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COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY

Food Technology for Rural Setting

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ABSTRACT: Agro-processing, in particular food processing is receiving considerable attention now in India. But the emphasis is generally on capital-intensive involvement and large-scale industries. To empower rural women through livelihood, cottage and small-scale food processing based on local raw materials is required. Dangoria Charitable Trust (DCT) has set up a tiny rural food processing and training center in the village of Narspaur, Medak district, Andhra Pradesh, India. Some of the products prepared, like cereal–pulse-based complementary foods, chutney powders from green leafy vegetables (GLV), and more, are of direct nutritional relevance, whereas others like pickles, tomato sauce, "murrabba" and others contribute to nutrition indirectly by preventing wastage and generating employment for rural women. When there is glut production of tomatoes and prices crash, tomatoes are solar-dried or juice is preserved as puree. Solar drying of GLV is done using appropriate blue shielding to cut off the UV radiation. This helps to preserve β-carotene. Some of the problem areas are: microbial contamination due to contaminated chili powder, complex procedures for getting FPO license, developing cost-effective and yet attractive packaging, transportation cost (since markets exist in urban areas), and most importantly establishing market linkages.

Introduction

The food industry is described as the "sunrise industry," particularly in India, a country among the largest producers of milk and among the top 2 in the world for production of vegetables, fruits, and food grains. Unfortunately, what is produced is still insufficient and out of reach of the poor due to their lack of purchasing power. A confounding factor is the wastage that occurs due to inadequate and substandard storage facilities, lack of cold storage, and shortage of food processing for value addition and to improve shelf life. According to one estimate, the annual wastage of agricultural produce in India due to inadequate storage and processing facilities is almost 30% and equivalent to almost 580 million rupees. The wasted food could feed almost 232 million people. The multiplication factor for food processing is 2.4, which means that for every Rs.1 wealth created directly, an additional Rs. 2.4 are earned indirectly through transportation, packaging, cold storage, and so on (DG Rao, lecture on October 16, World Food Day 2007, Hyderabad, India).

Apart from preventing wastage, generating employment, and making foods available off-season (which indirectly helps food security), food technology can directly contribute to food security through enhancement of nutrient density. Increasing protein density of cereal foods by fortifying with protein concentrate or a legume (food–food fortification); increasing micronutrient density by fortifying with 1 or more vitamins and/or minerals are examples. A lesser-tried strategy is fortification with dehydrated fruits and vegetables to increase the micronutrient density of cereal–pulse-based ready-to-cook (RTC) or ready-to-eat (RTE) foods. RTC, ready-to-heat (RTH), and RTE foods contribute to drudgery reduction and easy access. RTE bakery products like biscuits and bread and extruded and fried snacks have become popular even in rural areas. Thus the food industry can help nutrition security in different ways.

Though food processing is receiving considerable attention in India, emphasis is on capital-intensive involvement and large-scale industries. Establishment of tiny and cottage-scale food processing industries in rural areas would help to empower rural women through skill development and livelihood. This study shares the experience of Dangoria Charitable Trust in establishing and running a tiny rural food processing industry.

Preharvest Technologies

Food technology can be preharvest or postharvest. In preharvest technology, the nutrient content of a plant product is enhanced by biofortification (molecular breeding) or genetic engineering. In the former, favorable genes are introduced through their identification in natural varieties and incorporation by traditional marker breeding. In the latter, favorable genes are introduced even from unrelated sources, by genetic engineering. The former being closer to nature is not controversial, whereas the latter has raised controversies regarding environmental and health safety.

Primary processing

Farmers can be trained to do primary processing like washing, cleaning, grading, sorting, and more to fetch better prices by accessing urban markets where good-quality produce can be sold at a higher price. This has become important with the present trend of the corporate sector entering into the marketing of farm produce. However, many farmers who are in a hurry to sell their produce prefer to sell mixed-quality produce (vegetables and fruits) without sorting to middle men. The culture of primary processing for better value is, however, slowly growing.

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Secondary processing

Most secondary processing technologies, such as drying, preparation of preserves like pickles, jams, jellies, "murabba" (fruits preserved in sugar syrup), sauces, purees, and beverages like juices, squashes, as well as fermentation, de-hulling, malting, roasting, and grinding of food grains, oil extraction, extrusion, and even baking, are relatively simple, inexpensive, and can be set-up in rural areas with the available human resources.

