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Milk-Cereal-based Composite Complementary Foods and their Storage Stability: A Mini Review

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Abstract
In developing countries, depending upon the socio-economic situation, the nutritional status of the people is enhanced by encouraging increased use of inexpensive and available protein sources in child feeding. Traditional infant-feeding practiced in countries like India, is usually cereal based. Cereals in combination with milk solids are generally used for the preparation of weaning foods to improve the overall quality. Milk-cereal based complementary food is defined as food obtained from milk and milk solids, variety of cereals, pulses, soybean, millets, nuts and edible oil seeds and may contain other food additives and nutritionally significant minerals and vitamins. The quality of these food products during storage is affected by various factors such as inherent composition and exogenous factors such as packaging materials, head space air quality, storage temperature, humidity and handling. The published information about the milk-cereal based complementary foods along with the changes in the quality during storage has been briefly reviewed.

Keywords: *Milk-cereal based complementary food, protein sources, child feeding*

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INTRODUCTION

Malnutrition is the major hindrance to growth, development and learning capacity of children which accounts for 50 percent of all childhood deaths. In India 46 percent of the children of the age below "three" seems to be suffering from malnutrition, 47 percent of them are underweight and at least 16 percent are wastes, also many of them are severely malnourished. One out of the three children suffering from malnourishment is in India.

The amount and type of food intake and efficiency of nutrition absorption are the major reasons for the cause of malnutrition. The deficiency of vitamins and minerals also induce the disease [1].

Children after 6 months of age show high growth frequency and the mother's milk solely can't fulfil these requirements. Improperly fed children suffer from the malnutrition. Complementary food commonly called as weaning food or supplementary food, is intended to supplement the diet of infants aged above 6 months to 2½ years and has been assumed to overcome from early-age malnutrition. According to the Food Safety and Standards Authority of India (FSSAI), complementary foods are two types *viz.* milk-cereal and processed cereal based formulations [2]. Milk-cereal based complementary food is defined as food obtained from milk, variety of cereals, pulses, soybean, millets, nuts and edible oil seeds after processing.

It may contain edible vegetable oils, milk solids, various carbohydrates such as sucrose, dextrose, dextrin/maltodextrin, maltose and lactose, calcium salts; phosphates and citrates and other nutritionally significant minerals and vitamins. It shall contain a minimum of 10 percent milk protein by weight of the product. It shall also contain minimum 5 percent milk fat by weight.

It shall not contain hydrogenated fats containing trans-fatty acids. It may contain fungal alfa-amylases up to a maximum extent of 0.025 percent by weight, fruits and vegetables, egg or egg products. It may also include amino acids such as lysine, methionine, taurine, carnitine etc. It shall conform to the requirements given in Table 1.

Table 1: *Requirements of Milk-Cereal-based Complementary Food as per FSSR (2011) (2).*

1	Moisture, percent by weight (not more than)	5.0
2	Total protein, percent by weight (not less than)	15.0
3	Fat, percent by weight (not less than)	7.5
4	Total carbohydrates, percent by weight (not less than)	55.0
5	Total ash, percent by weight (not more than)	5.0
6	Ash insoluble in dilute hydrochloric acid, percent by weight (not more than)	0.1
7	Crude fibre (on dry basis), percent by weight (not more than)	1.0
8	Vitamin A (as retinol) µg per 100g. (not less than)	350
9	Added Vitamin D, µg per 100g. (expressed as cholecalciferol or ergocalciferol) (not less than)	5.0
10	Vitamin C, mg per 100g. (not less than)	25.0
11	Thiamine (as hydrochloride), mg per 100g. (not less than)	0.5
12	Riboflavin, mg per 100g. (not less than)	0.3
13	Niacin, mg per 100g. (not less than)	3.0
14	Folic acid, µg per 100g. (not less than)	20.0
15	Iron, mg per 100g. (not less than)	5.0
16	Zinc, mg per 100g. (not less than and not more than)	2.5 and 5.0
17	Bacterial count, per g. (not more than)	10000
18	*Coliform* count absent in	0.1g
19	Yeast and mould count absent in	0.1g
20	*Salmonella* and *shigella* absent in	25g
21	*E.coli* absent in	0.1g
22	*Staphylococcus aureas* absent in	0.1g

