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Specialty starches for snack foods

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Abstract

Specialty starches in snack foods serve as functional ingredients, contributing to desirable attributes such as increased expansion, improved crispness, reduced oil pick up and better overall eating quality. Starch-based coatings and adhesives can replace fat or oil in low-fat baked snacks. Dry hot melt starch-based adhesives are cost-effective tacking agents, while resistant starch provides high fiber nutritional claims for snack foods. The type of starches chosen will depend on their cost, availability, functionality and the quantity used. The present review highlights the functionality of specialty starches in a variety of snack foods. Types of specialty starches, their biochemical aspects, legal aspects and commercial availability are also discussed.

Keywords: Specialty starches; Snack foods; Cross-linked starch; Dextrins; Pregels; Starch hydrolysis products; Starch esters; Starch ethers; Resistant starch

1. Introduction

Snack, defined as a light meal eaten between regular meals include a broad range of products that can take many forms. Definitions of snacks are being modified to include sandwiches, yogurt and even ice creams. Native starches are frequently limited in their food applications, due to cohesive texture, heat and shear sensitivity, lack of clarity, opacity and low viscosity. Retrogradation or precipitation can result on storage, posing additional problems. This has led to the production of specialty starches, which can provide consistent results specific to the needs of the products. Specialty starches continue to outpace unmodified starches in the processed food industry because of their ruggedness and ability to withstand severe process conditions. In selecting a specialty starch for a particular application, both marketing and production requirements have to be considered. The market-related properties are product properties such as the structure (e.g. gelled), aesthetics (e.g. clarity, smooth or pulpy or grainy), organoleptic considerations (e.g. mouth feel, taste) and shelf stability (Dias, Tekchandani, & Mehta, 1997). The production-related requirements are properties like viscosity, resistance to shear, low pH, high temperature etc. Table 1 lists some of the specialty starches that can be prepared from various starch types and that also meet the formulation requirements.

Besides their textural and viscosity benefits, specialty food starches often reduce costs of established food products. More expensive ingredients such as tomato solids, fruit solids or cocoa powder can be extended with combinations of such starches, flavors and other inexpensive food substances. Considering the high degree of functional contribution, and the low rate of usage the cost allocation of specialty starch to finished product remains low (Langan, 1987).

2. Legality

Modified food starch is a food additive and limits of its modification, use and labeling are clearly defined in the US Code of Federal Regulations (21 CFR 172.892) (Moore, Tuschhoff, Hastings, & Schanefelt, 1984).

Abbreviations: SHP, starch hydrolysis products; DE, dextrose equivalent; MCC, microcrystalline cellulose; CMS, carboxymethyl starch; DS, degree of substitution; WAI, water absorption index; UHT, ultra high treatment; HP, hydroxypropylated; FDA, food and drug administration; DP, degree of polymerization; DF, dietary fiber; RS, resistant starch; WHC, water holding capacity; TDF, total dietary fiber; WPI, Whey protein isolate.

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Table 1
Types of specialty starches meeting some formulation needs

Marketing requirements	Regular maize	Waxy maize	High-amylose maize	Tapioca	Potato
Gelled	Thin-boiling		Thin-boiling		
Flowable	Stabilized	Cross-linked		Cross-linked	Cross-linked
Expanded		Cross-linked		Cross-linked	Cross-linked
Rigid			Thin-boiling		
Rubbery			Thin-boiling		
Clarity		Cross-linked		Cross-linked	Cross-linked
Opacity	Cross-linked		Cross-linked, Thin-boiling	Thin-boiling	
Pulpiness	Pregelatinized and cross-linked			Pregelatinized and cross-linked	
Smoothness		Cross-linked		Cross-linked	Cross-linked
Graininess	Cross-linked			Cross-linked	
High temperature storage	Cross-linked	Cross-linked		Cross-linked	Cross-linked
Low -temperature storage		Stabilized, cross-linked and stabilized		Stabilized, cross-linked and stabilized	Stabilized, cross-linked and stabilized
Low pH storage	Cross-linked			Cross-linked	Cross-linked

The European Directive on food additives allows the following food starches in foods.