Tertiary processing

This involves continuous processing instead of batch processing, computerization of operations and control mechanisms; automation and robotization are very sophisticated and beyond the competence of a rural entrepreneur or self-help group.

Evolution of Food Processing

Food processing is one of the oldest occupations. It blends science with art. Traditional home skills and grandma's recipes are still very popular. They are, however, subjective. With the introduction of modern science, standardization of processes and products began to occur. Individual art was transformed into science-based technologies, and manual labor began to be replaced by mechanization and automation.

Food processing centers/industry in rural areas

Since most food commodities are produced in rural areas, setting up decentralized food processing units near the production centers in rural areas where there is seasonal glut would help to access fresh produce and reduce wastage as well as cost of handling and transportation. It would also help to generate employment and reduce rural poverty. While this logic makes sense and pilot model food processing centers have been advocated for rural areas, such units face numerous problems.

Problems faced by rural processing units

(1) Erratic power supply.
(2) Lack of skilled labor.
(3) Paucity of artisans for maintenance of equipment.
(4) Only seasonal access to cheap vegetables and fruits, which renders dedicated equipment idle for rest of the year.
(5) Many ingredients and packaging materials have to be brought from the city and that involves transportation cost.
(6) Transportation cost to access urban markets for selling.
(7) Competition from branded products as well as low-end poor-quality cheap products.
(8) High cost of production due to low turnover.

Experience of "mahila udyog," dangoria charitable trust (DCT)

DCT has set up a food processing and training center in the village of Narsapur, Medak district, Andhra Pradesh, India. Financial assistance came from projects funded by government agencies like the Dept. of Science and Technology, Dept. of Biotechnology, and Ministry of Food Processing Industries through the Central Food Technological Research Inst., Mysore, India. A variety of cereal–pulse, vegetable-, and fruit-based products are being made and marketed. Rural women are being trained not only in food processing but also sanitation, hygiene, packaging, principles of HACCP (hazard associated critical control point), and explained nutritional importance. Fruit products order (FPO) license (Prevention of Food Adulteration Act 1954), for the center has been obtained for the fresh fruit and vegetable-based products like pickles, tomato sauce, and beverages. A license to market other products is obtained from the district authorities. The center has been registered as a "tiny food processing center" in the district.

Development of Low-cost Complementary Foods

Poshana, the cereal–pulse complementary food

Diet surveys show that Indian diets are qualitatively deficient in micronutrients, particularly iron, vitamin A, and riboflavin, perhaps even zinc, folic acid, and vitamin B_{12}. The diets of infants and children are particularly deficient in all nutrients. Rural mothers do not introduce complementary food till 12 mo of age. They do not have time or patience to prepare special foods for infants. The challenge, therefore, is to prepare a low-cost complementary food for infants and children. Most commercial foods are very expensive for the poor. A survey among rural mothers regarding infant feeding practices showed that 18% of mothers had given branded commercial foods, which are very expensive, on doctors' advice. Very often, the food was diluted using not too clean water to make it stretch.

DCT decided to make and promote a low-cost complimentary food. A product called "poshana," containing wheat semolina, Bengal gram "dal," and groundnut, fortified with iron as ferrous sulfate, was developed. The nutrient composition of this product, compared to a commercial food marketed by a multinational company is given in Table 1. Though poshana has a lower-than-required content of micronutrients (except iron, which is added), this deficit can be made up by food–food complementation through supplementing with mother's milk, buffalo/cow milk, and some green leafy vegetable (GLV) (Table 2). Such food–food complementation can meet more than 80% of the requirement of most nutrients (except riboflavin) for a 9-kg child. However, it costs only Rs. 30 to 50 per kg (landing price/maximum retail price (MRP)) against Rs. 272 or more for the commercial product. Fortification with riboflavin besides iron needs to be considered. Since vitamins are unstable on storage, additional amounts would have to be added. The price advantage

Table 1—Comparison of poshana with commercial baby food Nutrients from 100 g.