Table 2: *Requirements of Processed-Cereal-based Complementary Food as per FSSR (2011) (2).*

1	Moisture, percent by weight (not more than)	5.0
2	Total protein, percent by weight (not less than)	15.0
3	Total carbohydrates, percent by weight (not less than)	55.0
4	Total ash, percent by weight (not more than)	5.0
5	Ash insoluble in dilute hydrochloric acid, percent by weight (not more than)	0.1
6	Crude fibre (on dry basis), percent by weight (not more than)	1.0
7	Vitamin A (as retinol) µg per 100g. (not less than)	350
8	Added Vitamin D, µg per 100g. (expressed as cholecalciferol or ergocalciferol) (not less than)	5.0
9	Vitamin C, mg per 100g. (not less than)	25.0
10	Thiamine (as hydrochloride), mg per 100g. (not less than)	0.5
11	Riboflavin, mg per 100g. (not less than)	0.3
12	Niacin, mg per 100g. (not less than)	3.0
13	Folic acid, µg per 100g. (not less than)	20.0
14	Iron, mg per 100g. (not less than)	5.0
15	Zinc, mg per 100g. (not less than and not more than)	2.5 and 5.0
16	Bacterial count, per g. (not more than)	10000
17	*Coliform* count absent in	0.1g
18	Yeast and mould count absent in	0.1g
19	*Salmonella* and *shigella* absent in	25g
20	*E.coli* absent in	0.1g
21	*Staphylococcus aureas* absent in	0.1g

It shall be packed in hermetically sealed, clean and sound containers or in flexible pack made from film or combination or any of the substrate made of board paper, polyethylene, and polyester metallised film or in such a way to protect from deterioration. The processed cereal based complementary food may be obtained from variety of cereals, pulses, soya bean, millets, nuts and edible oil seeds after processing. It shall contain milled cereal and legumes combined not less than 75 percent. Where the product is intended to be mixed with water before consumption, the minimum content of protein shall not be less than 15 percent on a dry weight basis and the PER shall not be less than 70 percent of that of case in. The sodium content of the products shall not exceed 100 mg/100 g of the ready-to-eat product. It shall conform to the requirements given in Table 2. It shall also be packed in the way similar to milk-cereal based complementary food.

COMPOSITE COMPLEMENTARY FOODS

In developing countries, depending upon the socio-economic situation, the nutritional status of the people is enhanced by encouraging increased use of inexpensive and available protein sources in child feeding. Traditional infant-feeding practiced, in countries like India, is usually cereal based. To prepare such foods, grains are often germinated, fermented, processed and cooked in various ways to improve digestibility, and mixed with oilseeds or animal products to enhance their nutritional profile, however most of these complementary foods are reported to be less energy dense and less safe for children. Cereals in combination with milk solids are generally used for the preparation of weaning food to improve the overall quality [3]. Germination and malting increase the food value of cereal grains and addition of legume flour and vitamins can produce a balanced weaning food [4]. Weaning mixtures prepared with 45 percent precooked pearl millet flour, SMP, groundnut oil and sucrose was reported to alleviate energy malnutrition [5]. Pearl millet baby food prepared from 70 percent flour, 13 percent malt and 17 percent milk powder increased digestibility and lowered the viscosity of the foods and provided adequate protein and energy level for one year old children [6]. Extrusion of baby food prepared from 70 percent pearl millet and 30 percent cow pea supplied 17 percent of the daily needs of protein, 72 percent lysine and 110 percent of threonine in two year old children [7]. Dahiya and Kapoor developed four types of supplement mixtures using wheat or pearl millet, chick pea or mung bean, ground nut, amaranth leaves and jiggery using roasting and malting techniques [8]. Archana reported that weaning mixtures having pearl millet (raw/malted/blanched), cow pea or mung bean, SMP, sugar and ghee were highly acceptable with reasonable shelf life [9]. Zaheeruddin developed barley based nutrimix, a complementary food, by subjecting pearled and un-pearled barley to hydrothermal and extrusion processing in order to minimize phytic acid and polyphenols and pre-gelatinize the starch [10]. Phytic acid reduction was reported to be higher in pearled barley (70 mg/100 g) extrudates compared to un-pearled (25 mg/100 g). The extrudates so obtained were pulverized to obtain flour and dry blended with either whey protein concentrate (WPC-35), demineralised whey powder or skimmed milk powder (SMP). Cane sugar and flavourings were incorporated into the reconstituted nutrimix before serving. Shuddhodhan developed iron and zinc fortified pearl millet based nutrimix by subjecting cleaned, soaked, germinated and pearled pearl millet to extrusion processing [11]. The extrudates so obtained were pulverized to obtain flour and dry blended with either whey protein concentrate (WPC-70), SMP and iron and zinc salts. Cane sugar and flavourings were incorporated into the reconstituted nutrimix before serving. It was reported that ammonium ferric citrate and zinc sulphate were found suitable for fortification of nutrimix. The proximate composition of iron and zinc fortified pearl millet based nutrimix is given in Table 3.

