PRACTICAL ACTION
Technology challenging poverty

ICE CREAM PRODUCTION

technical brief

Introduction

There has been little tradition of ice cream production in tropical countries because of the requirement for refrigerated production equipment and frozen storage. Now demand is increasing for ice cream in many large towns and cities, and it has the potential to be a profitable product for small scale dairies. However, ice cream carries a high risk of causing food poisoning if it is not correctly made and stored (see Technical Brief: *Overview of Dairy Processing*), and it should therefore only be produced by dairies that have knowledgeable and experienced staff.

Ice cream is made by freezing and simultaneously beating air into (aerating) a liquid mixture that contains fat, sugar, milk solids, an emulsifying agent, flavouring and sometimes colouring.

The fat can be from milk, cream or butter or from a non-dairy source. However, the composition of ice cream is legally defined in many countries. Typically this is:

1. Standard ice cream that contains not less than 5% fat and not less than 2.5% milk protein (from casein or whey solids).
2. 'Dairy' ice cream must contain a minimum of 5% fat that is only milk fat and not any other type of fat.

There may also be legislation that covers the types of emulsifying agents, colourings, flavourings or other additives that are permitted in ice cream, and potential producers should check the local legislation at a Bureau of Standards before formulating a product.

Ingredient	Fat (%)	MSNF[1] (%)	Sugar (%)	Water (%)
Full cream milk	4.0	8.8		87.2
Liquid skim milk	-	9.0		86.0
Full cream milk powder	27.0	70.0		3.0
Skim milk powder	-	97.0		3.0
Double cream	48.0	4.5		47.5
Single cream	18.0	7.2		74.8
Butter	84.0	-		16.0
Sweetened condensed milk	9.0	22.0	44.0	25.0
Evaporated milk	9.0	22.0		69.0

Table 1: Typical composition of ice cream ingredients (From Opportunities in Dairy Processing).

[1] MSNF = milk solids not fat

Product variations

There are a large number of potential product variations, including a wide range of flavours (e.g. vanilla, chocolate or fruit flavours) and corresponding colours, and different textures that depend on the addition of additives or differences in the method of production. Fruit pulp may also be added during or after making ice cream, and fruit, chocolate or nut pieces can be used to decorate ice cream. In temperate climates, ice milk was the traditional lower-fat ice cream product, and in places where there is a demand for reduced-fat products (with fat contents as low as 4%) this may be an additional product in a range. Another product variation is frozen yoghurt (see Technical Brief: *Soured milk and yoghurt production*), which is frozen in a similar way to ice cream (below).

Practical Action, The Schumacher Centre for Technology & Development
Bourton Hall, Bourton-on-Dunsmore, Rugby, Warwickshire CV23 9QZ, UK
Tel: +44 (0)1926 634400 Fax: +44 (0)1926 634401 E-mail: infoserv@practicalaction.org.uk Web: www.practicalaction.org

Ingredients

Fats
Fats increase the richness of the ice cream flavour, produce a smooth texture, give 'body' to the ice cream and produce good melting properties when the ice cream is eaten. Although dairy fats (Table 1) are most commonly used to make ice cream, a number of vegetable fats (including hydrogenated palm oil, coconut oil or salt-free margarine) may be cheaper and are used to reduce the cost of ice cream.

Milk solids-not-fat
Milk solids-not-fat is included as skimmed milk powder or full-fat milk powder. They improve the body and texture of ice cream, allow a higher overrun (below), and produce a thicker, less icy product.

Sugars
Sweeteners improve the flavour, texture and palatability of ice cream. They contribute to a lower freezing point, so that the ice cream has some unfrozen water. Without this the ice cream would be too hard to eat. They also reduce the 'fattiness' of ice cream and help to produce a smooth texture. Granulated or castor sugar (sucrose) is used, but other sugars (such as dextrose powder) are also used to make the ice cream softer. Corn syrup produces a firmer and 'chewier' ice cream than sugar. It is available in different dextrose equivalents[1] (DE). The sweetness increases with higher DE values. Lower DE corn syrups have a greater stabilising effect.

