8. Post-harvest processing and storage with a focus on NSA

This chapter was developed with the support of Verena_Batlogg

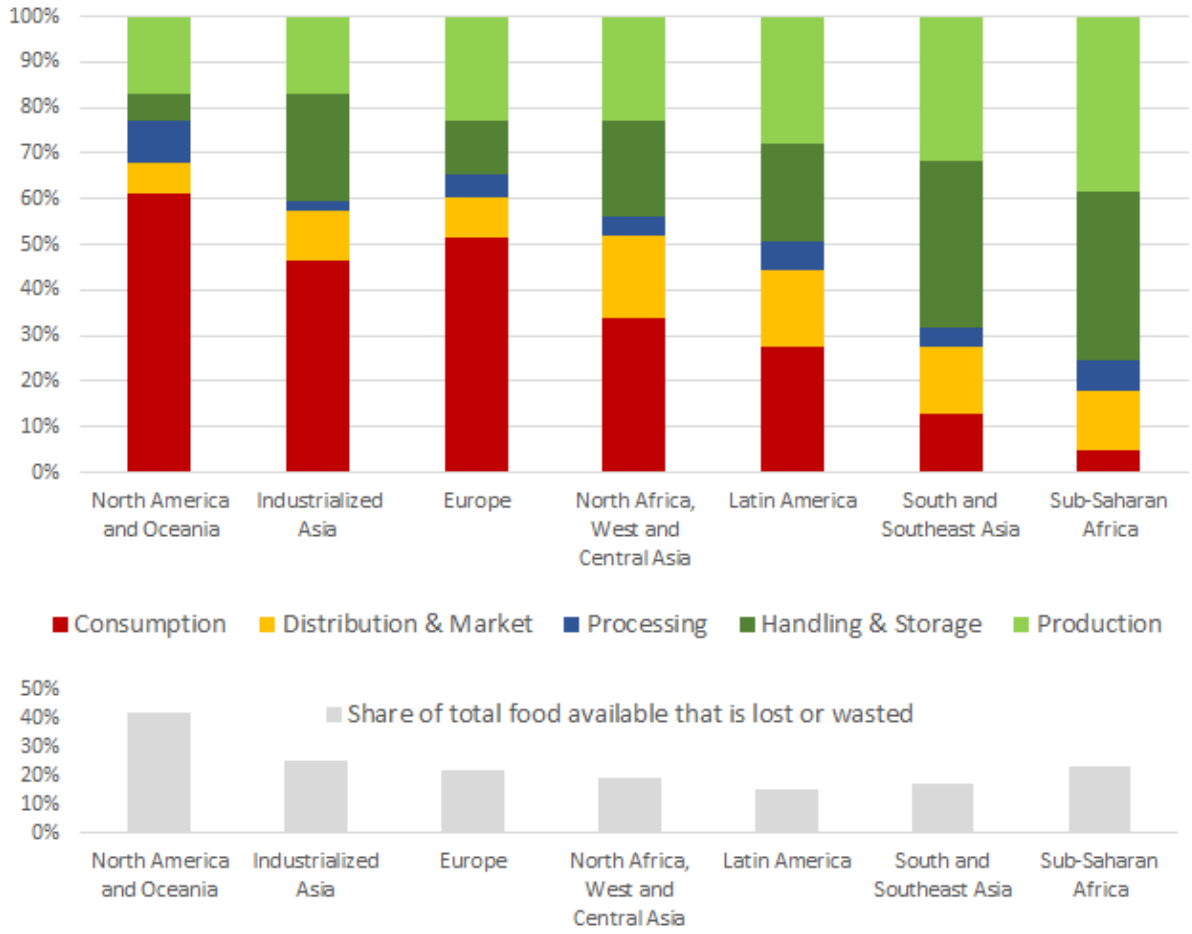
A. Importance of reducing food loss and food waste along value chains

Food loss occurs along the value chain from harvest through to the point at which food is made available to consumers. In contrast, **food waste** refers to food that is wasted by the consumers themselves. In Nutrition Sensitive Agriculture, both concepts are of greatest importance to prevent the loss of nutrients at any stage.

Roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tons — is lost or wasted (FAO, 2015). According to the FAO, food loss and waste amount to roughly US$ 680 billion in industrialized countries and US$ 310 billion in developing countries. Not only is this food not eaten and thus cannot provide any nutritional benefit to the consumer; there are also additional negative economic, environmental, and social impacts while important amounts of resources are spoilt, including water, land, energy, labor and capital.

Overall, **food loss** is of greatest importance in country contexts where postharvest handling faces logistical problems, which is often the case in poor countries and mountain areas. In contrast, **food waste** is more of an issue in industrialized countries, as the graph below shows: while over 50 % of losses in Europe and North America occur after the crop has reached the consumer (= '**food waste**'), in Sub-Saharan Africa, around 95 % of losses occur before that consumer buys the crop (= '**food loss**').

Share of wasted and lost food in different regions and continents:



Source: World Resources Institute, 2015

Further information

- SAVE FOOD: Global Initiative on Food Loss and Waste Reduction (FAO)
- Blog entry about food loss and waste from World Resources Institute (2015)
- Zero Hunger Challenge (UN)
- Technical Platform on the Measurement and Reduction of Food Loss and WTechnical Platform on the Measurement and Reduction of Food Loss and Waste (FAO)

B. Processing as a means to preserve foods and nutrients

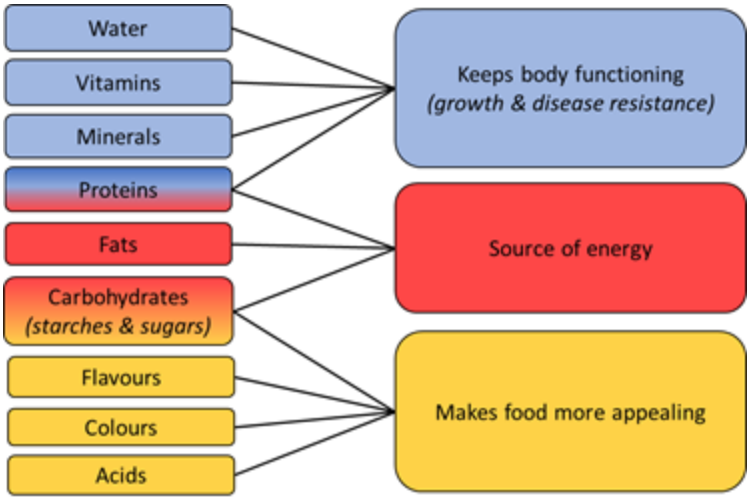
Small-scale farmers worldwide are not only involved in the production of food, but they also engage in relevant food processing activities. This is very much the case in mountain areas, where climatic conditions often involve a strong seasonality of harvests. Overall, appropriate processing is key for reducing post-harvest losses and thus increase the availability of food and thus nutrients during the whole year. As starchy foods prevail in mountain areas, one of the goals of processing must be to conserve especially micronutrient-rich foods and make them available off-season.

Food processing refers to a set of methods and techniques used at home or in processing facilities that transform raw agricultural produce into differentiated food products. Food processing may include both primary and secondary processing (FAO 2017):

- **Primary processing** serves the purpose to directly prepare food for consumption or for further processing; it includes basic cleaning, peeling, slicing, dicing, drying, milling and packaging.
- **Secondary processing** is the process whereby fresh foods or the products of primary processing are converted into other food products, often in a way that substantially alters their physical form (e.g. baking bread, making preserves).

Food preservation is one important goal of food processing. In this case, agricultural food produce is treated and handled in a way that its different food components specifically nutrients are conserved; by stopping or greatly slowing down spoilage, the shelf life of such food is prolonged and the nutritional value is enhanced (see graph below). Most common food preservation techniques includes refrigeration, freezing, fermentation, pickling, canning, and pasteurization.

Food components have different functions as part of the diet:



There are many advantages of food processing. Yet, in practice, also the disadvantages must be understood to prevent nutrient losses where possible. Both advantages and disadvantages may relate to specific processing techniques described in more detail below.