Nutrient	Commercial	Poshana
Calories	417	362
Protein (g)	15	13
Calcium (mg)	750	26
Iron (mg)	7.5	8.2 (fortified)
Vitamin A (μg)	360	7.1
Vitamin B1 (μg)	800	200
Vitamin B-2 (μg)	600	60
Vitamin C (mg)	35	1.0
Price (Rs/kg)	272	30–50

Table 2—Requirement (% recommended dietary allowance-RDA) of a 9-kg child met through food–food fortification of poshana. Poshana, 100 g; buffalo milk, 100 mL; amaranth, 25 g; breast milk, 600 mL. RDA established by Indian Council of Medical Research (1989).

Nutrient	% RDA
Calories	100
Protein	168
Calcium	85
Iron	100
Vitamin A (as β carotene)	269
Vitamin B1	80
Vitamin B-2	60
Vitamin C	100

however is enormous. Studies are needed to examine the stability of vitamins and bioavailability of micronutrients from processed foods fortified with pharmaceutical products as compared to farm products.

An additional advantage of poshana is that it can make a variety of sweet and savory products like porridge, "upma" (a salty, flavored gruel), idli (salty, fermented dumplings), dosai (salty fermented pancakes), and even egg-less cake. Currently, poshana is being marketed as a protein-rich food for the family and many old people find it convenient and like it. However, greater promotional effort is needed to broaden the market, particularly for children.

Ragi (finger millet) malt

Millets or coarse grains like jowar (sorghum), bajra (pearl millet), and ragi (finger millet) are referred to as nutritious grains, because their micronutrient density is higher than that of rice or wheat. They are also rich sources of fiber. (Table 3). Among the millets, finger millet is unique because of its high content of calcium. Malting improves the availability of micronutrients like iron and zinc (Shankar Rao and Deosthale 1983). (Table 4). Information on the effect of malting on calcium availability in finger millet is not available, but in other grains it is not as marked as for iron and zinc. Thus, hydrothermal treatment and malting of barley improved zinc absorption but not calcium absorption in humans (Fredlund and others 1997). Assimilation of micronutrients depends on the presence of promoters like vitamin C for iron, phosphorus for calcium and inhibitors like phytate and polyphenols.

Table 3—Nutrient content of food grains (per 100 g).

Grain/ nutrient	Bajra	Jowar	Ragi	Rice-milled	Maize	Wheat-flour
Protein (g)	11.6	10.4	7.3	6.8	11.1	12.1
Calcium (mg)	42	25	344	10	10	48
Iron (mg)	8	4.1	3.9	3.2	2.3	4.9
Zinc (mg)	3.1	1.6	2.3	1.4	2.8	2.2
Vitamin B1 (mg)	0.33	0.37	4.2	0.06	0.42	0.49
B2 (mg)	0.25	0.13	0.19	0.06	0.10	0.17
Folic acid (mg)	45.5	20	18.3	8.0	20	36.6
Fibre (mg)	1.2	1.6	3.6	0.2	2.7	1.2

Source: Gopalan and others (2004).

Table 4—Effect of malting on bioavailability of iron from ragi (finger millet).

	Total iron (mg/100g)	Ionisable iron (mg/100g)	% Total iron
Whole grain	3.9	0.29	7.4
Malted	3.4	2.98	88.3

Source: Shankar Rao and Deosthale (1983).

Ragi malt can be consumed in the form of porridge, salty gruel mixed with buttermilk ("ambali"), ragi mudde (thick gruel made into balls), or ragi sangati (ragi added to rice when almost cooked). It is especially recommended for children, as well as for pregnant and lactating women. Among the various products made by DCT ragi malt is the fastest moving.

Ragi laddu

This is a sweet preparation in which ragi is added to sugar syrup, cooked briefly, and made into balls. Sesame seeds and flavoring like cardamom are added.

Ragi "Papad"

Papads are dietary adjuncts generally made from black gram dal. Ragi flour in combination with a small quantity of sago also makes good papads. Dough is cooked, rolled into very thin rounds and dried. It can be fried or microwaved before cooking.

The nutrients of ragi products are given in Table 5.

Dehydration of vegetables and fruits

Dehydration of vegetables and fruits enhances shelf life, reduces bulk, and provides some flexibility in cooking.