Stabilisers
Stabilisers are used to help bind together the complex mixture of fats, sugars, air and tiny ice crystals that are present in ice cream and give a smooth texture. They increase the viscosity in the unfrozen water to produce a firmer ice cream that resists melting (see 'Product control' below). Historically gelatine was used, but now the most widely used commercial stabiliser is carboxymethyl cellulose (CMC), which may have small amounts of vegetable gums (such as guar gum or locust bean gum), or seaweed extract (available as sodium alginate) mixed with it to improve its stabilising action. The vegetable gums may also be used instead of CMC. The amounts of stabiliser used should follow the manufacturer's recommendations.

Emulsifiers
Emulsifiers create a smooth texture and good melting characteristics. The traditional emulsifier used in ice cream was egg yolk, but now mono- and di-glycerides and Polysorbate 80 are used in most ice cream formulations.

Flavourings and colourings
Few people like unflavoured ice cream and both synthetic and natural flavours are used. The colouring normally matches the flavour (e.g. green colour with mint flavour or orange with mango). The flavours and colours must be 'food grade' and are usually available in supermarkets in major towns and cities or from bakery ingredient suppliers. Vanilla flavour is often the most popular flavouring, but producers should find out local preferences before deciding the range of flavours to offer (see for example ice cream makers such as *Ben and Jerry's*, *makeicecream.com,* or flavour suppliers such as *H. E. Stringer* or other large producers for the range of possible flavours).

Formulating an Ice Cream Mix
It is important that small producers understand how to develop new ice cream mixes to meet changing customer demands. 'Balancing' the mix involves maintaining the correct balance between:

- Fat and sugar which controls the 'fattiness' of the product in the mouth.
- Water and solids which controls the texture or hardness/softness.

The formulation of an ice cream mix should also take into account the cost and availability of ingredients. Details of the method used to calculate the weights of each ingredient in a recipe are beyond the scope of this Technical Brief, but details are given in Dairy Science and Technology

[1] DE is a measure of the reducing sugar content of the syrup calculated as % dextrose

Education and ice cream recipes are available at http://makeicecream.com and www.ice-cream-recipes.com. Examples of ice cream mixes are shown in table 2.

	Low-fat ice creams	Soft-frozen ice creams	Hard ice creams		
			Standard brands	Premium brands	Super-premium brands
Component	(%)	(%)	(%)	(%)	(%)
Fat	3.0 - 8.0	10.0 - 10.0	10.0 - 12.0	12.0 - 15.0	15.0 - 18.0
Milk Solids-not-fat	13.0 - 11.5	12.5 - 12.0	11.0 - 9.5	11.0 - 9.5	11.0 - 9.5
Sucrose	11.0 - 12	13.0 - 10.0	10.0 - 15.0	10.0 - 15.0	10.0 - 15.0
CSS	6.0 - 4.0	4.0 - 4.0	5.0 - 3.0	5.0 - 3.0	5.0 - 3.0
Stabilizer	0.35 - 0.15	0.35 - 0.15	0.35 - 0.15	0.35 - 0.15	0.35 - 0.15
Emulsifier	0.15 - 0.10	0.15 - 0.15	0.15 - 0.10	0.15 - 0.10	0.15 - 0.10
Water	66.3 - 63.7	64.0 - 63.7	64.0	62.0 - 60.0	<60.0
Total Solids	33.6 - 36.3	36.0 - 36.3	36.0	38.0 - 40.0	>40.0

Table 2: Mixes for ice creams (Adapted from: Dairy Science and Technology Education)

Production method

The general method for producing ice cream is shown in Figure 1.
The increase in volume of ice cream due to the incorporation of air is known as the '% overrun', and in commercially produced ice creams this varies from 60-100% or more. In some countries there is a legal maximum of 120% overrun.
Overrun % can be calculated as follows:

$$\text{Overrun \%} = 100 \times \frac{\text{weight of a given volume of mix} - \text{weight of same volume of ice cream}}{\text{weight of same volume of ice cream}}$$

If, for example, 3.1 kg of ingredient mixture is needed to fill a container so that it is level with the top of the container and then with 1.6 kg of ice cream, again level with the top,

$$\text{the \% overrun} = 100 \times \frac{(3.1 - 1.6)}{1.6}$$
$$= 100 \times 1.5/1.6$$
$$= 93.75\%$$

Because ice cream is sold by volume, the amount of air in the finished product has an important effect on profitability. Small batch freezers (below) can only beat small amounts of air into the mixture as it freezes, to give an overrun of 50% or less. Commercial freezers are more efficient at incorporating air and overruns can be 100% or more.

