THE FUTURE OF THE WESTERN CAPE AGRICULTURAL SECTOR IN THE CONTEXT OF THE 4TH INDUSTRIAL REVOLUTION

Review: Conservation Technology

October 2017

University of Stellenbosch Business School

Table of Contents

1. Technology Overview and Detailed Description

Food preservation is a process of maintaining the original quality or existing state of food by treatment(s) that will prevent its spoilage or deterioration[1]. It implies putting microorganisms in a hostile environment to cause their death[2].

The term **food preservation** refers to any one of several techniques used to prevent food from spoiling. The following are the general methods of food preservation:

- **application of heat**, such as canning and preserving, pasteurization, evaporation, sun-drying, dehydration and smoking,
- **application of cold**, as ill cold storage, refrigeration and freezing,
- the **use of chemical substances** such as salt, sugar, vinegar, benzoic and lactic acids,
- **fermentation**, examples being acetic, lactic, alcoholic,
- such **mechanical means** as vacuum, filtration and clarification processes, devices or agents for preventing chemical deterioration or bacteriological spoilage (the use of oil, paraffin and water glass are included here),
- **natural preservation** techniques,
- **controlled atmosphere** techniques (containers),
- **combinations** of two or more of the above.

2. Application Examples and Case Studies

Annexure 2 is a summary of food preservation examples, the principles behind their function, and examples of application, as reported in the literature[3,4,5,6,7,8,9,10,11].

3. Technology or Application Life Cycle: Current Status and Expected Development in 2020 and 2050

Table 1: Life Cycle

Technology Area	Current application in agriculture	Expected applications in agriculture by 2020	Expected applications in agriculture by 2050
Food preservation	Extension of shelf life of food	One-person food packages	3-D printing of food

4. Business Eco-System View

Conservation Technology overlaps with other technologies, namely:

- 3D printing
- 4D printing
- Smart materials

- Genetics and Biotechnology
- Nanotechnology
- Sensor technology
- Transport technology

5. Benefits and Risks

The benefits and risks documented for the use of food preservation technologies are indicated below.

Benefits[12]

The main benefit of conservation the application of food conservation technologies the inactivation of food-borne pathogens, natural toxins and enzymes as is normally required by Food Safety Legislation in all jurisdictions of the globe.

Other key benefits of food conservation extracted from the literature are:

- To prolong the shelf-life of food;
- To facilitate improved digestibility and bioavailability of nutrients (increase nutritional value);
- To improve sensory quality, such as taste, texture and flavour for the consumer;
- To exploit the functional health benefits of food, and gain access to the benefits of probiotics, prebiotics, Maillard reaction products (MRPs), flavonoids, for example;
- To introduce diversity into diets, and reduce dependence on the seasonal availability of foods;
- To reduce time to prepare and supply food to the market.

The functional roles of selected food components are tabulated below in Table 2 to illustrate the benefits to mankind, especially in maintaining product consistence and quality:

Table 2: Functional roles of selected food types

Component	Function	Outcome
Emulsifiers	give products a consistent texture and prevent them from separating.	**To maintain product consistency**:
Stabilizers and thickeners	give smooth uniform texture	
Anticaking agents	help substances such as salt to flow freely	
Vitamins and minerals	added to many common foods such as milk, flour, cereal and margarine to make up for those likely to be lacking in a person's diet or lost in processing.	**To improve or maintain nutritional value:**
Preservatives	retard product spoilage caused by mould, air, bacteria, fungi or yeast. Bacterial contamination can cause food borne illness, including life-threatening botulism	**To maintain palatability and wholesomeness:**

Component	Function	Outcome
Antioxidants	preservatives that prevent fats and oils in baked goods and other foods from becoming rancid or developing an off-flavour; prevent cut fresh fruits such as apples from turning brown when exposed to air.	
Leavening agents	help cakes, biscuits and other baked goods to rise during baking by releasing acids when reacting with baking soda	**To provide leavening or control acidity/alkalinity:**
Spices	enhances the taste of foods.	**To enhance flavour or impact desired colour**
Colours	enhance the appearance of certain foods to meet consumer expectations.	