E1400: Dextrin (roasted starch)
E1401: Acid treated starch
E1402: Alkaline modified starch
E1403: Bleached starch
E1404: Oxidized starch
E1410: Monostarch phosphate
E1412: Distarch phosphate
E1413: Phosphated distarch phosphate
E1414: Acetylated distarch phosphate
E1420: Starch acetate
E1422: Acetylated distarch adipate
E1430: Distarch glycerine
E1440: Hydroxypropyl starch
E1441: Hydroxypropyl distarch glycerine
E1442: Hydroxypropyl distarch phosphate
E1450: Starch sodium octenyl succinate
E1451: Acetylated oxidised starch

Modified starches consist essentially of starch with low to very low levels of substituent groups. Extensive safety studies reviewed by independent regulatory bodies provide adequate assurance of their safety (Wurzburg & Vogel, 1984). Table 2 shows the chemically modified starches allowed for use in foods by the Food Chemicals Codex.

3. Specialty starches as functional ingredients

3.1. As fat replacers

3.1.1. Maltodextrins and other starch hydrolysis products (SHP)

Among the carbohydrate-based fat replacers are α-amylase converted tapioca and potato starches and maltodextrins, having a DE of about 5 or less (Lenchin, Trubiano, & Hoffman, 1985) at 25–35% solids. The starches so prepared form gels in water that have a neutral taste and a smooth creamy consistency. The replacement products are comparable to the controls at the correct replacement level. Low DE maltodextrins based on potato starch based are fat replacers in low fat dressings and spreads (Minoru, Naoko, Masami, Masaki, & Tsukasa, 1993), while that derived from waxy maize can be used to replace over 50% of bakery fats in a range of bakery products. Hydrolyzates prepared by acid roasting of a native tapioca/sweet potato starch, having an amylopectin/amylose ratio of 80–85: 15–20, are useful as partial substitutes for oils and fats in butter cream (Minoru et al.). Batz, Mueller, and Drummond (1994) prepared a high moisture (50%), low-fat cheese product by mixing skimmed milk curd, starch hydrolyzate, salt and an emulsifier. At levels of 1–5%, maltodextrin imparts a custard-like texture to yogurt.

Carbohydrates having an spheroidal shape and a particle-size distribution of about 0.1–2 microns are reported to have the organoleptic character of an oil-in water emulsion (Singer, Chang, Tang, & Dunn, 1990). A fat-like carbohydrate characterized by a high strength starch gel comprising 20–30% by weight short-chain amylose is used in foods as a replacement for up to 100% by weight of one or more fats contained in foods. It is prepared by the enzymic debranching of cornstarch with pullulanase, which specifically degrades the α-1,6-D-glucosidic linkages of the starch molecule. The short-chain amylose may be used in a refined form or as a mix, further comprising long chain amylose, amylopectin or combination thereof. It may be modified by derivatization, conversion or cross-linking before or after debranching the starch. Foods in which the short chain amylose can be used in place of fat, cream, oil, oil-in-water and water-in-oil emulsions are ice cream, spoonable and pourable salad dressings, margarine low-fat spreads, low-fat cheese, baked foods, breaded foods, sauces,

Table 2
Chemical modifications of starch permitted in foods (USA) (Food Chemicals Codex, 1996)