Stage in process	Notes
Weigh	Premix dry ingredients with 3 or 4 times their weight of sugar. Weigh all main ingredients, except fat, into pasteurisation vessel.
↓	
Heat	To 50°C and add any solid fats.
↓	
Pasteurise	At 65°C for 30 minutes or 72°C for 10 minutes with thorough mixing.
Cool	For a minimum of 4 hours at 3-5°C to allow fats to crystallise and the viscosity to increase.
↓	
Freeze and aerate	Using an ice cream machine to reduce the temperature to –5°C as quickly as possible.
↓	
Pack	Fill into pots or cardboard cartons.
↓	
Harden	At below -20°C
Cold store	At –18 to -20°C

Figure 1: Method of ice cream production

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Equipment

Pasteuriser
A pasteuriser is used to heat the ice cream mixture. At a micro-scale of production, a stainless steel pan (or less desirably an aluminium pan) is heated with constant stirring to prevent the mixture overheating or burning at the base of the pan. At small- and medium-scale production, a jacketed stainless steel pan (see Technical Brief Pasteurised milk) gives better control over heating. Steam from a boiler heats the space between the outer jacket and inner pan to give more uniform heating and avoid localised burning of the product. It may be fitted with an agitator.

Ice Cream Freezers
Small manual or electric ice cream makers have a stainless steel bowl that is frozen by one of three methods:

- the bowl is immersed in a freezing liquid (e.g. an ice/salt mixture).
- a double-walled bowl is placed in a freezer, and the salt/ice between the bowl walls is frozen (the bowl needs to be refrozen for the next batch). Typically, both can freeze ice cream within 15 - 20 minutes.
- the bowl is surrounded by refrigeration coils that are built into the machine (Figure 2). Some machines also have a built-in pasteuriser.

Other designs (Figure 3) pump the ice cream mixture to freeze and aerate it. These types of machines can produce ice cream continuously and may be used in retail outlets.
Each type of ice cream maker has a rotor that scrapes the frozen ice cream mixture from the bowl wall and at the same time incorporates air. Freezing continues until the liquid is frozen at -4 to -7°C. This soft ice cream is then either sold directly or hardened in a freezer at –18°C. At a larger scale, more expensive continuous freezers that have capacities above 200 litres per hour are used.

Figure 2: Small ice cream maker
(Courtesy of Musso ice cream machines)

Figure 3: Commercial ice cream maker
(Courtesy of Robot Coupe)

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Quality assurance

The quality and amounts of dairy ingredients and the processing conditions that are used for making ice cream should be standardised so that consistent quality products are made each time. This involves control of factors in the process that affect the quality or safety of the product. These are known as 'control points' and are the points at which checks and measurements should be made (Table 3).

HACCP[2]

The specific potential hazards in making ice cream are food poisoning bacteria from the dairy ingredients, poor hygiene and sanitation during processing, and incorrect processing conditions. Other hazards that are common to all types of food processing (including contamination of foods by insects, glass etc.) are prevented by correct quality assurance, including the design and operation of the processing facilities, staff training in hygiene and production methods, and correct cleaning and maintenance procedures.

Hygiene

Technical Brief: *Dairy Processing - An Overview* gives details of hygiene and sanitation, the design of a dairy and the use of correct cleaning procedures. Hygiene requirements are also described in Technical Brief: *Hygiene and Safety Rules in Food Processing.*

Avoiding food poisoning

Unclean equipment, contaminated ingredients, poor hygiene of production staff, and incorrect processing and storage conditions can each lead to bacteria contaminating the ice cream. Although the low temperatures during frozen storage prevent the bacteria from growing, they can cause illness when the ice cream is eaten. All equipment should be thoroughly cleaned after use and checked before production starts again. The temperature and time of heating the ingredient mixture should be monitored and controlled to ensure that it is not over- or under-heated.

Ingredient control

The milk used to produce the dairy ingredients should be fresh, good quality and free from dirt and excessive contamination by bacteria. Older milk may impart an unpleasant flavour to the final product. Technical Brief: *Dairy Processing - An Overview* gives details of the methods needed to ensure that good quality milk is used, and Technical Briefs: *Butter and Ghee* and *Pasteurised Milk* describe the quality assurance procedures for making some of the dairy ingredients. Careful weighing is needed for all ingredients to make sure that the same amount is used in every batch.

