TECHNICAL REPORTS

Setting up a food-processing unit

Part 2: Design and layout of the production unit

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This is the second of three articles on the decisions that face small-scale processors when starting a new business or when expanding to a larger building. The article focuses on the design and layout of food production units. The third article will describe the materials that are needed to construct food processing buildings and equipment.

Design of the production unit

All food processing units should be easily cleaned and sealed from sources of contamination

All food processing units should have specific design features that enable sanitary operations to take place. Their design should ensure that buildings are easily cleaned and that processing areas are sealed from sources of contamination. Most food businesses require a dedicated building that is not used for any other activities. Many processors begin production using a converted room in the family home and later expand to a purpose-built production unit. In many countries, these aspects are covered by law and failures to comply with food hygiene regulations are among the most common reasons for a business to be closed down by the regulatory authorities. Prospective processors should obtain advice on local regulations from the Ministry of Health, Bureau of Standards, or other local or national government departments that are responsible for advising on, and inspecting, food premises.

Building design

A food processing building should be designed to meet four main sanitary requirements:

1. It should be easy to completely clean all surfaces to minimize the risk of harbouring pests and microorganisms that would contaminate foods.
2. It should allow foods to move through a process and through the building in a way that prevents processed foods becoming contaminated by incoming raw materials.

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3. Utility services should be routed through the building in a way that cannot cause a build-up of dust or leakage from pipes that would contaminate products.
4. The design should minimize the risk of workers contaminating products and also minimize the risks of accidents or injury to workers.

To meet the above requirements, the design features described below should be incorporated into both new and converted food processing buildings.

High sanitary specifications do not guarantee safe food if facilities are not cleaned and maintained

It is often easier and cheaper to build a new facility that has the correct sanitary criteria than it is to convert and upgrade an existing building. However, it is important to note that a facility that is designed and built to high sanitary specifications does not guarantee a safe food product if it is not routinely cleaned and maintained to adequate standards. Hygienic working practices, cleaning, and building maintenance schedules are essential components of quality assurance.

Production rooms and storerooms

Processing rooms should be large enough to contain all the required equipment with sufficient space between machines for staff to easily and safely operate, maintain, and repair them. The room should be designed to allow staff to move around it without their paths crossing. This is particularly important to avoid the risk of them colliding with each other if they are required to move or carry hot liquids (e.g. boiling jam) between processing and packing areas. The size of the building should also allow for possible future expansion of production, but it should be appropriate to the expected profitability of the enterprise: an excessively large building increases the amount of start-up capital required, the size of any loans required, and depreciation and maintenance charges.

Processing stages should be physically separated to prevent products coming into contact with raw materials

Different stages in a process should be physically separated wherever possible so that there is a flow of materials around the room. This prevents finished products coming into contact with raw materials. It is especially important when making ready-to-eat foods (e.g. sandwiches, cream, ice cream, salads, some types of meat products, and weaning foods), to prevent contamination after they have been processed. The flow of materials should be in one direction and follow a logical sequence from raw material handling to finished product storage (Figure 1).

There should be separate storerooms for incoming raw materials, ingredients, packaging materials, work in progress, and finished products (including a separate store for products that are in quarantine or have failed quality inspections). Perishable raw materials should be stored separately from non-perishable ingredients, preferably in cold rooms. Raw materials and finished products should never be stored together in the same room. Storerooms should be large enough to accommodate the amounts of materials required for the expected production levels. This is especially important if seasonal crops are bought in the harvest season and stored for a year's production. The storerooms should also be positioned so that they contribute to the correct flow of materials through the processing room (Figure 1).