FACTORS AFFECTING THE QUALITY OF FOODS DURING STORAGE

The quality of food products during storage is decided by several factors classified into two major groups *viz.* endogenous factors which mainly includes inherent composition of food products and exogenous factors such as packaging materials, head space air quality, storage temperature, humidity and handling. The effect of these factors on the quality of complementary foods is given below.

Table 3: *Proximate Composition of Mineral Fortified Pearl Millet Nutrimix.*

Chemical Constituent	Quantity(g/100g)
Moisture	3.24
Carbohydrate	80.79
Protein	14.64
Fat	1.70
Crude fibre	1.05
Ash	1.82
Iron (mg/100g)	8.29
Zinc (mg/100g)	4.64
Calcium (mg/100g)	193.47

Source: *Shuddhodhan (2012) [11].*

Chemical Constituents

The food quality deterioration attributed to chemical, physical and microbiological changes is manifested mainly through sensory analysis and loss in nutritional components. The non-enzymatic browning is good example for chemical related changes, develops due to reaction between carbohydrates and protein groups and also lipid based changes due to auto-oxidation trigger by oxygen and added free iron content. The length and conditions of storage and the specific composition of the cereals can all influence the progress of the maillard reaction that occurs during their processing [12, 13]. The Maillard reaction is one of the most important modifications in foods contains proteins and reducing carbohydrates. Loss of available lysine, the worst nutritional consequence of the Maillard reaction, was particularly significant in cereals, where this amino acid is limiting [14]. The browning index during storage of the weaning food made up of multi-purpose flour, papaya powder and milk powder was found to increase from 0.341 to 0.593 [15]. The apple puree based weaning food observed with browning changes; the intense red colour was promoted during length of storage [16]. The non-enzymatic browning and free fatty acids development were found to be progressively increased during storage of weaning food made of extruded peanut, maize and soybean [17]. Similar results regarding generation of Maillard browning during storage were obtained in apple based beikost [18]. Both Maillard reaction and lipid oxidation exerts positive approach on increasing browning of food and both are inter-related in the sense of curtailing and promoting their pathways [19]. The consequent physical changes in complementary food like caking, browning etc. are due to absorption of moisture at higher relative humidity, storage at elevated temperature and also hygroscopic nature of food constituents.

Light

Food can be adversely affected by prolonged exposure to light. The chemistry of light-catalyzed changes can be quite complex and may promote various chemical reactions. For example, oxidation of fats and oils to produce the complex of changes known as oxidative rancidity and oxidation of milk leading to formation of volatile and unpleasant mercaptans and changes in various pigments. Riboflavin is especially photosensitive and when exposed to sun light it loses its vitamin value and also activates or sensitizes other components to photo degradation. Ascorbic acid is also quite sensitive to light and it interacts with other components during light exposure. Sensitivity of a given class of foods to various wavelengths of light can vary with the method of processing. The most penetrating quanta of light are those with wavelengths which are least effective per quantum of energy. Thus, ultraviolet rays penetrate less deeply into food than the red light components. In addition to wavelength the intensity and duration of exposure are also important.

Oxygen

Oxidation reactions are often the cause of undesirable changes in foods. Apart from fats and oils, many vitamins, pigments and some amino acids and proteins are oxygen sensitive. The amount of oxygen available in the headspace and concentration of oxygen in the food are the two variables that are important here. By packaging in a hermetically sealed container which is constructed of an impermeable material, it can be assured that the total amount of oxygen available to react with food is finite. However, the concentration

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of oxygen in food depends on the oxygen pressure. The relation between rate of oxidation and oxygen pressure varies with type of reaction, type of product and temperature. It has been reported that the relationship is nonlinear and above some level of oxygen pressure has no effect on oxidation rate.