Risks/Disadvantages[13,14,15]

- Sulphites (used in the fruit industry) cause headaches, palpitations, allergies, and even cancer;
- Nitrates and Nitrites (used as curing agents in meat products) can be converted into nitrous acid, a suspected stomach cancer agent;
- Benzoates (used in foods as antimicrobial preservatives), and have been suspected as causal agents of allergies, asthma and skin rashes.
- Sorbates/sorbic acid (are also added to foods as antimicrobial preservatives), and rare reports urticaria and contact dermatitis have been documented;
- Nuclear radiation as a preservative does not make foods radioactive, causes changes in food colour and texture, sensory changes, decrease in nutritional contents such as vitamins (thiamine);
- Consumer reluctance to consume food preserved using radiation losses of certain (essential) nutrients due to chemical reactions (e.g. vitamin C, available lysine);
- formation of undesired compounds, e.g. acrylamide, acrolein chloro-propanediols and chloro-esters, heterocyclic amines;
- in some cases, formation of compounds that have a negative effect on flavour perception (for instance, sulphur compounds formed during heating of milk)[16]
- loss of texture and discolouration

6. Potential Economic, Social, Ecological and Political Developments and Impacts

Economic Developments and Impacts

Eighty percent of global agricultural land is used to produce grain to feed meat animals and yields only 15% of human calorie intake. It has been suggested that world food shortages could be greatly reduced by consuming less meat and consuming the grain supplies consumed by animals. If developed nations consume much less meat, the price of meat will fall, and poorer nations will consume more. If more grain is consumed, grain prices will rise, to the detriment of populations that already rely heavily on grain[17].

Social developments and impacts

Continued improvements in food and beverage processing and packaging to deliver safe, nutritious, and affordable food have been suggested as credible solutions to meeting the challenge of food demands for future populations[18].

In the developing world, about 795 million people were undernourished in 2014[19]. However, with modern technologies in food preservation being developed and applied, this is set to decline. This is more the case when technologies are developed, and are applied to reduce the cost the food, so that poorer nations can afford such food, with the appropriate nutritional value.

Ecological (Environmental) Developments and Impacts

Conservation technology has the potential to address the effects of climate change by reducing postharvest losses and waste. This is relevant to developing nations, whose losses are more than 50%, and, coupled with climate change effects on agricultural production levels, the availability of food would pose as a threat to social and political stability.

Political Developments and Impacts

Declines in household incomes from the global economic downturn has been exacerbated by high food prices in developing countries[20]. The response of governments will be to review policies around food security, influenced by food subsidies, improving technologies, the economic environment and price changes.

Annexure 1 illustrates the alignment of Conservation Technologies with the key policy mandates of DAFF, articulated in the NDP, and APAP, and illustrates where biorefineries and biofuels, and possibly technologies of the future may be used to support the delivery of the South African government's proposed interventions as articulated in the APAP.

7. Conclusions, synthesis and key trends from the literature

- Consumer perception of (mainly industrial) processing is rather negative, probably due to the large attention paid to the formation of undesired compounds.
- A clear understanding of the mechanisms underlying the biological effect is essential, so that the intended beneficial effect in the food product can be obtained. If such

knowledge becomes available, modern technologies may provide new opportunities to deliver health, quality and safety in food systems.

- The translation of consumer perceptions (particularly flavour, texture and the presence of health promoting components) into manageable industrial scale technologies is a major challenge for the food industry, as it limits the extent to which the current science underpinning modern food-processing technology is understood and applied.
- A better understanding of the relevance of in vitro results for human health benefits is needed.
- There is an overall lack of information databases about how foods are processed, with respect to:
    - The translation of antioxidant capacity *in vitro* to health beneficial effects in humans.
    - The effects of processing on protein digestibility, notably the effects on allergens.
    - The effects of non-thermal processes on phytochemicals, melanoidins and allergens[21].