Food–food fortification of cereal–pulse products with dehydrated vegetables/fruits, prevents overdosing with mironutrients and may prevent adverse interactions between micronutrients like one micronutrient interfering with the absorption of another. Green leafy vegetable (GLV) powders would also provide health promoting phytochemicals and other micronutrients. Research is, however, needed to study the stability of micronutrients, particularly vitamins during dehydration and their subsequent shelf life. Bioavailability of micronutrients from dehydrated vegetables also needs to be studied.

Methods of dehydration of vegetables and fruits

The commonly used methods for dehydration of vegetables and fruits are:

(1) Hot air driers. They need power, which is erratic in rural areas.

(2) Sun drying (shade drying). There is a considerable loss of nutrients.

(3) Solar drying. A good method, but solar driers with solar panels, which give the best product are expensive. Loss of β-carotene can be reduced by adding a blue shield.

(4) Osmotic dehydration. Used for fruits. Gives a sweet product.

(5) Osmo-air drying. Used for fruits.

Dehydrated green leafy vegetables (GLV) as sprinkles and foodlets

Instead of blending the micronutrients in the processed foods, sprinkles and foodlets have been suggested as an approach that is more empowering for the person who is cooking because she/he can sprinkle the micronutrient mix into the food

Table 5—Nutrient content of finger millet (ragi) products values per 100 g.

Item/ nutrient	Protein (g)	Energy (cals)	Ca (mg)	Fe (mg)	B_1 (mg)	B_2 (mg)	Crude fiber (g)
Ragi malt	7.79	350	367	4.2	0.45	0.2	3.84
Ragi papad	6.62	290	271.6	3.7	1.98	0.89	0.91
Ragi laddu (each weighs 10 g)	4.5	444.4	215	2.4	0.3	0.1	0.22
RDA for adult women.	50	2000	400	30	1.0	1.2	

Source: Gopalan and others (2004) ; Indian Council of Medical Research (1989).

Table 6—Nutrient content of dehydrated green leafy vegetables[a] (per 10-g serving).

GLV	Calcium (mg)	Iron (mg)	Beta carotene (μg)	Vitamin C (mg)	Folic acid (mg)	Riboflavin (mg)
Amaranth gangeticus (Totakura)	200	3.9	8340	10	14.9	0.3
Spinach	91	1.4	3288	35	15.4	0.32
Curry leaves	232	0.26	1991	1.12	39.5	.02
Drumstick leaves	185	3.6	8270	92.4	39.4	0.02
RDA-adult woman[b]	400	30	2400[c]	40	100[c]	1.3

[a]Calculated from values given in Gopalan and others (2004).
[b]Indian Council of Medical Research (1989).
[c]Upward revision of RDA is being considered by the Indian Council of Medical Research.

Table 7—Nutrients from GLV rich in iron [a] (per 10-g serving).

GLV	Ca (mg)	Fe (mg)	Beta carotene (μg)	Vit. C (mg)
Benagal gram leaves	129	9.0	–	–
Knolkhol leaves	555	10.0		
Raddish leaves	282	16.4	2002	96.5
Amaranthus peniculatus—rajakeerai	249	8.7	–	38
Amaranthus. Polygonoidis	251	27.3	–	22
RDA-adult woman[b]	400	30	2400[c]	40

[a]Calculated from values given in Gopalan and others (2004).
[b]Indian Council of Medical Research (1989).
[c]Upward revision of RDA is being considered by the Indian Council of Medical Research.

Table 8—Nutrients from GLV chutney powders.[a]

Product	Vitamin C (mg)	Beta Carotene (μg)	Antioxidant Vit. E Eq.
Curry leaf chutney powder	7.24	554	4.55
DS leaves chutney powder	6.31	633	3.33
RDA for adult woman[b]	40.0	2,400	8.0

[a]Analysis done at the National Institute of Nutrition, Hyderabad, India, 3 mo after preparation of the powder.
[b]Indian Council of Medical Research (1989).

Table 9—Vitamin C content of "amla" (Indian gooseberry) "supari" and lime squash.