Water Content

The water content of foods is dependent on the relative humidity of the immediate environment. It has been observed that the state of the water is related to the vapour pressure of food. Greater the proportion of free water, greater will be the vapour pressure and vice versa. Increased bound water reduces vapour pressure. Walter in 1924 was probably the first researcher to relate relative water vapour pressure to microbial growth, the main cause of food spoilage. A decade afterwards, Scott and Salwin independently applied this relationship and introduced the concept of water activity (a_w). This will be a measure of 'Free State', 'boundness' and 'quality' of the water in food [20]. The distilled water shows a humidity of 100% and all foods show humidity less than 100%. For convenience, the humidity of food is expressed in decimals and is called water activity of foods.

Temperature

It is a well-known theory about temperature that it speeds up the rate of chemical reactions in food products and hence it is crucial factor to safeguard the food for long shelf life. The complementary foods are stable at room temperature compared to elevated storage temperature may leads to certain undesirable outcomes. The rate of deterioration of peanut, maize and soybean based extruded weaning food was found to be sensitive to temperature change [17]. Also, the temperature was found to have an effect on the shelf life of weaning food made from malted ragi and green gram [21]. Ramirez-Jimenez *et al*. reported that the loss of nutrients and generation of browning components varied with storage temperature of infant rice cereal [22]. The studies on milk-based powdered infant formula revealed to have higher vitamins losses were higher with increase in storage temperature and whereas, minerals found to be stable throughout the storage [23].

Packaging Materials

The package offers protection against agent that degrades the product. Generally, the basic properties of packaging materials required for better protection are measured in-terms of water vapour transmission rate (WVTR), oxygen transmission rate (OTR), thermal stability etc. The requirements of packaging materials, however, depend on the type of product, if the product is moisture sensitive then it should have high barrier to moisture and if the product is sensitive to oxygen related deterioration then it should have high oxygen barrier. A great variety of materials are used in food packaging to address these requirements *viz.* glass, metal, plastics, paper boards, etc. Glass containers have been used for many centuries and still are among the important packaging materials. Glass containers possessing the proper type of closure can be used for practically all types of food packaging applications. Physically, glass is a super cooled liquid of very high viscosity. Chemically, it is a mixture of inorganic oxides of varying composition. Most container glass is of the soda-silica type. The most important properties of glass with respect to food packaging are exceptionally high barrier to water vapour and gases. However, it is poor barrier to light. The light barrier properties of glass could be controlled by inclusion of small amounts of oxides of various metals such as chromium, cobalt, iron, etc. Tinplate, which consists of a base sheet of steel with a coating of tin applied to it by hot dipping or electrolytic process, is the most common metal used for food packaging applications. A typical tinplate may be 0.01 inches thick, with the tin coating contribution only about 0.00005 into this thickness. To make the tin can more suitable for specific packaging applications enamels or lacquers can be applied to the tinplate. The composition of lacquers varies with intended use and may include plastics, shellacs, resins, inorganic oxides, etc. Tin-free steel utilizing direct chromium-containing coatings or such very thin thermoplastic coatings are also used. The greatest advantages of tinplate, tin-free steel and aluminium foil with respect to food packaging are barriers to light, water vapour, gases and microbes all of which contribute for extending the shelf life of foods. Also, among the metal packaging materials, aluminium foils have been found to have wide applications. Plastics are organic polymers of varying structure, chemical composition and physical properties. Among all the materials used for food packaging applications, plastics account for more than 40 percent. Polyolefins, polyamides, polyesters, vinyl derivatives including polystyrene, etc. are the commonly used plastics in food packaging. Among the polyolefins, low density polyethylene (LDPE) with high branching has the advantage of maximum flexibility and low cost and is widely used for packaging of foods in bags or as an overwrap. High density polyethylene (HDPE) has the least branching and as a result the greatest thermal stability adds the lowest permeability. HDPE is used in film form as well as for production of rigid plastic containers. Among all the plastics, LDPE and HDPE have good water vapour barrier property. Polypropylene (PP) is closely related to polyethylene and its properties and uses are similar. However, it is widely used for packaging of autoclavable or retort pouches. Properties of vinyl derivatives such as polyvinyl chloride, polyvinylidene chloride, polystyrene, etc. are dependent on the nature of substituents, on molecular weight, on the spatial arrangement of groups within the chains and especially on orientation and crystallinity. The polyester of most importance in food packaging is polyethylene terephthalate (PET), a condensation product of ethylene glycol and terephthalic acid is a crystalline linear polymer of excellent strength and inertness. Polycarbonates are polyesters of carbionic acid and have carbonate linkages. Polyesters have outstanding mechanical properties over a wide range of temperatures. Polyamides, usually called as nylons in trade, are condensation polymers of diamines with diacids which are inert and heat resistant and possess excellent mechanical properties. Nylon is also an essential element in a retort pouch and widely used along with PET for vacuum packaged products.