Process control

A process control schedule should be prepared for each product. Table 3 is an example of a process control schedule for ice cream production.

Stage in process	Activity	Process control points
Weighing/mixing	Weigh out ingredients and mix	Check ingredient weights (+/- 1g)
Pasteurisation	Heat mixture to destroy micro-organisms and enzymes.	Check temperature and time (e.g. 72°C +/- 1°C for 10 minutes).
Cool	By immersing vessel in cold water and stirring milk	To 4°C +/- 1°C within 20 - 30 minutes and store for 4 hours.
Freezing/ Aeration	In ice cream machine	To - 5°C. Check % overrun.
Packaging	Fill into pots or cartons	Check the net weight of each pot (e.g. 100g +/- 1g)

[2] Hazard Analysis Critical Control Point

Seal	Seal pots with a foil lid or clip-on plastic lid	Check that the foil seal is properly formed
Label	Attach label to pots	Check that correct labels are used, that they are correctly positioned, and show the correct use-by date and batch number.
Refrigerate	Harden at -18 to -20°C and store at this temperature.	Check freezer temperature.

Table 3: Process control points in ice cream production

It is particularly important that the temperature and time of heating and cooling the mixture should be controlled. Over-heating and slow cooling causes changes to the flavour and colour of the milk, whereas under-heating may lead to survival of undesirable micro-organisms, risking food poisoning from the product.

Product control
The main quality factors for ice cream are the colour, texture and taste. The colour should remain unchanged as bright white/cream during processing if colours are not added. The texture of ice cream can be either soft, or harder and made into blocks.
An understanding of the structure of ice cream is useful to help create the required texture: ice cream has three components:

1. It is a foam (it has air bubbles in the unfrozen liquid).
2. It is an oil-in-water emulsion (made up of tiny globules of milk fat contained in a complex water phase)
3. The water phase contains ice crystals and a concentrated unfrozen solution of sugars, milk solids and other ingredients.

The two main factors that affect the texture of the ice cream are:

1. the incorporation of air (overrun), which increases the softness and lightness of the product and allows it to be easily scooped; and
2. the rate of freezing which affects the size of the ice crystals.

Commercially made ice creams usually have a smooth, soft texture, due in part to faster freezing which produces smaller ice crystals. The smaller the ice crystals, the less detectable they are by the tongue. They also need less heat to melt in the mouth and as a result the ice cream does not feel excessively cold when eaten. Slow freezing creates larger ice crystals that give the product a gritty texture, and it may also feel too cold when eaten. Other ingredients, including proteins from the dairy ingredients and added emulsifiers, stabilise both the air bubbles and the emulsion to give a smooth texture.

Packaging and storage control
The ice cream should be stored in a freezer at -18°C. It should not be allowed to melt for two reasons: first this would allow any bacteria in the ice cream to grow and spoil the product, and secondly the air in the ice cream escapes and it loses its texture to become solid ice when re-frozen. When ice cream is warmed (e.g. by opening a freezer door) some of the ice crystals nearest to the warm air partially melt and then refreeze when the temperature drops again. This causes the ice crystals to grow and the ice cream to taste more 'gritty'. Therefore producers should advise retailers to minimise the number of times and the duration that ice cream freezers are opened. There should also be rapid stock turnover to prevent the development of grittiness in the products. Ice cream requires protection against dust and insect contamination during distribution and retail display. Plastic pots are most commonly used, sealed with a foil cover or clip-on plastic lid. Other alternatives are waxed paperboard cartons or cups.

Summary

Ice cream is high-risk product that has the potential to cause food poisoning, but with care it can be made successfully at a small scale. It may have a high demand in urban areas and a wide range of products can be made with different flavours, textures and colours, provided

that suitable ingredients are available and the required skills and experience exist in the dairy.

Equipment required

- Pasteurising pan preferably made from stainless steel, but aluminium is acceptable (see Technical Brief: *Pasteuriser milk*).
- Thermometer (-30 to 100°C) for checking product and freezer temperatures (preferably an electronic thermometer).
- Ice cream maker
- Freezer or frozen storeroom
- Scales (e.g. 0-10 kg +/- 2 g for weighing ingredients).

Optional

- Pot sealer. Pot sealers can be made locally by fixing a domestic electric iron to a drill stand. Commercially available pot sealers have a thermostatically controlled sealing head, which can be adjusted for sealing foil or plastic lids.