Annexure 1: Food preservation technologies: principles, methods and application examples

Purpose	Method	Examples, application, principle of preservation
Inhibition	Storage at low temperature	Refrigeration temperature lowers the growth rate of micro-organisms and chilling can slow down the enzymatic and microbial changes in food.
	Reduction in water activity	Inhibits microbial growth by drying or by additions of solutes (sugars, spices, or salts)
	Decrease of oxygen	Anaerobic condition means a condition lack of or containing only a minimum amount of air or oxygen, and can prevent the surviving bacteria in food from growing in the container.
	Increase of carbon dioxide	Carbon dioxide is a form of enriched modified atmosphere in a packaging. When using carbon dioxide as a method of preservation, there is specific inhibition of some micro-organisms, through slowing down bacterial growth by displacing the oxygen.
	Acidification	Use of acids (vinegar or citric acid), which lower the pH and thus inhibiting the growth of many micro-organisms, and is more effective against yeast and bacteria than moulds. About 20% vinegar (acetic acid) prevents the spoilage of most products, and is used in the preservation of pickles, sauces and chutney. Citric acid, is also used in the preservation of certain fruits and vegetables, jams, jellies and squashes, by lowering the pH of the food products and can prevent the growth of moulds.
	Fermentation	Fermentation is a naturally occurring chemical reaction by which a natural food is converted into another form by pathogens. It is a process in which food spoils, but results in the formation of an edible product, e.g. cheese and bread.
	Adding preservatives	Sodium benzoate and benzoic acid, calcium, sodium propionate, propionic acid, calcium, potassium, sodium sorbate, and sorbic acid, sodium sulphite, potassium sulphite, calcium, sodium ascorbate, and ascorbic acid (vitamin C) may be added to food in various combinations to prevent food spoilage by preventing the growth of mould, yeasts and bacteria.
	Adding antioxidants	BHA (butylated hydroxyanisole) and BHT (butylated hydroxytoluene) prevent chemical reactions which cause the oxidation of food, and therefore its spoilage.
	Control pH	The ideal pH for the growth of micro-organisms is pH 6-8. Maintaining pH at either extremes of this range controls, by limitation, the growth of microorganisms
	Freezing	Pathogens that cause food spoilage are killed or do not grow very rapidly at reduced temperatures, but there is the risk that organisms are reactivated when frozen food is thawed.
	Drying	Controlled temperature air drying is especially popular for the preservation of grains such as maize and barley. In vacuum drying, air is removed, and enzymes that cause oxidation of foods are inhibited. Freeze-drying makes use of the physical principle known as sublimation, the process by which a solid passes directly to the gaseous phase without first melting. Freeze-drying is a desirable way of preserving food because at low temperatures (commonly around –10°C to –25°C) chemical reactions take place very slowly and pathogens have difficulty surviving. Spray drying is the process