	Serving	Vitamin C content[a] (mg/serving)
Amala supari	2 g	13.4
Lime squash	50 mL	3.33
RDA for adult woman[b]		40 mg

[a]Analysis done at the National Institute of Nutrition, Hyderabad, India, 2 mo after preparation.
[b]Indian Council of Medical Research (1989).

or use micronutrient spreads (foodlets), a cross between food and tablets. Thus, sprinkles and foodlets can be used without introducing new foods.

In a country like India, where throughout the year a variety of GLVs are available in plenty and are the cheapest vegetables, people should be encouraged to use them for food–food fortification. The next best alternative is to use dehydrated vegetables like GLV, which are rich in micronutrients. Table 6 and 7 show that there is an ample supply of micronutrients such as β- carotene, vitamin C, and calcium in GLVs and GLV powders can be effectively used for food–food fortification to supply these nutrients. Meeting the requirement of iron and some B vitamins like folic acid and riboflavin can be a problem. Some GLVs are also rich in iron (Table 7).

Instead of using pharmaceutical preparations for sprinkles or foodlets, natural foods like the GLV powders, which are rich in micronutrients can be used as food–food supplements (sprinkles) to enrich the diet.

Chutney powders (karap pudi) from solar-dried GLV

In South India, chutney powders made from legumes and spices are used as embellishment with rice, and breakfast foods like "idlis," "dosai," and others. In Andhra Pradesh, India, chutney powders are made from legumes in combination with sun-dried GLV like curry leaves. DCT is marketing "karap pudi" made from curry leaves, drumstick-curry leaf combinations, and "gongura"("ambadi") (Hibiscus cannabinus) leaves. Nutrient compositions of the 1st two, based on analysis, are given in Table 8. These powders are rich sources of β-carotene, vitamin C, and antioxidants, as well as minerals.

Vitamin C-rich products

Apart from citrus fruits, Indian gooseberry or "amla" is rich in vitamin C. A mouth freshener ("supari") is being made from solar-dried amla. Generally, supari is made from areca nut. Table 9 gives the vitamin C content of amla supari and lime squash. The former is a very rich source of vitamin C.

Pickles, murabbas, and relishes. These can be made from many fruits and vegetables. DCT also makes the following products: pickles from solar-dried and fresh tomatoes; pickles from fresh lime, drumstick, and mango; toffee from ginger, murabba (fruit pieces preserved in sugar syrup) from raw mango; and tomato sauce. All these products have some nutritional or medicinal value.

Spices and condiments. A rural food-processing center can make a variety of spices and condiments for which there is a great demand in India. DCT makes coriander powder, "sambhar and rasam" powders, and roasted Bengal gram powder.

Marketing

In today's age of globalization, small industries face tremendous problems of competition both from the larger industries as well as unscrupulous small-time producers who make and market substandard products at low cost. For instance, most bakeries in Hyderabad, India, buy cheap tomato sauce that sells at Rs. 10 per kilogram. These products (tomato sauce and ketchup) do not meet the requirement of Brix, and they contain thickeners like potato, pumpkin, and starch. Thus, the biggest challenge for a rural food processing industry is finding markets.

A Market Survey on Consumer Perception and Purchase Behavior was done through the School of Agri Business Management, College of Agriculture, Acharya N.G. Ranga Agriculture Univ., Hyderabad, India. The salient findings are:

(1) Brand disadvantage.
(2) Packaging not attractive.
(3) Pricing has to be much lower than branded products.
(4) Publicity through medical professionals should be done.
(5) Insufficient margin.
(6) Supply to institutions should be encouraged.

Fancy packaging adds to the cost and is not affordable with products of low turnover. There is vested interest at every level and demand for bribes, which a charitable trust cannot give. Despite difficulties, sale has increased almost 4-fold in the last 5 y. (Table 10).

Conclusions

Rural food processing industry requires much support from government to make it competitive. Entry of large companies even for products like pickles, papads, spices, and condiments limits the sustainability and employment generation capability of rural industries. Rural women have to be trained in costing and marketing skills. They have to be aggressive and attempt to capture at least the rural market.

Table 10—Sale proceeds from processed foods.

Year	Rs.
2002	45128
2003	73305
2004	130006
2005	168102
2006	176190

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