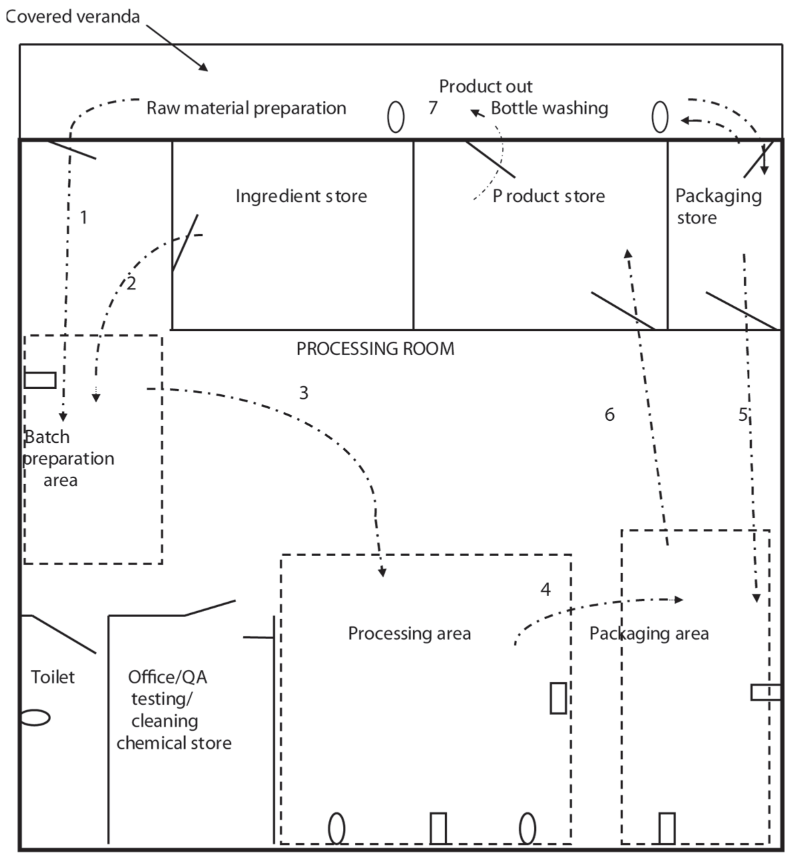

Figure 1. Example of the layout of a processing room for fruit products

1 Prepared raw materials in
2 Ingredients from store
3 Prepared batch to processing area
4 Processed food to packaging area
5 Packaging from store
6 Packaged product to store
7 Products leave store for distribution

▭ = power point

⬯ = water tap

Access to storerooms and goods reception areas should be carefully planned to ensure that access openings are large enough and correctly positioned to easily move bulky materials on pallets or in sacks. When deciding the size of storerooms, adequate space should be allowed for inspection and cleaning between stored materials and the storeroom walls. Economically, it is also important to use the whole volume of storerooms by stacking pallets of materials or using high-level shelving, provided that equipment is available to safely handle materials that are stored at a high level. A separate storeroom is required for cleaning chemicals to prevent them from coming into contact with stored raw materials or processed foods.

Storerooms should have adequate space for inspection and cleaning between stored materials and storeroom walls

In some types of processing, an outside covered area or a separate building is useful for operations that create waste materials that would contaminate foods. For example, washing reused bottles should be done outside the processing room so that any glass splinters from breakages cannot contaminate products. Similarly, operations that create potential contaminants, such as smoke from ovens or smoking kilns, or dust from milling flours, spices or sugar, should take place away from the main processing area.

In larger-scale operations (Figure 2), an area of the building should be set aside for an employees' rest room with changing and toilet facilities. Rest rooms should have lockers to safely store clothes and personal items, which should be fixed to walls and have sloped, rather than flat tops to prevent accumulation of dust. Rest rooms and changing/toilet facilities should not open directly onto processing areas. In most countries, food regulations require them to be either separated by two doors from processing areas or located in a separate part of the building. Hand-washing and changing facilities should be located so that staff can use them when entering or leaving a processing room. For higher-risk ready-to-eat foods that are not heated before consumption, the building should be designed so that staff have to pass through changing and hand-washing facilities before entering the production area.

Hand-washing facilities should be located for staff to use them when entering a processing room

A laboratory is generally not needed by most small-scale processing businesses, but there should be a separate room or area for conducting quality assurance checks or check-weighing packages of finished products. This can be located adjacent to either the goods reception or the processing areas.

Utilities and services

Power supplies

Electric power sockets should be positioned close to the equipment that they serve to prevent cables trailing across the room. Ideally electrical wiring should be located above the ceiling, with cables