Purpose	Method	Examples, application, principle of preservation
		during which concentrated solution of foods like coffee in water is sprayed through a disk with many small holes in it. The surface area of the original coffee grounds is increased many times, making dehydration of the dry product much more efficient
	Concentration	By the partial elimination of water, the preservation of the food is enhanced, but not sufficient, and must be combined with other preservation treatments, such as the addition of chemicals (like sugar or salt), or “hot methods” as pasteurization or sterilization. In the manufacturing of jam, the main techniques are (1) Concentration by evaporation, (2) Cryoconcentration, and (3) Concentration by membrane technologies
	Surface coating	The food packaging can be sanitized on the surface by using vapours of hydrogen peroxide (H_2O_2).
	Structural and chemical modifications	Sequestrants are compounds that "capture" metallic ions, such as those of copper, iron, and nickel, and remove them from contact with foods. The removal of these ions helps preserve foods because in their free state they increase the rate at which the oxidation of foods takes place. Some examples of sequestrants used as food preservatives are ethylenediamine-tetraacetic acid (EDTA), citric acid, sorbitol, and tartaric acid.
	Gas removal	Carbon dioxide (CO_2), nitrogen (N_2) or their mixtures are the most widely used gases to create a modified atmosphere. By removing or displacing the oxygen, the microbial growth is slowed.
	Hurdle technology	This is a method of rendering the food to be free from contaminating and spoilage bacteria and pathogens by the combination of one or more methods. The pathogenic microorganisms must pass through these individual approaches called “hurdles” for maintaining their activity in food products. Proper combination of hurdles will lead to destruction of the microbes and can prevent their further growth. An example: processing at elevated temperature, storage at low temperature, lowering pH (increasing acidity), lowering water activity (a_w) and/ or redox potential including the presence of bio-preservatives or other preservative components in food products has been shown to be effective.
Inactivation	Sterilization	Sterilisation is the application of temperature at 100°C or above, or the application of radiation to kill micro-organisms. The time and temperature necessary for sterilisation vary with the type of food.
	Pasteurization	Milk, for example, can be "flash-pasteurized, by raising its temperature to about 71°C for a minimum of 15 seconds (HTLT). In ultra-high-pasteurization, even higher temperatures, of the order of 90–130°C, for periods of a second or more are used (HTST)
	Irradiation	Food absorbs and is heated up by radiant energies. In this process, radiation can kill microorganisms without marked increase of temperature as well as marked changes food composition. Examples of radiation are gamma rays, x-rays, electromagnetic, ultra-violet radiations, commonly used for food preservation, over a wide spectrum of food types.
	Electrification	Pulsed electric field (PEF) treatment is based on the delivery of pulses at high electric field intensity (5-55 kV/cm) for a few milliseconds, and is applied fruit juice and liquid eggs.

Purpose	Method	Examples, application, principle of preservation
	Pressure treatment	Food treated with high-pressure processing (HPP) is exposed to a high hydrostatic pressure (up to 1000 MPa) for a few minutes (fruit juice, salad dressing)
	Blanching	The vegetables are subjected to "BLANCHING" or burn, a very short cooking that inactivates the enzymes that could alter the food quality.
	Cooking	Most harmful pathogens are killed at temperatures close to the boiling point of water.
	Frying	Like heat application, using oils. The result is often a physically-altered product
	Extrusion	Food extrusion is generally considered a high-temperature, short-time (HTST) process. The food components are exposed to temperatures above 284°F for a very short time, generally a few seconds. This process pushes a material through a specially engineered opening to give a desired shape and texture through increases in temperature, pressure, and shear forces. Examples of traditional extruded foods are pasta, noodles, vermicelli, and breakfast cereals.
	Light	Use of ultraviolet light to destroy microorganisms on food surfaces
	Magnetic field	The application of magnetic field to decrease microbial count in food.
Prevention of recontamination	Packaging	Canning: a process in which over 100°C is used for killing all spoilage organisms and their spores as well as inactivating enzymes and thereafter, sealing in sterile airtight containers.
	Hygienic processing and storage	Packaging materials such as polyvinyl chloride (PVC), and polypropylene (PP) offer low moisture permeability. Similarly, packaging materials with low gas permeability are used for fatty foods to minimize oxidation reactions. Because fresh fruits and vegetables respire, they require packaging materials, such as polyethylene (PE), that have high permeability to gases.
	Aseptic processing	Aseptic processing and packaging of low-acid foods is a complex food manufacturing process. This is the continuous sterilization of food in bulk, followed by cold-aseptic packaging, in sterile containers. It requires careful control at all stages of production to produce and maintain the asepsis of the food processing, filling and packaging systems. The control system embraces many operations which are inter-related.
	HACCP	Quality and safety management processes, which are audited.
	GMP	
	ISO 9000	
	TQM	
	Risk analysis and management	

End Notes

[1] International Food Information Service (IFIS). 2005. *Dictionary of food science and technology.* Oxford: Blackwell Publishing.