Specialty starch	Treatment to produce the starch; residuals limitation
Gelatinized starch	Sodium hydroxide, not to exceed 1%
Thin-boiling or acid-modified starch	Hydrochloric acid and/or sulphuric acid/α-amylase enzyme (GRAS)
Starch ether-esters	Phosphorus oxychloride, not to exceed 0.1%, and propylene oxide, not to exceed 10%; not more than 3 mg/kg of residual propylene chlorohydrin
Oxidized starch ethers	Chlorine, as sodium hypochlorite, not to exceed 0.055 lb (25 g) of chlorine per lb (454 g) of dry starch: active oxygen obtained from hydrogen peroxide, not to exceed 0.45% and propylene oxide, not to exceed 25%; not more than 1 mg/kg of residual propylene chlorohydrin
Bleached starch	Active oxygen obtained from hydrogen peroxide, and/or peracetic acid, not to exceed 0.45% of active oxygen. Ammonium persulfate, not to exceed 0.075% and sulfurdioxide, not to exceed 0.05%. Chlorine, as sodium hypochlorite, not to exceed 0.0082-lb (3.72 g) of chlorine per lb (454 g) of dry starch. Potassium permanganate, not to exceed 0.2%; not more than 0.005% of residual manganese (as Mn). Sodium chloride, not to exceed 0.5%.
Oxidised starch	Chlorine, as sodium hypochlorite, not to exceed 0.055lb(25 g) of chlorine per lb (454 g) of dry starch.
Starch acetate	Acetic anhydride or vinyl acetate; not more than 2.5% of acetyl groups introduced into finished product
Acetylated distarch adipate	Adipic anhydride not to exceed 0.12% and acetic anhydride; not more than 2.5% of acetyl groups introduced into finished product
Starch phosphate	Monosodium orthophosphate; not more than 0.4% of residual phosphate (calculated as *P*).
Starch octenyl succinate	Octenyl succinic anhydride, not to exceed 3%, followed by treatment with α-amylase
Starch sodium octenyl succinate	Octenyl succinic anhydride, not to exceed 3%.
Starch aluminium octenyl succinate	Octenyl succinic anhydride, not to exceed 2%, and aluminium sulfate, not to exceed 2%
Distarch phosphate	Phosphorous oxychloride, not to exceed 0.1%; sodium trimetaphosphate, not more than 0.04% of residual phosphate
Phosphated distarch phosphate	Sodium tripolyphosphate and sodium trimetaphosphate; not more than 0.4% of residual phosphate (calculated as P).
Acetylated distarch phosphate	Phosphorous oxychloride, not to exceed 0.1%, followed by either acetic anhydride, not to exceed 8%, or vinyl acetate, not to exceed 7.5%; not more than 2.5% of acetyl groups introduced into finished product.
Starch sodium succinate	Succinic anhydride, not to exceed 4%.
Hydroxypropyl starch	Propylene oxide, not to exceed 25%; not more than 1 mg/kg of residual propylene chlorohydrin.

whipped toppings, icings, pudding, custards, mayonnaise and coffee whiteners (Chiu & Mason, 1992).

3.1.1.1. Low-fat butter spreads/margarine. Low DE starch hydrolyzates having good water binding properties can function more effectively as fat replacers in comparison to high DE starch hydrolysis products (SHP). Potato starch hydrolyzate of DE 2–5 at 3–5% is suitable as fat substitute without any impairment in taste (Mishra & Rai, 2002). The capacity of these gels to compensate textural and physical properties of milk fat may be attributed to two mechanisms i.e. impact on mouth feel and colloidal properties of these hydrolyzates. In one study, a blend of hydrogenated fat and liquid oil was used for the preparation of low fat butter spreads. When the fat content of the spread was reduced to 57% by incorporating starch hydrolyzate along with hardened oil, the spread showed better spreadability at refrigeration temperature and better stand up properties at high storage temperature as that of commercial butter (Reddy, Nalinnakshi, & Chetana, 1999). The maltodextrin, termed SHP, is produced by α-amylase action on starch granules before and during gelatinization, rather than afterwards as in the case for conventional maltodextrins (Bulpin, Cutler, & Dea, 1984). Maltodextrins at 1–5% maintain body in sour cream.

A non-fat edible plastic dispersion which has rheological properties similar to solid margarine includes fat mimetic selected from the group consisting of gelling type maltodextrin, starch modified by acid hydrolysis to remove amorphous regions, branched chain amylopectin starch, and inulin as a texturizing agent (Buliga et al., 1996).

3.1.1.2. Low-fat mayonnaise, salad dressings, sauces. The formulation of a low-fat mayonnaise consists of typically 60–78% water, 1–12% egg white (or other protein), 0.25–5.00% MCC and 1–15% polydextrose. Polydextrose may be replaced by maltodextrin with a DE of about 10 at 3–8% (Meiners, Merolla, Smagula, Bernardini, & Harkabus, 1992). A granular cold-swelling starch, at 3–7% of total product weight is a fat substitute in foods such as mayonnaise, salad dressings, sauces and dips (Melwitz, Spitzfaden, Seewi, & Stute, 1992). High-acid liquid systems such as pourable salad dressings are often thickened with modified and pregelatinized waxy starches. Low to moderate cross-linking is sufficient for the cling to salad contents (Langan, 1987).

A method of preparing the peanut spread comprises a premix of the granular starch hydrolyzate and water, fragmenting the granular starch hydrolyzate and then blending the resulting particle gel with a peanut component to produce a macroscopically homogeneous blend (Prosser, 1995). The fragmented granular starch hydrolyzate is capable of forming an aqueous dispersion at 20% solids.