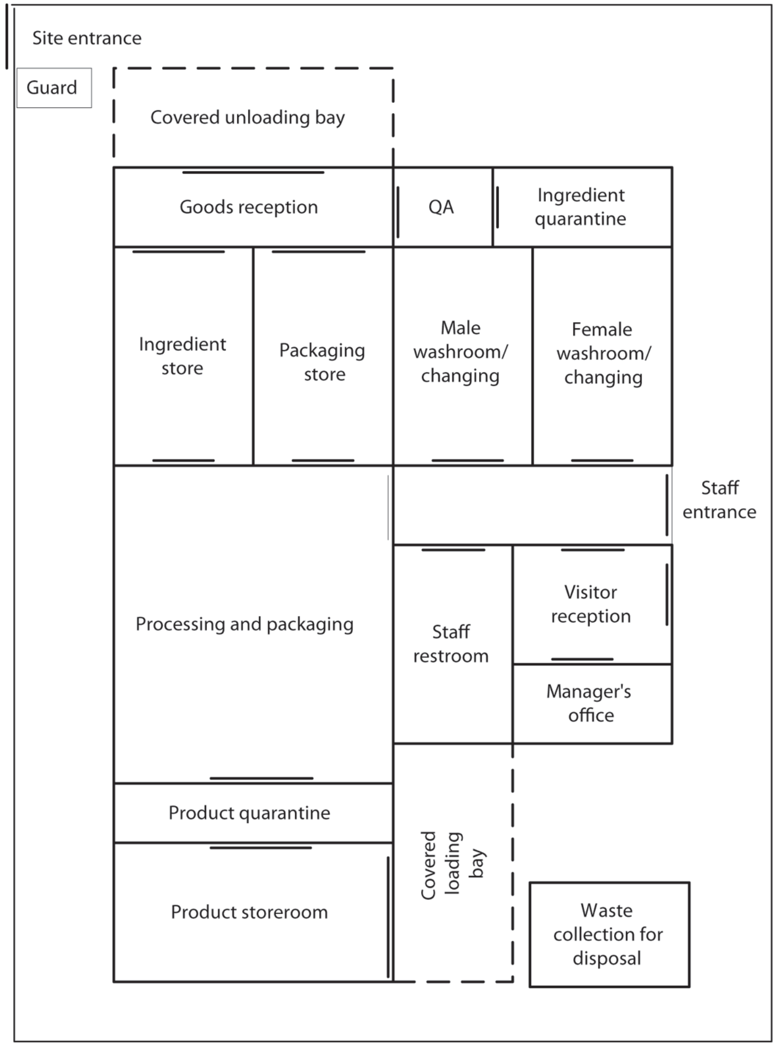

Figure 2. Example of the layout of a larger processing unit

enclosed in conduits dropping vertically down to equipment. If power points are fitted to walls, they should be placed at a sufficiently high level that there is no risk of water entering them when washing the floor or equipment. Preferably, waterproof sockets should be used. Each electric socket should only be used for one application and adaptors should not be used to power multiple machines, as they risk overloading a circuit and causing a fire.

Lighting

Natural daylight is better quality light than electric lighting and it is free. The building design should take into account the numbers and positioning of windows to enable a processing room to be adequately lit for safe working. Where electric lighting is needed, the brightness depends on the operations that take place in a particular area, with storerooms, reception areas, and staff rooms having lower light levels than processing areas. The highest lighting levels are in raw material or product inspection areas. The lights should be located above equipment and should be of sufficient number, spaced so that they do not cast deep shadows. In contrast, raw material and ingredient storerooms should not have windows because both the sunlight itself and the changes it causes to the temperature of the storeroom can accelerate deterioration of foods.

The highest levels of lighting are needed in raw material or product inspection areas

Security lighting in external areas may attract flying insects and the lights should be located to prevent insects from entering buildings. Lighting should be mounted on poles at least 10 metres from buildings with the light directed towards entrances.

Temperature control

Depending on the climate and the type of process, heating, ventilation or air conditioning may be needed to maintain the required ranges of temperature and humidity in the building. In tropical climates, design features that can be used to keep processing areas cool include overhanging roofs to shade the walls and prevent sunlight entering a room directly through windows, and having windows that face northwards. Where a process produces localized heat or steam, working conditions are made more comfortable by installing high-level screened vents, ceiling fans above working areas, or extractor fans in external walls, which both remove heat and steam and encourage a flow of fresh air through the processing room. In cooler climates, the number, location and type of heaters should be considered when designing the building so that it is heated throughout to the required temperature. All forms of heating or cooling should be designed so that any resulting air flows are directed away from the finished product area and towards the raw material preparation area, and not the other way round.

Products that are particularly sensitive to high ambient temperatures or humidities may benefit from air-conditioned processing areas and/or storerooms. These are usually independent units that are mounted on external walls. However, centralized air conditioners that use ducted air are also used. If this type of air conditioner (or blown-air heater) is used it is important to take into account the potential risks of contamination from airborne pathogenic microorganisms (especially *Listeria monocytogenes* and those causing Legionnaires' disease). Systems should be designed, installed, cleaned, and maintained so that they do not become a source of contamination. Ducting should be located outside processing areas so that any leakage cannot contaminate foods being processed.

Dust

Dust both attracts insects and risks contamination of products. The internal design features of a processing room, especially for dry processes such as milling and baking, should avoid ledges and other areas on which dust can settle: for example, window sills should slope at a steep angle (more than 45°) so that dust cannot collect on them. If dust is likely to be a serious problem the design of the room should incorporate extractor fans through an external wall to remove the dust.

Water and drainage

An adequate supply of potable water should be available in the processing unit. If provision of safe mains water is not available or not reliable, the building design should include at least two high-level storage tanks that can be filled from either boreholes or the mains supply when it is available. Water pipes should be routed so that taps are positioned where they are required, for example to clean incoming raw materials, to wash bottles, or for hand-washing.