Advantages of food processing:

- Can contribute to reducing post-harvest food loss and food waste.
- Makes food available out of season (i.e. bridging of seasons when people have no or little access to their own harvests or food).
- Improves food security and provides greater nutritional balance in the diet.
- Eliminates or reduces microbes / micro-organisms / pathogens that may be harmful to human health.
- Helps reduce price fluctuations of food and reduces seasonality of food insecurity.
- Can improve the nutritional value of foods (e.g. through fermentation and germination).
- Can improve taste and functional properties of products.
- Gives the diet more variety and flavors.
- Allows for simpler and more convenient handling, transport and marketing of processed foods compared to fresh products.
- Increases the convenience and reduces preparation time for the end consumer by making semi-processed or processed foods readily available for cooking.
- Can help increase household income (i.e. access to additional farm income, especially when selling off-season).

Possible disadvantages of food processing:

- The vitamin content generally diminishes during processing and storage.
- Especially processing techniques that expose foods to high levels of heat, light, and/or oxygen tend to cause relevant nutrient losses.
- Adding large amounts of sugar, salt/sodium or fat to food ingredients during processing can be detrimental to nutrition quality because this increases the number of calories in the food while not adding any significant nutritional content (e.g. vitamins and minerals). As a consequence, a food processed in this way often has unhealthily high sodium levels (e.g. pickles, fermented vegetables) or many so-called ‘empty calories’ (e.g. fried foods, fruit preserves).
- Nutrients can be ‘washed out’ of foods by fluids that are introduced during a cooking process.
- Processes that remove the hull of grains reduce their content of vitamins, minerals and dietary fiber.
- The original taste may be altered.
- When high quality and hygiene standards during processing are not guaranteed, germs may proliferate and cause serious consequences on consumer health and safety.
- Food processing is often associated with high costs, making the food more expensive.

Further information

- Nutritional Effects of Food Processing
- Nutrition-sensitive agriculture and food systems in practice - options for intervention (FAO, 2017)
- Processed foods for improved livelihoods (FAO, 2004)
- Selecting products and processing methods - Guidelines for small-scale fruit and vegetable processors (FAO, 1997)
- Designing nutrition-sensitive agriculture investments (FAO, 2015)
- The Role of Traditional Food Processing Technologies in National Development: the West African Experience (Aworh, 2008)
- Study of traditional methods of food preservation, its scientific understanding and technological intervention (ISTP, 2014)
- Role of food processing in food and nutrition security (Augustine et al., 2016)
- Agriculture to Nutrition (ATONU)

C. Selected post-harvest processing methods and their relevance for NSA

Post-harvest processing relies on different techniques to preserve food. Below, different basic food processing, preservation and cooking techniques are described. These methods were selected because they require little or no specialized equipment and are relevant in rural, mountainous areas.

Cooking

Processing method:	Heating of food by boiling, baking, frying, roasting/grilling, steaming or smoking.
Description of method:	Food is heated using hot and dry air (e.g. in an oven), hot steam (e.g. in a steam cooker), direct contact with a hot surface (e.g. in a frying or cooking pan) or radiating heat (e.g. over an open fire).
Advantages:	• Converts nutrients into a form that is more easily digestible by the human body (e.g. starchy food such as potatoes or cereal grains, raw meat). • Produces the desired texture and flavor in food. • Kills harmful microorganisms that can lead to illness. • Destroys substances that would otherwise interfere with the digestibility of the proteins or produce toxic effects in the body (e.g. anti-nutrients found in legumes such as soya beans, lima beans, lentils and chickpeas). • In the case of heating egg whites and some fish, it makes biotin and vitamin B1 better absorbable. • Heating flour by baking increases the amount of niacin that can be utilized by the body. • Losses of protein and carbohydrate during cooking are generally small.
Disadvantages:	• Heating can destroy heat-sensitive nutrients, such as vitamin C, and to a lesser extent vitamin B1 and the other water-soluble vitamins.
Common examples:	Baking bread, cooking vegetables in soups, grilling meat, stir-frying vegetables, deep-frying dough.
Tips:	• Shortening the cooking time increases the amount of nutrients retained (" use of pressure cooker). • Water-soluble vitamins dissolve in the cooking water, so it is advisable to minimize the amount of water used to cook for examples fruits and vegetables and to not throw away the cooking water, but rather, to incorporate it into food.