IMPORTANCE OF WATER ACTIVITY (a_w) IN STABILITY OF FOOD

The definition of water activity is based on the chemical potential of water within a food system, which at equilibrium must be same as the chemical potential of water in the surroundings of the food. Hence, water activity can be defined as the ratio of vapour pressure of pure water to that of vapour pressure of water in food at the same temperature and pressure conditions [24]. At equilibrium, a_w is related to the relative humidity of the surrounding atmosphere by:

$$a_w = \frac{P}{P_0}$$

where, P is vapour pressure of water in the food material at any given temperature,
P_0 is the vapour pressure of pure water at that temperature. A_w is the important phenomenon in food products to control their stability against deterioration. Understanding and control of water activity contributes to safer food storage conditions in general and forms the basis of modern food formulation and preservation. The effect of water activity on chemical reactions between food components has been described by many investigators such as accelerated non-enzymatic browning associated with a loss of free amino nitrogen occurred during storage, lipid oxidation which shows the peculiarity of a minimum at the monolayer (M_0) with increased rates below and above it, etc. Water activity affects the stability, flow and caking and clumping of powders during storage. This is because of the ability of water to acts as a solvent, reaction medium, and reactant. Controlling water activity in a powder product below critical levels maintains proper product structure, texture, and flowability, density and rehydration properties. Knowledge of the water activity of powders as a function of moisture content and temperature is essential during processing, packaging and storage to prevent the deleterious phenomenon of caking, clumping and stickiness. Caking is dependent on water activity, time and temperature and is related to the collapse phenomenon of the powder under gravitational force [25]. Textural quality is also greatly affected by moisture content and water activity. Dry crisp foods (e.g., potato chips, crackers) become texturally unacceptable upon gaining moisture above the 0.35–0.5 a_w range [26]. Intermediate moisture foods like dried fruits and bakery goods, upon losing moisture below 0.5–0.7 a_w become unacceptably hard [27].