The building design should ensure that there are an adequate number and size of floor drains and that they are appropriately located to collect spillages and washwater. The processing room should have floors that slope towards one or more drainage points so that all water drains away after equipment has been washed down. This prevents pools of stagnant water forming, which would risk insect or bacterial growth that would contaminate equipment and foods. Floor drains can also be an important source of microbial contamination, and their design and installation requires special attention to ensure that they can be cleaned and maintained in good repair. In general, drains should be designed to flow away from production or finished product areas to raw material preparation areas (not the other way round) to minimize the risk of bacteria or other contaminants being transferred to products. Facilities for water treatment should be included at the design stage if this is necessary. Storm drains should be designed and located to ensure that they can cope with anticipated storm water and prevent any water from entering the building.

Sloping floors prevent stagnant water and the risk of insect or bacterial contamination

Fuels and electricity supplies

Fuels and/or electricity are needed in temperate climates to heat buildings and most types of processing involve heating foods at some stage, even if it is only to heat water for washing equipment. The main sources of energy for heating foods are:

- electricity;
- gas (natural gas or bottled liquid petroleum gas [LPG] or biogas);
- liquid fuel oil (diesel or kerosene [paraffin]);
- solid fuels (anthracite, coal, wood, charcoal, or bagasse for sugar boiling).

Price and availability are the main factors that determine which fuel is chosen

The availability of different types of fuel varies in different countries and their relative price and availability are the main factors that determine which one is chosen. Other factors to consider are shown in Table 1.

Electricity has advantages for heating because it is clean; does not produce smoke or gases; is easy to use; and does not have the delivery or storage requirements of other fuels. It is usually more expensive than solid or liquid fuels, but in countries that have hydro-electric power generation, it may be more competitive in price. However, mains electricity may not be available in all areas or the supply may be unreliable, and in these cases the design of the processing unit may need to incorporate a diesel or petrol backup generator with fuel storage facilities.

The on-site generation of electricity and heat from a single fuel source, known as 'combined heat and power' (CHP) may have applications for small-scale processors that cannot be connected to mains power and require heat for processing. Since electricity is generated

Table 1. Advantages and limitations of different energy sources for food processing

	Electricity	*Gas*	*Liquid fuel oils*	*Solid fuels*
Cost per kJ of energy	High	Low/moderate	Low	Low
Energy per unit mass/volume of fuel (kJ/kg x 1,000)	–	1.17–4.78	8.6–9.3	5.26–6.7 (coal), 3.8–5.26 (wood)
Heat transfer equipment cost	Low	Low	High	High
Efficiency of heating[1]	High	Moderate/high	Moderate/low	Low
Flexibility of use	High	High	Low	Low
Fire/explosion hazard	Low	High	Low	Low
Risk of contaminating food	Low	Low	High	High
Labour and handling costs	Low	Low (mains gas), moderate (LPG)	Moderate	High

1 Efficiency is the amount of energy used for heating divided by amount of energy supplied
Source: adapted from Fellows, 2009

on site, processing is not affected by disruptions in the mains power supply, and the waste heat is used to produce process heat, generate steam, or heat buildings. Further cost savings and environmental benefits can be gained if CHP uses waste products (e.g. methane biogas or biomass fuels) instead of fossil fuels.

It is important that smoke, fumes, and gases that are produced by burning fuels do not come into contact with products (except of course smoked foods). The selection of a fuel therefore also depends on the amount and type of combustion products that are produced and the designs of heating equipment that are available or affordable. If mains or bottled gas is available, this is the best choice as there are fewer combustion products that would cause tainting of foods; they are flexible to use in different types of processing equipment; and the overall costs are usually lower than other fuels. The main disadvantage is the higher risk of fires and explosions. If gas is not available or affordable, charcoal, anthracite and then coal are the next best alternatives. Anthracite and coal are dense and compact, making them easier to handle and transport. Each of these fuels has a high calorific value and produces compact ash that has a lower risk of contaminating foods and is more easily disposed of than wood ash. In less developed economies, charcoal and wood continue to be important because of their lower cost and more widespread availability; but deforestation is a serious concern in many countries and there are increasingly strict restrictions on tree-felling and charcoal production. Wood also produces a light ash that can easily contaminate products; it has a lower calorific value than charcoal or coal; and it requires more labour, and hence additional costs, to prepare it for use. Once the type of fuel has been selected, it is necessary to include fuel storage facilities in the building design. These can include a separate store for solid fuels or an outside tank for liquid fuels or gas.

Other design features

If the processing unit is built on a hillside, it may be possible to take advantage of gravity to move foods through pipework, on rails or in ‘flumes’, thereby reducing energy consumption. Similarly a multiple storey building can be used to allow foods to descend by gravity through different processing stages on each floor. In tropical climates, a cellar may be constructed to produce a cooler area, either for processing (e.g. cheese ripening) or for cool storage.

Reference

Fellows, P.J. (2009) *Food Processing Technology*, 3rd edn, Woodhead Publishing, Cambridge.