Pasteurization

Processing method:	Food (usually in liquid form) is heated for a short time for the purpose of killing harmful (but not all) micro-organisms and some enzymes.
Description of method:	Two main methods: (a) batch processes in which a liquid is heated in a container to a specific temperature. Can be done easily without specialized equipment (for example: milk is heated to 63 °C and kept at this temperature for 30 minutes); (b) continuous process, in which steam is injected into a constant flow of liquid (for example, milk pasteurization equipment heats milk to 73 °C for 15 seconds before the milk is cooled down again. However, industrial equipment is necessary for this processing method.
Advantages:	• Increases safety of milk and fruits/vegetable juices by destroying microorganisms that may cause illness (by pathogens). • Slows down the spoilage of milk because microorganisms and enzymes are destroyed that contribute to a reduced quality and shelf life.
Disadvantages:	• Pasteurization appeared to qualitatively reduce concentrations of vitamins B12 and E.
Common examples:	Pasteurization of fresh milk, ice cream, fruit juices or beer.
Useful tips:	• It is always a combination of temperature and holding time that will cause the desired pasteurization effect. The higher the temperature, the shorter the holding time needs to be. • Shorter heating times result in better taste and less loss of vitamins. • To delay spoilage and nutrition loss during storage, store food in a refrigerator or cool surroundings and away from light after pasteurization. • At higher altitudes, the boiling point of water, and liquids in general, is lower (100 °C at sea level-0m, 93 °C at 2’000m, 87 °C at 4’000° C). The temperatures necessary for pasteurization, however, are not changed. • Attention: Adding larger quantities of sugar raises the boiling point (e.g. when making marmalades).

Milling

Processing method:	Grinding
Description of method:	Physical grinding process to produce flour or meal.
Advantages:	• Brings agricultural ingredients into a form which can easily be stored, and possibly further processed. • Makes the ingredients more easily digestible because they are ground into smaller pieces.
Disadvantages:	• Milling and refining processes, in which the coarse fibrous bran or seed coat of the grain is removed, results in significant nutrient losses particularly of fat (found in the germ of cereals), B-vitamins, niacin and minerals (found in the outer layers).
Common examples:	Grains, legumes
Useful tips:	Foods made from whole meal flour are better sources of nutrients than those prepared from white and refined flour.

Air-Drying

Processing method:	Reducing water content through air drying (including solar drying)
Description of method:	Moisture is removed by passing hot air past the product. Several methods exist: direct, indirect, mixed mode, natural circulation, forced circulation. Air can be ambient temperature (not specifically heated), or hot (heated, for example, by an oven or solar energy).
Advantages:	• Retains many nutrients while enabling storability of the product under ambient temperatures. • Inhibits microbial growth: drying lowers the amount of free unbound water available for microbial growth in food. Since microorganisms need certain amounts of free water for growth, their growth is halted below defined minimum levels of moisture (e.g. bacteria, yeasts and molds). • Causes a reduction in weight and volume, minimizing packing, storage, and transportation costs.
Disadvantages:	• Loss of thiamine and vitamin C. • Increased risk of damage and post-harvest loss by pests and growth of unwanted microorganisms (e.g. mold) during the drying process. • Variable quality products due to over- or under-drying. • Large areas of land or surface space on drying tables/trays may be needed for the shallow layers of food. • Slow drying in cloudy or humid weather and at night if sunlight and/or dry air are needed. The use of electric dryers produces better quality, but access to electricity is not always given and may be expensive.
Common examples:	Vegetables (tomatoes, onions, etc.), fruits (apples, berries), herbs, meats, etc.
Useful tips:	• Agricultural products, especially fruits and vegetables, require hot air in the temperature range of 45–60 C for safe drying. • Sun drying is only possible in areas where the weather allows foods to be fully dried immediately after harvest.