3.1.1.3. Low fat milk type product (Wheelock, 1994). A new milk type product 'Halo' was developed by Northern Dairies, UK in response to consumer demand for low fat milk type product, using a fat replacer based on starch hydrolyzate with a more acceptable flavor and texture than semi-skim milk.

3.1.1.4. No-fat/low-fat ice cream (Gross & Haralampu, 1999). A formulation of skim milk 23.24 kg, non-fat dry milk 2.04 kg, sugar 3.86 kg, maltodextrin (5 DE) 1.45 kg, corn syrup solids (36 DE) 0.83 kg, stabilizer 0.08 kg, mono and diglycerides 0.06 kg and microcrystalline starch-based product 0.26 kg are dispersed in the liquid using an overhead stirrer for 5 min. The mixture is then pasteurized in a regenerating PHE in which the premix is heated to 71 °C in the regeneration portion of the heat exchanger and homogenized through a two-stage homogenizer (2000/500 psi) followed by pasteurization at 85 °C, for 25 s before being cooled to 4 °C. The premixes are aged overnight at 4 °C and frozen at −7 °C, packed in 946 ml containers and hardened overnight at −40 °C. The ice-cream formulation is organoleptically similar to normal ice creams. Potato starch hydrolyzate of DE 2–5 functions as a body and viscosity enhancing agent and fat substitute at 3.5% level in ice cream without impairment in taste of the product (Dorp, 1996b).

3.1.1.5. Baked low-fat snacks. Pregelatinized waxy cornstarches are used to produce low-fat snacks that are made by baking or by indirect expansion process (low-shear extrusion followed by microwave baking or frying). Pregelatinized waxy cornstarch is necessary because the temperature rises slowly in the dough and the raw starch does not have sufficient time to gelatinize (Huang & Rooney, 2001). In cakes, total replacement of fats with amylodextrins and octenyl succinylated amylodextrin results in higher firmness than control (Young, Won, Lim, & Lin, 2001). N-Lite B, of National Starch, a waxy maize starch-based maltodextrin, can be used to replace over 50% of bakery fats in a range of bakery products (Anon, 1993).

3.1.2. As clathrate inclusion complexes

The formation of clathrate inclusion complex is yet another form which can be used as a fat replacer. It can be prepared by suspending acetylated starch in water, heating the resultant suspension past the gelation point of the starting material, cooling the resulting hydrogel while adding a lipid such as a triglyceride and homogenizing the resulting product at a temperature below the melting point of the lipid in the case of fats and 45° (in the case of oils). The clathrates are stable and resistant to retrogradation, can be dispersed into a variety of foods, and also reduce fat in ice creams and tortillas (Nickel & Berger, 1996). Starch–lipid composites can be used as a fat replacer in low-fat beef patties (Warner, Eskins, Fanta, Nelsen, & Rocke 2001).

3.1.3. Modified starches and other miscellaneous forms

A microcrystalline starch-based product comprising resistant microcrystalline starch, glucose and short chain glucooligosaccharides can be used as a fat extender in low-fat or fat-free food formulations (Gross & Haralampu, 1999). A propoxylated starch-cross-linked acetylated starch mix that has been previously heated to 180 °C and cooled is reported to be useful in low-fat formulations of salad dressings, margarines and ice creams (Rispoli, Sabhlok, Ho, Scherer, & Giuliano, 1981).

A new fat-replacement technology, based on high-pressure steam cooking of starch and soybean oil, was developed at the USDA labs in Peoria, IL. It was found that after cooking starch and oil together, they obtained a gel that could be easily dried and ground into a powder. The oil did not separate out on further heating or freezing. It was reported that by using as little as 2% of this ingredient, called 'Fantesk' in a frozen dairy product, a 0.3%-fat ice milk had the same taste and texture as an 8-to-10%-fat ice-cream. Bedford, MA-based Opta Food Ingredients has obtained an exclusive license on Fantesk.

Hydroxypropyl starches may be used in conjunction with other thickeners for e.g. with carrageenan in milk systems to be retorted and with xanthan gum in salad dressings (Rutenberg & Solarek, 1984).

3.2. To reduce oil uptake

High amylose starches and tapioca dextrins form oil-insoluble films, which hinder oil pickup in fryers and oil migration into or out of the product (Huang & Rooney, 2001). Dough formed from vital gluten, gelatinized amylopectin from maize and a stabilizer or thickener produces a chip that possesses an excellent bite, and has a considerably reduced fat content in the finished product.

