Lacto fermented vegetables and their potential in the developing world

SIMON GORMAN

Lacto fermentation is an ancient method of food preservation that, with greater control over the process, has great potential as a low-cost, low-energy and culturally acceptable method of improving food security and nutrition in developing countries. It prevents the growth of most food-borne pathogens and obviates the need for pasteurization or the addition of preservatives. In some cases lacto fermentation can also reduce or remove naturally occurring toxins and anti-nutritional compounds in certain raw fruits and vegetables.

Keywords: Lacto fermentation, starters, fermented vegetables, food preservation, food security

In a study for FAO, Battcock and Azam-Ali (1998) state:

> Fermentation is a relatively efficient, low-energy preservation process which increases the shelf life and decreases the need for refrigeration or other forms of food preservation technology. It is therefore a highly appropriate technique for use in developing countries and remote areas where access to sophisticated equipment is limited.

Fermentation increases the shelf life of a product without the need for refrigeration

When the fermentation process is successful, the resulting fermented foods are stable and safe (Breidt, 2005), and can be stored in a cool, dark place for an almost unlimited time. However, traditional lacto fermentation is normally an uncontrolled process, and the results are often unpredictable and inconsistent. Consequently, it is not always possible to rely on the shelf life, nutritional value or safety of the foods produced in this type of uncontrolled process. This paper describes the possible ways that the process of lacto fermentation of vegetables may be adapted and controlled, based on scientific and technological developments, in order to realize its full potential to benefit large numbers of people in developing countries. These benefits include

Simon Gorman (simongorman1@gmail.com) is the Director of International Development at Vitality Foods Ltd, responsible for promoting the application of science to the traditional practice of lacto fermenting vegetables in the developing world and the private sector (www.vitalityfoods-eu.com).

doi: 10.3362/2046-1887.2011.007 ISSN: 2046-1879 (print) 2046-1887 (online)

the potential to preserve food safely; prevent food wastage; improve nutrition; and provide additional income to farmers or processors.

History and background

Even before cultivating vegetables, people fermented wild plants

Lacto fermentation has been used to preserve food by many peoples throughout history, in all parts of the world. Even before cultivating vegetables, man fermented wild plants. Lacto fermented cabbage was known in ancient China, and served as a staple food for those employed in building the Great Wall of China (Yokotsuka, 1985). Captain Cook's sailors were fed fermented cabbage on their voyages, since it was well known at that time as an effective way to prevent scurvy.

Today, sauerkraut is a national staple food in Germany, and is also widely consumed in the USA. Many people, in particular the Koreans, Japanese and Northern and Central Europeans, use lacto fermentation as a practical method of preservation, as well as for the particular flavour that the process gives to foods. Other examples of traditional fermented vegetable products include:

- pickled cucumbers, red cabbage, beets and rutabagas: fermented vegetables from Germany and Northern Europe;
- *gundruk*: a fermented dried vegetable from the Indian sub-continent;
- *bai-ming*, *leppet-so* and *miang*: fermented tea leaves from South-east Asia;
- *kimchi*, *dan moogi*, *kachdoo kigactuki*, *kakduggi*, *mootsanji*, *oigee*, *oiji*, and *oiso baegi*: fermented vegetables, fruits and vegetable seeds from East Asia;
- *lamoun makbouss*, *mauoloh* and *msir*, *mslalla*: pickled fruits and vegetables from Africa;
- *kushuk*: a fermented vegetable dish from the Middle East.

Raw fermented foods are known to contribute to health and prevent disease

With the development of pasteurization, canning and freezing as methods of preservation, the traditional technique of lacto fermentation has fallen into disuse in most developed countries. However, raw fermented foods are empirically known as an important factor contributing to health and disease prevention, and researchers throughout the world are currently examining the scientific basis for the therapeutic qualities of such foods. Table 1 compares the attributes of fresh cut vegetables, regular commercial pickles and raw lacto fermented vegetables.