Equipment suppliers

Note: This is a selective list of suppliers and does not imply endorsement by Practical Action.

The website www.smalldairy.com/dairy%20resources.html also lists equipment suppliers, laboratory supplies, books and contacts for small dairy processing.

Dairy processing equipment

- Fullwood Ltd., Grange Road, Ellesmere, Shropshire, SY12 9DF, UK. Tel: +44 (0) 1691 622391. Fax: +44 (0) 1691 622355. Website: www.fullwood.com

Batch Pasteuriser.

- C Van t Riet Dairy Technology, Dorpsstraat 25, 2445 AJ Aarlanderveen, The Netherlands, Tel: +31 172 571304, Fax: +31 172 573406, E-mail: info@rietdairy.nl, Website: http://www.rietdairy.nl/
- Dairy Udyog, C-230, Ghatkopar Industrial Estate, L.B.S. Marg, Ghatkopar (West), Mumbai - 400 086, India. Tel: +91 (0)22 2517 1636 / 2517 1960. Fax: +91 (0) 22 2517 0878. E-mail: jipun@vsnl.com
- Finest Kind, P.O. Box 1, Plettenberg Bay 6600, South Africa, Tel: +27 (0) 44 533 1623, E-mail**:** info@finestkind.co.za, Website: www.finestkind.co.za/equipment.html
- Lehman's, P.O. Box 41, Kidron, Ohio 44636, USA. Tel: +1 877 438 5346, +1 888 438 5346, E-mail: info@lehmans.com, Website: http://www.lehmans.com

Ice cream machines - small refrigerated machines

- Musso ice cream machines, c/o , Bats Singapore Pte Ltd., Attn: Kitchen Equipment Division, 371 Beach Road, #21-06, Key Point, Singapore 199597, Tel: +65 62925658, Fax: +65 62961651 E-mail: info@bats.sg, website: www.bats.sg/musso.htm
- Cuisinart® Commercial Quality Ice Cream Maker, contact for individual countries via website: http://www.cuisinart.com/contact/international/

Ice cream machines - larger commercial machines

- Alfred & Co**,** West Carr Road Ind. Est., Retford, Nottinghamshire, DN22 7SN, UK., Tel: +44 (0) 208 795 5869, Fax: +44 (0) 208 795 5869, E-mail: info@icecream-alfred.co.uk. New and second-hand machines.
- Bravo Trittico, Tel: 1 949 366-3480, Email: specequip@cox.net, Website: www.sendicecream.com/brtrgebafrpa.html
- Gelato Batch Freezer & Pasteurizer, Bravo Trittico, Tel: +1 949 2129753, Email: specequip@cox.net, Website: www.makeicecream.com/comeq.html
- Kitchen Professionals LLC, Hewitt, NJ. 07421, USA., Tel: +1 888 2332722, Fax: +1 973 9570344, E-mail: info@kitchenprofessional.com, Website: http://icecreamprofessional.com/fiume-page.php

- Luna (UK) Ltd, Unit 20, The Vanguards, Vanguard Way, Shoeburyness, Essex, SS3 9QJ, UK, Tel: +44 (0)1702 297090, e-mail: info@lunamil.net, Website: www.lunamil.net/OurMachines.php
- Robot Coupe, Head Office, Unit 16/1 Short Street, Chatswood, NSW. Australia 2067, P.O. Box 146, Northbridge, NSW. Australia 1560, Tel: +61 (0) 2 9417 6233, Fax: +61 (0) 2 9417 6787, E-mail: sales@robotcoupe.com.au Website: http://www.robotcoupe.com.au/categories.asp?cID=55
- Taylor equipment, E-mail: info@taylor-company.com, Website to find local distributors: www.taylor-company.com/dist_intl/distributor.htm

Lists of suppliers are given at www.makeicecream.com/cuisicsupcom.html and www.ice-cream.org/.
A guide to choosing and buying a small ice cream maker is given at http://kitchen.cookery-guide.info/how-to-choose/ice-cream-makers.php

Ingredients
Essences and food colourings
These ingredients are used for bakery products and are suitable for use in ice cream. They are available in large cities from supermarkets or bakery suppliers, or they can be ordered from flavouring suppliers, for example:

- H E Stringer Ltd., Icknield Way Industrial Estate, Tring, Hertfordshire, HP23 4JZ, UK., Tel: +44 (0) 1442 822621, Fax: +44 (0)1442 822727, E-mail: info@stringer-flavour.com, Website: www.stringer-flavour.com/rich/

References

- *Butter and ghee* Technical Brief
- *Dairy processing - an overview* Technical Brief
- *Hygiene and safety rules in food processing* Technical Brief
- *Pasteurised milk* Technical Brief
- *Soured milk and yoghurt* Technical Brief
- *Ben & Jerry's flavours*, Ben & Jerry's Homemade Holdings, Inc., 30 Community Drive, South Burlington, VT 05403-6828, USA Tel: 1 8028461500, Website*:* www.benjerry.com/our_products/flavor_locator/
- *Dairy Science and Technology Education,* Goff, D., website at the University of Guelph, www.foodsci.uoguelph.ca/dairyedu
- *makeicecream.com*, ice cream flavours, available at website: www.makeicecream.com/15mospopicec.html
- makeicecream.com, *ice cream recipes* website: www.makeicecream.com/recformakice.html

Further reading

- *A Guide to the Safe Handling and Service of Ice Cream*, Ice Cream Alliance Ltd., 3 Melbourne Court, Pride Park, Derby, DE24 8LZ, UK., Tel: +44 (0)1332 203333, Fax: +44 (0) 1332 203420, E-mail: info@ice-cream.org . 1999.
- *Appropriate Food Packaging*. Fellows, P., and Axtell, B., IT Publications, 1993.
- FAO dairy information page: www.fao.org/ag/aga/lps/dairy/index.htm. FAO Information at www.fao.org/docrep/007/y3548e/y3548e09.htm or www.fao.org and search 'dairy processing book' for a list of publications that can be downloaded. FAO small scale dairy manual (5 volumes): www.fao.org/ag/AGA/AGAP/Dairyman/Dairy/title1.htm
- *Ice cream and aerated desserts*, Andreasen, T.G. and Nielsen, H., in (R. Early, Ed.) Technology of dairy products, Blackie, London, pp 197-220, 1992.
- *Ice Cream Making*, A practical booklet. J.Rothwell, Ice Cream Alliance Ltd., 3 Melbourne Court, Pride Park, Derby, DE24 8LZ, UK, Tel: +44 (0)1332 203333, Fax: +44 (0)1332 203420, E-mail: info@ice-cream.org. 1999.
- *Ice Cream! The Whole Scoop*, Damerow, G., Glenbridge, 1991, ISBN 0-944435-09-2
- *Opportunities in Dairy Processing*, Fellows, P.J. and Axtell, B.L.A., (Eds.), CTA, 2008.

- *Preparation of Dairy Products, Agrodok 36*, Agromisa, Agromisa Foundation P.O. Box 41, 6700 AA Wageningen, The Netherlands 1991. www.agromisa.org/

Support organisations

- Agromisa Foundation, P.O. Box 41, 6700 AA Wageningen, The Netherlands 1991. www.agromisa.org
- Centre for Dairy Research, Madison, WI. www.cdr.wisc.edu
- Ice Cream Alliance Ltd., 3 Melbourne Court, Pride Park, Derby, DE24 8LZ, UK., Tel: +44 (0)1332 203333, Fax: +44 (0)1332 203420, E-mail: info@ice-cream.org, Website: www.ice-cream.org
- Practical Action, Peru, Soluciones Prácticas, Av Jorge Chávez 275 - Miraflores, Apartado Postal 18-0620, Lima 18, Peru, Tel: (511) 447-5127, 444-7055, 446-7324, Fax: (511) 446-6621, Email: info@solucionespracticas.org.pe, Website (in Spanish): www.solucionespracticas.org.pe
- SKAT, Vadianstrasse 42, CH-9000 St. Gallen, Switzerland. Tel: +41 71 228 54 54, Fax: +41 71 228 54 55, E-mail: info@skat.ch, Website: www.skat.ch.
- Strengthening African Food Processing, www.safpp.net

Practical Action
The Schumacher Centre for Technology and Development
Bourton-on-Dunsmore
Rugby, Warwickshire, CV23 9QZ
United Kingdom
Tel: +44 (0)1926 634400
Fax: +44 (0)1926 634401
E-mail: inforserv@practicalaction.org.uk
Website: http://www.practicalaction.org/

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