Fermentation

Processing method:	Anaerobic process that produces chemical changes in organic substrates through the action of enzymes
Description of method:	With enzymes, carbohydrates are degraded by producing lactic acid, to produce e.g. sour foods as pickled cucumbers, kimchi, and yogurt, as well as alcoholic beverages such as wine and beer. Under controlled conditions (e.g. temperature), the growth of ‘good microorganisms’ is encouraged while the growth of ‘bad micro-organisms’ is inhibited. Quick heating is sometimes used to end the fermentation process by killing the fermenting microorganisms (e.g. production of alcoholic beverages).

Advantages:	• Can be applied to many different types of foods. • Usually does not require any specialized equipment. • Synthesis and availability of nutrients: Fermentation can increase the availability of vitamins and minerals for human bodies to absorb. Additionally, by boosting the beneficial gut bacteria (intestines), the bacterial flora is better able to manufacture B vitamins and synthesize vitamin K. • Digestions and absorption: As some of the sugars and starches in food are broken down through the process, fermented foods are easier to digest. For example, fermentation breaks down the lactose in milk to simpler sugars (glucose and galactose) which can make products such as yogurt and cheese potentially easier to digest, which is relevant especially for people with lactose intolerance. • Immune functions: Fermented foods are rich in probiotic bacteria. So by consuming fermented foods, beneficial bacteria and enzymes are added to the intestinal flora, increasing the health of the gut (digestive system), which helps to enhance the immune system.
Nutritional disadvantages:	• Some people dislike the sour taste of fermented foods.
Common examples:	Dairy products (kefir, yoghurt, cheese); vegetables and tubers (sauerkraut and kimchi [fermented cabbage]); foufou [fermented cassava], pickles; legumes and grains (sourdough bread; miso; tempeh; injera [bread from fermented teff]); beverages (wine, beer and other alcoholic beverages; kombucha).
Useful tips:	• Use starter cultures or small amounts of a previously fermented product to start or speed up the fermentation process.

Curing and smoking

Processing method:	Application of liquids and smoke to conserve food, especially meat
Description of method:	Curing: Use of salt, acid and/or nitrates. When salt is used, the method is called ‘Salting’. During salting, the salt draws out moisture and creates an environment in which bacteria cannot grow. Smoking: Use of hot or cold smoke to dry the product and to incorporate smoke particles into the food. Cold smoking changes the color and flavor of the food, but the food is not cooked or preserved by the process. Hot smoking cooks and dries the product as well as changes the color and flavor.
Advantages:	• Can greatly increase shelf life, up to many years. • These are ancient preservation techniques, which do not require specialized equipment.
Disadvantages:	• Eating smoked products may increase the risk of cancer development in some parts of the world – especially if technology is not well applied.
Common examples:	Cured sausage
Useful tips:	Smoked meat is less likely to turn rancid or grow mold than unsmoked meat.

Pickling / canning / making preserves

Processing method:	Use of meaningful amounts of salt to preserve foods by either anaerobic fermentation in brine or immersion in vinegar.
Description of method:	Pickling is widely used to preserve meats, fruits and vegetables. The use of salt combined with vinegar effectively inhibits bacteria growth, with a pH of 4.6 or lower.
Advantages:	• Very simple technology, not requiring big investments. • The high sugar content and acidity of all preserves prevents mold growth after opening the pack, so that it can be used a little at a time.
Nutritional disadvantages:	• Increases salt content of food. • Increases the sugar content of the food (more ‘empty calories’, increased risk of cavities.

Common examples:	Chutney, escabeche
Useful tips:	Try to conserve meat, fruits, vegetables, cheese. To make pickles, cucumbers are soaked in a 10-percent salt-water brine for several days, then rinsed and stored in vinegar to preserve them for years.

Other processing methods

- Cooling and freezing (removing heat from the food) slows microbial growth. Both tend to kill some but not all microorganisms. Especially toxins are resistant to the cold and can remain active even in frozen products.
- Germination of grains and legumes in which nutritious sprouts are produced that make the nutrients in the seeds/grain more available for digestion. The sprouts are eaten fresh.
- Malting of grains and pulses can enhance their vitamin, mineral and protein content and bioavailability.
- Freeze-drying, removing moisture from a food taking advantage of cold ambient temperatures and a physical phenomenon called 'sublimation'. Ancient practice in the high Andes to preserve potatoes.