Table 1. Product comparison

Attribute	*Fresh cut vegetables*	*Commercial pickles*	*Raw lacto fermented vegetables*
Storage	Chilled	Ambient	Chilled or in cool, dark place
Post-processing shelf life	Short	Long	Long
Additives	None	Sometimes	None
High value by-products	No	No	Yes, fermented juices
Cooked/pasteurized	No	Yes	No
Salt content	None	High	Medium
Contains lactic acid bacteria	No	No	Yes
Image	Healthy	Processed	Healthy with nutritional benefits

Nutritional benefits

Freshly harvested vegetables contain fibre, minerals, trace elements and vitamins, the last of which are often destroyed or significantly damaged by commercial processing. Raw vegetables that are lacto fermented retain all these components, and also contain active enzymes, live lactic acid bacteria and lactic acid. Numerous health benefits have been associated with fermented vegetables and their lactic acid bacteria (Parades-Lopez, 1992; Svanberg and Lorri, 1997; Lee, 1997; Kovac, 1997). While many health claims have yet to be demonstrated clinically, various scientific and government bodies around the world endorse the ‘functional’ properties of fermented foods (benefits other than the nutrients required for normal health). Live lactic acid bacteria are claimed to:

- contribute to the protection of the body against certain infections and stimulate the immune system;
- ease the digestion process by regulating the level of acidity in the digestive tract through stimulating the production of beneficial intestinal flora;
- generate antioxidant molecules;
- have a soothing effect on the nervous system;
- facilitate the synthesis of B-group vitamins (B_1, B_2, B_{12}, folic acid) and slow the degradation of vitamin C;
- facilitate the breakdown of proteins and hence their assimilation, by producing proteases.

Live lactic acid bacteria are claimed to have a number of health benefits

Fermented vegetables are often recommended for people suffering from diabetes, since the sugar content of the vegetables is reduced by lactic acid bacteria when it is converted to lactic acid. They are also an important component of yeast-free diets, for example, recommended in the case of candidiasis. It has become standard practice for commercial producers of sauerkraut and other fermented vegetables to pasteurize their products, or to add chemical preservatives to increase their stability and extend their shelf life for wider distribution. Some manufacturers even forgo the fermentation stage altogether, opting to use vinegar or added lactic acid instead. These short cuts may offer economies for large-scale production, but result in inferior products that are devoid of live bacteria and active enzymes, and lack the distinctive taste and texture of the traditional raw fermented versions.

Production process

Traditional lacto fermentation relies on naturally occurring beneficial bacteria, the lactobacilli, which are similar to cultures used to make yoghurt and sourdough bread. Lactobacilli break down the sugars in fruit and vegetables and produce lactic acid, which acts as a natural preservative. First, fresh fruits or vegetables are washed and cut into pieces. They are then mixed with a small amount of sea salt, which draws out the juices, preserves the fruits or vegetables while the fermentation gets started and helps to regulate the fermentation process. The mixture is then packed into airtight fermentation vessels and placed in a warm place to ferment. The optimum temperature range depends on the bacteria strains that are active in the fermentation of the selected vegetable, and the required result. For cabbage, carrots, beets and the like, the ideal temperature is 19°C, a mid-point for the preferred temperatures of the three strains involved. Cucumbers are fermented as rapidly as possible at 26–29°C in order to favour homofermentative bacteria to reduce the risk of bloating associated with overproduction of CO_2 by *Leuconostoc* bacteria. *Kimchi* is fermented at 10–15°C to favour *Leuconostoc* over *Lactobacillus* in order to achieve a less acidic product with a pH of no less than 4. The final acidity at the end of a successful fermentation is ideally in the pH range 3.2–3.6, thus effectively inhibiting pathogenic bacteria, and preserving the vegetables for out-of-season use. Once the initial fermentation is finished and the desired acidity is achieved, the products can be left in the fermentation vessels, or repackaged into smaller airtight containers, and transferred to a low temperature area (for cabbage this would be 4–6°C) for a period of maturation and storage. If the process is correctly controlled, the final products are stable and safe, and can be kept in a cool, dark place for an almost unlimited time.