[2] Oladapo, A.S., Akinyosoye, F.A. & Abiodun, O.A. 2014. The inhibitory effect of different chemical food preservatives on the growth of selected food borne pathogenic bacteria. *African Journal of Microbiology Research*, **8**(14), 1510-1515.
[3]. Hoover, D.G., Metrick, C., Papineau, A.M., Farkas, D.F. & Knorr, D. 1989. Biological effects of high hydrostatic pressure on food microorganisms. *Food Technology,* **43**, 99-107.
[4]. Smelt, J.P.P.M. 1998. Recent advances in the microbiology of high pressure processing. *Trends in Food Science and Technology,* **9**, 152-158.
[5] Gervilla, R., Ferragut, V. & Guamis, B. 2000. High pressure inactivation of microorganisms inoculated into ovine milk of different fat contents. *Journal of Dairy Science,* **83**(4), 674-682.
[6] Qin, B.L., Pothakamury, U.R., Barbosa-Canovas, G.V. & Swanson, B.G. 1996. Nonthermal pasteurization of liquid foods using high-intensity, pulsed electric fields. *Critical Reviews in Food Science Nutrition,* **36**(6), 603-627.
[7] Gervilla, R., Ferragut, V. & Guamis, B. 2000. High pressure inactivation of microorganisms inoculated into ovine milk of different fat contents. *Journal of Dairy Science,* **83**(4), 674-682.
[8] Jeantet, R., Baron, F., Nau, F., Roignant, M. & Brule, G. 1999. High intensity pulsed electric fields applied to egg white: Effect on Salmonella enteritidis inactivation and protein denaturation. *Journal of Food Protection,* **62**(12), 1381-1386.
[9] Alasalvar, C. 2010. *Seafood quality, safety and health applications*. Hoboken, NJ: John Wiley and Sons.
[10] Ganguly, S. 2012. *Food microbiology.* Saarbrücken: LAP LAMBERT Academic Publishing GmbH & Co. KG.
[11] Abdullahi, N., Ariahu, C.C. & Abu, J.O. 2016. Critical review on principles and applications of hurdle technology in food preservation. *Annals of Food Science and Technology,* **17**(2), 485-491.
[12] Inetianbor, J.E., Yakubu, J.M. & Ezeonu, S.C. 2015. Effects of food additives and preservatives on man: A review. *Asian Journal of Science and Technology,* **6**(2), 1118-1135.
[13] Kinderlerer, J.L. & Hatton. P. 1990. Fungal metabolites of sorbic acid. *Food Additives and Contaminants*, **7**(5), 657-669.
[14] John, E.M. 2003. Ionizing radiations sources, biological effects. *Emission and Exposures,* **83**, 1766.
[15] Sharma, S. 2015. Food preservatives and their harmful effects. *International Journal of Scientific and Research Publications,* **5**(4), 1-2
[16] de Wit, R. & Nieuwenhuijse, H. 2008. Kinetic modelling of the formation of sulphur-containing flavour compounds during heat-treatment of milk. *International Dairy Journal,* **18**, 539-547.
[17] Stokstad, E. 2010. Could less meat mean more food? *Science,* **327**(5967), 810-811.
[18] Floros, J.D., Newsome, R., Fisher, W., Barbosa-Cánovas, G.V., Chen, H., *et al.* 2010. *Feeding the world today and tomorrow: The importance of food science and technology.* [Online] Available: https://www.ift.org/knowledge-center/read-ift-publications/science-reports/~/media/Knowledge%20Center/Science%20Reports/IFTScientificReview_feedingtheworld.pdf [Accessed: 2 November 2017].
[19] The United Nations Food and Agriculture Organization. 2015. *The state of food insecurity in the world.* [Online] Available: http://www.fao.org/3/a-i4030e.pdf [Accessed: 31 October 2017].
[20] Fanzo, J., Pronyk, P., Dasgupta, A., Towle, M., Menon, V. & Denning, G. 2010. *An evaluation of progress toward the millennium development goal one target: a country-level food and nutrition security perspective.* New York, NY: UNDG.
[21] Van Boekel, M., Fogliano, V., Pellegrini, N., Stanton, C., Scholz, G., *et al.* 2010. A review on the beneficial aspects of food processing. *Molecular Nutrition & Food Research,* **54**(9), 1215-1247.