Overview table of commonly used processing methods

	Fruits	Vegetables	Grains	Meats	Milk	Legumes / Pulses
Cooking	x	x	x	x	x	x
Pasteurization	x	x			x	
Milling			x	x		x
Drying	x	x	x	x		
Fermentation	x	x	x	x	x	x
Curing & Smoking				x		
Canning, Pickling & Preserves	x	x				
Salting		x	x	x		
Cooling & freezing	x	x		x	x	

Further information

- Meat Processing technology for small to-medium-scale producers (FAO, 2007)
- Solar Drying Technologies: A review (Sontakke, 2015)
- A Review of Solar Drying of Agricultural Produce (Tiwari, 2016)
- Processed foods for improved livelihoods (FAO, 2004)
- 10 Best Benefits of Sprouting

D. Storage techniques for harvested and processed products

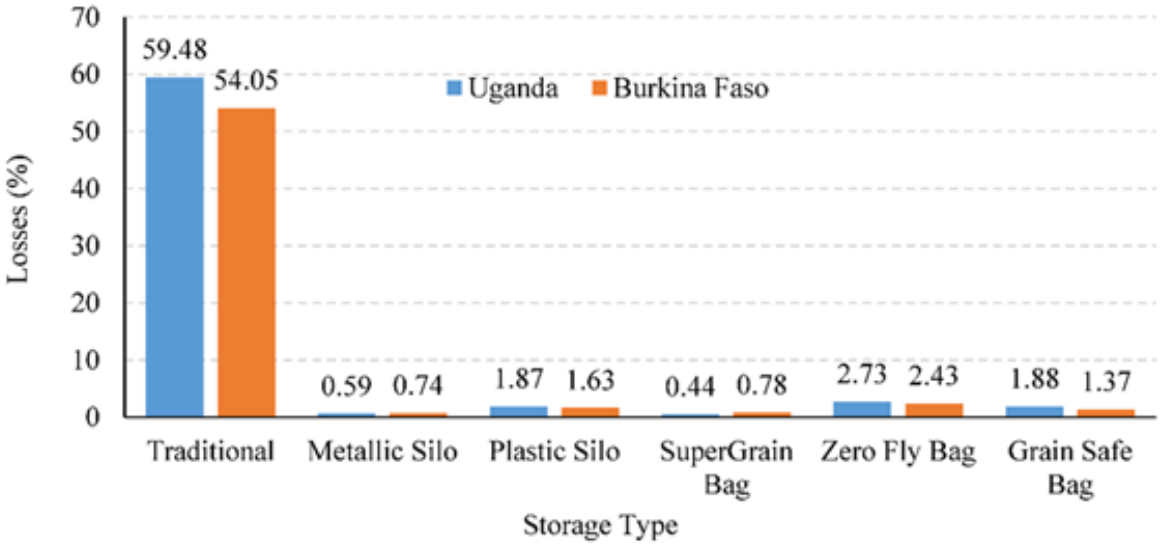
Storage techniques vary according to the type of products that need to be preserved. For instance, dried products must be packaged in airtight containers—e.g. glass or plastic bottles or sealed plastic bags—to be protected from moisture. Canned and bottled products must be kept in high-quality containers that provide good seals, protecting the products from access of air. Moreover, dried and canned or bottled products are best stored in cool, dark places.

Important is the fact that good storage cannot correct product quality deficiencies that originate from mistakes relating to the primary production, harvesting or post-harvest handling of agricultural produce. Thus, good product quality of stored food products implies attention in different areas:

- Mitigation of pests and diseases, including aflatoxins, during production and post-harvest management.
- Harvesting at maturity, avoiding damage and bruising during harvest, transport and post-harvest handling.
- Grading, washing and drying fresh produce before storage, where applicable.
- Using cool, dark, well-ventilated facilities to protect vulnerable crops against insects and rodents.
- Good planning of transportation, in order to avoid exposing harvested crops to sun and rain for too long.
- Careful storage of seed and planting materials.