STORAGE STABILITY OF PACKAGED COMPLEMENTARY FOODS

The published information about the use of different packaging materials for complementary foods has been briefly reviewed in this section along with the changes in the quality during storage. For complementary foods the packaging materials should possess high moisture and oxygen barrier properties. Commercially the complementary foods are packed in tin jars or flexible bags with nitrogen flushing [22]. Shelf life of low dietary bulk weaning food based on malted ragi and green gram packaged in different flexible packaging materials (LDPE, 200 gauge; HDPE, 250 gauge; laminate of paper, aluminium foil (0.009 mm) and PE, 150 gauge) and stored at 38ºC and 92 percent relative humidity (RH) and 27ºC and 65 percent RH was studied by Malleshi *et al.* [21]. It was found that during 150 days of storage, as the storage period increased, there were increases in moisture content and free fatty acid (FFA). At any given time, the moisture content was high for samples packed in LDPE and low for laminate and intermediate for HDPE pouches. Under accelerated storage conditions, FFA values increased from 5.5 to 21.3 and 29.5 percent in samples packed in LDPE pouches at the end of 70 and 90 days of storage, respectively. Higher FFA values in samples stored at elevated temperature and humidity indicated that the low dietary bulk weaning food based in malted ragi and green gram was prone to hydrolytic rancidity. However, it was further reported that throughout the storage period the peroxide value remained low indicating low level of oxidative rancidity [21]. Malleshi *et al.* further reported that the viscosity of the weaning food increased considerably from 550 to 6000 centipoise at the end of 150 days of storage period and indicated that it was not a desirable feature as high viscosity limits intake of food by the child. Also, it was reported that, with respect to sensory flavour and overall acceptability, sample packed in LDPE and HDPE pouches and stored at ambient temperature (27ºC and 65 percent RH) were stable upto 90 days while the samples packed in laminates were stable till 120 days. However, under accelerated conditions (38ºC and 90 percent RH), LDPE and HDPE packed samples were found stable upto 70 days while sample packed in laminates had a shelf life of 90 days only. As a result Malleshi *et al.* recommended use of paper/foil/poly or metallised polyester/poly for long term storage of low dietary bulk weaning food [21]. The multipurpose flour (rice and gram flour), papaya powder and milk powder based weaning food was developed by Ahmad *et al.* [15]. The formulated powder was made into slurry and by suspending it in water (1:4) followed by autoclaving and dried (100ºC for 4–6 h) in a cabinet dryer. The product so obtained was packed in PET jars and combination film (CF) in presence of either air (APS) or nitrogen gas (NP) and stored for 120 days. It was reported that the moisture content increased from 3 to 6 percent, 6.4 and 4.3 percent in CF (APS), PET jar (APS) and CF (NP), respectively. It was reported that the initial browning index of weaning food sample was 0.398 which increased to 0.476 at the end of 120 days in CF (NP) samples. The sensory scores of samples stored in CF (NP) were also reported to be higher compared to others. Complementary food made up of dried broken rice is widely used in Thailand. Chitpan *et al.* developed the calcium and iron fortified dried broken rice based complementary food at the levels recommended by the WHO [28]. It was reported that ferric sodium ethylene diamine tetra acetic acid (NaFeEDTA) was the most appropriate iron fortificant. The stability of the iron fortified complementary food under fluorescent and luminescent lamps was studied by packing about 70 g of the sample in either laminated (nylon-polyethylene) or metallized (oriented polypropylene-metallized cast polypropylene) pouch and storing for three months at 42ºC. The authors reported that only a slight increase in moisture content and a_w was observed for both the packaging. Further, the product fortified with NaFeEDTA that was packed in metallized bags was most stable in terms of oxidative rancidity. No losses in thiamine, vitamin used as indicator, were observed in fortified products packed in either type of packaging. Afoakwa *et al.* studied the quality characteristics of cowpea fortified maize-based traditional weaning food packaged in polypropylene bags and stored at ambient conditions (26–31ºC and 85–100 percent RH) of the Ghana, where the study was conducted [29]. It was reported that the acidity of the extracted fat during storage increased from 204.20 to 214.95 mg KOH/100 g dry sample. Plahar *et al.*

studied the stability of extruded weaning foods based on peanut, maize and soybean packaged in polyethylene bags and stored at 30, 45 and 55 ºC. Non-enzymatic browning and development of free fatty acids (FFA) were used as indices of storage stability [17]. It was reported that browning rates followed zero order kinetics at all three temperatures. Further, the rates of production of FFA were found to be faster by 28, 57 and 72 percent at 30, 45 and 55 ºC, respectively. The authors reported that at normal refrigeration temperatures, the extruded products can be kept for at least three years. The effect of tin cans and polypropylene bags on the physicochemical and rheological characteristics of iron-fortified whole meal flour during storage was determined by Huma *et al*. [30]. It was reported that the fortified minerals were stable for about 28 days of storage. Further it was reported that the flour stored in polypropylene bags proved to be more stable than those stored in the tin cans.

CONCLUSION

Presently, developing countries like India are facing problems of child malnutrition and hidden hunger which are leading to morbidity and death. Complementary food commonly called as weaning food or supplementary food, is intended to supplement the diet of infants aged above 6 months to 2½ years and has been assumed to overcome from early-age malnutrition. Milk-cereal based complementary foods may contain milk solids and a variety of cereals and millets fortified with micronutrients. Like any other food products, complementary foods also need to be safeguarded against critical environmental factors. Usually such foods are stored using high moisture and oxygen barrier properties possessing packaging materials. The commercial success of complementary foods is envisaged when packed in tin jars or flexible bags with or without nitrogen flushing.

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