify all the hazards related to the production of a specific foodstuff, and define preventive measures and corrective actions. In particular, the HACCP system can:

a) Prevent possible hazards and supply safe products

b) Minimise risks of food poisoning

c) Increase consumer confidence
d) Increase industry authenticity

e) Supply an active auto-control system

f) Minimise product cost

g) Maximise advantages over the competition

h) Make marketing easier

i) Increase products’ shelf life

j) Solve product problems systematically

k) Make product export easier, due to its international acceptability

l) Increase food safety and hygiene awareness of food industry staff

m) Due diligence in the event of a food safety outbreak

The HACCP requirements should take account of the principles contained in the *Codex Alimentarius*. They should provide sufficient flexibility to be applicable in all situations, including in small businesses. In particular, it is necessary to recognise that, in certain food businesses, it is not possible to identify critical control points and, in some cases, good hygienic practices can replace the monitoring of critical control points. Similarly, the requirement of establishing ‘critical limits’ does not imply that it is necessary to fix a numerical limit in every case. In addition, the requirement for retaining documents needs to be flexible in order to avoid undue burdens for very small businesses.

Food safety is a result of several factors:

- legislation should lay down minimum hygiene requirements;
- official controls should be in place to check food business operators’ compliance
- food business operators should establish and operate food safety programmes and procedures based on the HACCP principles.

Critical control points (CCP) for mushroom cultivation have been identified together with preventive measures, monitoring procedures and corrective actions by the project partners and are intended to reflect those appropriate to the situation in Ghana, Nigeria and similar countries. These have been agreed by the project partners in these countries and serve as a guide. It should be noted that a HACCP plan would need to be developed specifically for each individual producer or processor.
Figure 4: Process flow for mushroom cultivation with identification of CCP
Table 2: HACCP plan for mushroom cultivation with identification of critical control points (CCP)

<table>
<thead>
<tr>
<th>Step</th>
<th>Hazard</th>
<th>Preventive measure</th>
<th>CCP</th>
<th>Critical Limits</th>
<th>Monitoring Procedure</th>
<th>Corrective action</th>
</tr>
</thead>
</table>
| 1    | Cassava peels and stalks | Heavy metals, pesticides, pathogenic microorganisms | • Analysis of peels  
• Reception area in good sanitary conditions | YES | Critical limits to be fixed according to mushrooms capacity of concentration of contaminant | Analysis of peels and stalks | Rejection of peels with level of contaminant higher then critical limits |
| 2    | Storage of peels and stalks | Dirtiness, contamination with parasites and pathogenic microorganism | • Pest Control  
• Hygiene schedule | NO | • Analysis of peels and stalks.  
• Clean reception area before each stocking | Rejection of peels with level of contaminant higher then critical limits |
<p>| 3    | Bag filling | Contamination with pathogenic microorganisms and heavy metals | Good hygiene practices | YES | Critical limits to be fixed according to mushrooms capacity of concentration of contaminant | Analysis of bag contents | Rejection of bags with high level of contamination |</p>
<table>
<thead>
<tr>
<th>Step</th>
<th>Hazard</th>
<th>Preventive measure</th>
<th>CCP</th>
<th>Critical Limits</th>
<th>Monitoring Procedure</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Incubation</td>
<td>Appearance of pests, contamination with water vapour</td>
<td>Installation of pest traps, water HACCP, control of air, environment and substrate temperature</td>
<td>NO</td>
<td>Check pest traps, water, air and growing environment hygiene</td>
<td>Rejection of inoculated bags with contamination</td>
</tr>
<tr>
<td>5</td>
<td>Fruiting (Pre-fruiting)</td>
<td>Higher dose and/or use of unauthorised insecticides and fungicides, inadequate quality of irrigation water</td>
<td>• Approved phytosanitary treatments, • Analysis of irrigation water</td>
<td>YES</td>
<td>Authorised phytosanitary treatments, application of correct dose, respect of security periods</td>
<td>• Correct the treatment • Reject mushrooms with high levels of contamination after harvest</td>
</tr>
</tbody>
</table>
8. Conclusions

Mushrooms are an important commodity from an economic point of view and for food diversity and nutrition of the population. Therefore, it is extremely important to cultivate them according to good hygiene, agricultural and manufacturing practices in order to minimise contamination and loss of the products and to protect consumers, especially the vulnerable. Food operators must be trained in mushroom farming as they are the focal point for protecting the health of consumers.

References