As food losses can be very high in inappropriate storage facilities, it is essential to look into crop-specific improved technologies, especially when stored on-farm. Special silos or 'grain bags' can, for instance, reduce losses to a minimum and thus contribute to significant dietary improvement. Over the years, the FAO has contributed to the establishment of 45,000 small, metal storage silos—just big enough for use by a single farmer—in 16 different countries. These silos have cut food loss during the storage phase to almost zero. Even using a plastic crate instead of a plastic bag during transport can cut losses dramatically by preventing bruising and squashing.

Food losses originating from traditional storage versus improved storage techniques



Source: Manufacturer's website of the SuperGrain Bag

Further information

- Innovative Small-Scale Postharvest Technologies for Reducing Losses in Horticultural Crops (Kitinoja, 2013)
- Small Scale Postharvest Handling Practices: A Manual for Horticultural Crops (University of California - Davis, 2002)
- Farmer's Training Manual on Post Harvest Management of Sorghum, Groundnut and Rice (UNIDO)
- Rice Knowledge Bank – Post-production (International Rice Research Institute)
- How Do I Manage Storage Pests in Grains? African Organic Agriculture Manual Booklet Series (FiBL, 2011)
- Training Manual for Improving Grain Postharvest Handling and Storage (WFP, 2012)
- Post-Harvest Handling Training Manual for Extension Workers (USAID, 2012)
- Training Manual for Improving Grain Postharvest Handling and Storage (WFP, 2012)
- Quality assurance of selected commodities (FAO, 1995)
- Clay Pot Cooler for food storage (Rinker, 2004)
- Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries (Kumar and Kalita, 2017)

E. Videos of innovative experiences to improve food conservation in rural contexts

- Mexico: Solar-Powered Fridge Helps Homes without Electricity
- Uganda: Use of simple silos and training to reduce post-harvest losses
- Kenya: Post-harvest Fish Handling
- How to Build a Solar Grain Dryer & How to use it

F. Food processing glossary

Aflatoxin	Toxins produced by a mold (a type of microorganism) that grows in nuts, seeds, and legumes. These are often caused by improper post-harvest storage and processing conditions.
Enzymes	Proteins that catalyze and speed up chemical reactions. There are hundreds of different enzymes in foods, some of which cause spoilage (e.g. by causing foods to darken or develop a rancid flavor.
Food poisoning	Caused by some types of bacteria from raw materials or poor personal hygiene by people who handle foods. It can result from eating a food that has a large number of live bacteria or from poisons (toxins) produced by bacteria in the food. Some types of toxins can withstand and remain in the food after the microorganisms have been destroyed.
Food spoilage	Changes in flavor or texture, loss of color, shriveling and drying out or damage caused by pests and by microorganisms.
Microorganisms	Minute creatures that cannot be seen without a microscope. If they are present in large numbers, they are visible to the naked eye (e.g. a spot or mold on bread). Some are safe and are used in processing, but others cause food spoilage or food poisoning. In general, **yeasts** prefer more acidic and wet foods (such as fruit products), **bacteria** prefer less acidic and wet foods (such as meat, milk and fish) and **molds** are able to tolerate dry foods better (such as cereals or nots) than the other types.
Minerals	Elements in foods that our bodies need to develop and function normally. Those essential for health include calcium, phosphorus, potassium, sodium, chloride, magnesium, iron, zinc, iodine, chromium, copper, fluoride, molybdenum, manganese, and selenium.
Pathogens	Microorganisms that cause food poisoning, illness or disease.
Shelf life	The time before a processed food begins to spoil, usually expressed in days, weeks or months.
Toxins	Substances created by plants and animals that are poisonous to humans. Toxins also include some medicines that are helpful in small doses, but poisonous in large amounts. Most toxins that cause problems in humans come from germs such as bacteria. (e.g. cholera is caused by a poisonous bacteria). Other toxins that cause problems include metals, such as lead, and certain chemicals in the environment.
Vitamins	Substances that our bodies need to develop and function normally. They include vitamins A, C, D, E, and K, choline, and the B vitamins (thiamin, riboflavin, niacin, pantothenic acid, biotin, vitamin B6, vitamin B12, and folate/folic acid).

Source: Adapted from Medlineplus U.S. National Institute of Health website