The optimum temperature range depends on the bacterial strains that are active, and the required result

If the process is correctly controlled, the final products can be kept for an almost unlimited time

Challenges

The quantity of naturally occurring bacteria that are present on the surfaces of fresh fruits and vegetables can vary for many reasons. Traditional lacto fermentation is therefore an uncontrolled process, and the results are often inconsistent. The outcome depends on the available levels of these bacteria, and on several other factors that can affect the quality, consistency and safety of the final product, including:

- vegetable freshness and quality;
- fermentation time;
- temperature;
- salt quality and content;
- secondary fermentation (after the product is packaged) causing swelling and 'fizziness'.

In order to ensure that lacto fermentation provides a consistent supply of safe and nutritious food, it is essential to ensure that the fermentation is correctly regulated.

Solutions

Stabilization and control of traditional lacto fermented vegetable production requires a scientific approach, and microbiologists at major research centres worldwide, including the Food Research and Development Centre (FRDC) of Agriculture and Agri-Food Canada, are continuing to study the complex workings of traditional lacto fermentations of vegetables and fruits. The research has found that an important requirement is to use a mixed-strain starter culture that contains the appropriate bacterial strains for vegetable fermentation in the correct proportions. The ideal mixed-strain starter culture for vegetables should comprise three specific bacteria strains, which are isolated from vegetable ferments rather than the more common dairy origin. This provides a critical 'boost' to the fermentation process, helping to regulate and stabilize it. The FRDC has developed a number of mixed-strain bacterial starter cultures, one of which has been patented. These starter cultures, together with precisely controlled fermentation techniques and conditions, result in the following benefits:

> A mixed-strain starter culture is important for vegetable fermentation

- shortened fermentation time;
- reduction or elimination of secondary fermentation;
- reduction of salt levels compared with commercial pickles;

- retention of the flavour, colour and texture of traditionally fermented vegetables, as well as all their important health benefits;
- consistent, stable production on a small or large scale;
- products that are safe, nutritious and stable for extended periods of time when stored in appropriate conditions.

Introducing controlled fermentation requires development of specific starter cultures and appropriate procedures for particular vegetables in each area

Some of the advantages of using an appropriate starter culture for fermenting vegetables are listed in Table 2.

The techniques and procedures developed at the FRDC have been tested in a commercial environment for over 15 years. Currently these starter cultures and procedures are used to control the fermentation of vegetables generally consumed in the West, such as white and red cabbage, carrots, and beets, and to make the Korean dish, *kimchi*. Extending the benefits of controlled fermentation to regions of the developing world requires development and testing of the specific starter cultures under controlled scientific conditions and development of procedures that are appropriate to the particular vegetables that are normally produced and consumed in each area. Additional training compared with local, traditional methods is needed to implement and control the process.

Table 2. Comparison of fermentations with and without starter cultures

Attribute	*Without starter culture*	*With appropriate mixed-strain starter culture*
Fermentation type	Spontaneous	Controlled
Optimal fermentation time	21–30 days	7 days
Optimal maturation time	3–6 months	2 months
Acidification rate	Variable, slow (> 3 days to pH 4.0)	Fast (< 1 day to pH 4.0)
Final pH	3.2–3.6	3.2–3.6
Salt level	2.0–2.5%	1.8%
Stability (chilled)	Variable	1 year shelf life
Final yeast levels	Variable	Below detectable limits
Secondary fermentation	Frequent	Rare
Lactic acid/acetic acid ratio and concentrations	Variable	Fixed
Taste, colour and texture	Variable	Consistent
Vitamin C levels	Reduced by 50%	100% retained
Safety	Need pasteurization or preservative chemicals	Safe without heat or preservatives

Potential in the developing world

Stabilization and control of the lacto fermentation process for vegetables can greatly enhance food security in developing countries by:

- *Preserving food safely and at low cost*. Many vegetables deteriorate quickly after harvest, especially in warm regions. Alternative preservation methods are not always suitable for small-scale use in developing countries (e.g. the risk of contamination by botulin during canning or the high cost and impracticality of canning and freezing).
- *Preventing waste*. Excess produce can be fermented and preserved instead of being left to rot. Vegetables that are sound but unmarketable due to their shape, size, markings or colour can be fermented. Foods that would not normally be usable for human consumption can be fermented to make them digestible (Battcock and Azam-Ali, 1998).
- *Improving the health of people in disadvantaged areas*. The nutritional value of their diet is increased, in addition to providing food security with a year-round supply of safe, nutritious food for their families. The action of microorganisms during fermentation can also help to reduce or remove naturally occurring toxins and anti-nutritional compounds in some raw fruits and vegetables.
- *Saving energy*. Traditional fermentations are much less demanding on the environment than other food preservation methods, which often consume large amounts of energy for pasteurization or sterilization. To reduce consumption of energy further, the fermentation and storage areas can be built into the ground, enabling a constant temperature range to be maintained with only minimal additional heating or cooling.
- *Providing additional income*. Vegetable growers in developing countries may be able to benefit from the added value of fermented products and increased demand from growing awareness of the health benefits of fermented vegetables in their own and other countries. Unpasteurized fermented vegetables are in high demand in some countries, and offer farmers and small-scale processors opportunities to add value to their vegetables and earn a reasonable income from relatively small scales of production, without significant investments in equipment. This may require a basic infrastructure for chill chain transportation and storage. Packaging options for the final products include individual portion packs or bags, tubs, and larger drums to supply catering outlets and institutions. The fermentation usually produces fermented liquids. These by-products are rich in live lactic bacteria and active enzymes, and may have considerable value when marketed as healthy tonics, or used as ingredients in salad dressings and sauces.

Excess produce can be fermented and preserved instead of being left to rot

Unpasteurized fermented vegetables are in high demand in some countries

Conclusion

The potential exists for extending the known benefits of lacto fermentation of vegetables to developing countries, by stabilizing and regulating the fermentation process using proven technological developments. These advanced methods need to be scientifically tailored to the foods produced and consumed in each specific area of the developing world, and appropriate training is required at personal and group levels to ensure the correct use of starter cultures and fermentation procedures.

A pilot project is taking place in 2011 to introduce the use of starter cultures to groups of small-scale farmers in India, for fermentation of their vegetables.

References

Battcock, M. and Azam-Ali, S. (1998) 'Fermented Fruits and Vegetables: A Global Perspective', FAO Agricultural Services Bulletin no. 134 [online], available from: www.fao.org/docrep/x0560e/x0560e00.htm [accessed 1 April 2011].

Breidt, F. (2005) 'Safety of minimally processed, acidified, and fermented vegetable products', in G.M. Sapers, J.R. Gorny and A.E. Yousef (eds), *Microbiology of Fruits and Vegetables*, pp. 313–35, CRC Press, Boca Raton, Florida.

Kovac, B. and Raspor, P. (1997) 'The use of the mould rhizopus oligosporus in food production', *Food Technology and Biotechnology* 35:1 available from: http://www.ftb.hr/index.php/ftb/article/view/151 [accessed 5 April 2011].

Lee, C.H. (1997) 'Lactic acid fermented foods and their benefits in Asia', *Food Control* 8: 259–69.

Parades-Lopez, O. (1992) 'Nutrition and safety considerations in applications of biotechnology to traditional fermented foods', report of an Ad Hoc Panel of the Board on Science and Technology for International Development, National Academy Press, Washington DC, USA Food Research and Development Centre (FRDC) of Agri-Food and Agriculture Canada (AAFC).

Svanberg, U. and Lorri, W. (1997) 'Fermentation and nutrient availability', *Food Control* 8: 319–27.

Yokotsuka, T. (1985) 'Fermented protein foods in the Orient, with emphasis on Shoyu and Miso in Japan', in B.J.B. Wood (ed.), *Microbiology of Fermented Foods*, pp. 197–247, Elsevier Applied Science, London.