Esterified propoxylated starch has been used to prepare reduced-calorie French fries (Cooper, 1993). Carboxymethyl corn starch (CMS) at 0.5–3.0% has been shown to reduce fat content in the Indian deep fat fried snack 'sev', based on Bengal gram flour (Bhattacharyya, Chhaya, Singhal, & Kulkarni, 1995).

In case of cake donuts, partial replacement of the traditional wheat flour with rice ingredients, or using modified flour or starch (gelatinized long grain rice flour or precooked acetylated and cross-linked rice starch) as additives reduce the oil content. These additives have superior water-holding capacity and require extra water to maintain proper dough consistency and firmness of the doughnuts. The extra water added normally correlated to higher moisture content and lower oil uptake (Shih, Daigle, & Clawson, 2001). Doughnuts showing reduced oil absorption during frying can also reportedly be manufactured by using baking powder comprising $NaHCO_3$, rapid-acting acidic agents, slow-acting acidic agents and α-starch (Hisato, Hideyo, & Nobuyoshi, 2001).

3.3. To improve the handling properties of the dough/use of dough improvers, artificial flours

Pregelatinized starches that maintain their granular shape improve the handling and forming properties of the dough used to make expanded products (Huang & Rooney, 2001) 2–14% of high amylose starches (over 50%) improves the dough for leavened pastries with reduced thickness and proofing time, and gives tender stable crust of more uniform thickness and fewer tendencies to shrink (Radley, 1976). High amylose starch strengthens extruded pasta, inhibiting disintegration when retorted in the presence of sauce and adds crispness to extruded half-products which are later expanded in hot oil.

Starch phosphate in combination with amino acids (e.g. glycine) and anionic or non-anionic edible surfactants are useful as macaroni dough structure improver, which increases efficiency, reduces cracking during drying, and improves cooking properties (Schneider, Kalinina, & Ivanova, 2000).

A ready-to-bake, frozen bread dough using 1–20% artificial flour has been reported. The artificial flour consists of 30–70% protein and 70–30% modified starch. The modified starch may be cross-linked waxy maize starch, while the protein component may consist of gelatin and non-gelling gelatin, hydrolyzed gelatin and collagen (Ortiz & Sanders, 1996).

3.4. For instant puddings, dry mixes and instant gravies

Instant puddings are expected to have very smooth textures and heavy-bodied consistency. Since these mixes are high in sugar and other dry ingredients to aid dispersion, fine grind potato (owing to their blandness) pregels are recommended (Dias, Tekchandani, & Mehta, 1997). Lightly cross-linked tapioca with good refrigerator stability is preferred. Cross-linking is needed to avoid complete disruption during drum drying, which would result in an unacceptable slimy and cohesive texture in the pudding.

Acetylated starches are pregelatinized for use in dry mixes and instant gravies and pie fillings. The dry formulation consists principally of soluble starch, sugar flavoring together with salts, which produce enough viscosity in milk to keep the starch suspended until it hydrates. Upon addition of cold milk, the starch quickly dissolves and sets to a gel (Mitch, 1984). Cold water swelling starch phosphate with 3–4% bound phosphorus can be prepared by heat-reacting starch with a 1:2 mixture of NaH_2PO_4 at 150–165 °C, for 4–6 h. The starch is washed with alcohol and dry-mixed with sugar and flavoring and added to cold milk to form puddings, which set rapidly to have a smooth texture and good eating quality. Cold water swelling starch can comprise of a blend of at least 2 starch components, an amylose free starch and a starch containing at least 20% amylose which is used as a thickening agent in both cooked and instant food formulations e.g. gravies, soups, sauces, dressings, hot beverage mixes and puddings (Eastman, 1987).

A pregelatinized starch phosphate of DS 0.7 gelatinizes at ambient temperatures, and is used in instant pie fillings, dessert powders and icings (Hoseney, 1994a; Othmer, 1995). Maltodextrins are sprayed on instant tea and coffee, instant soup mixes to keep the granules free flowing.

3.5. As thickening agents/replacers for pectin, vegetable solids

Cross-linked stabilized starches such as acetate, phosphates and hydroxypropyl ether starches derived form tapioca, potato and waxy maize either in granular form or after pregelatinization are used as thickeners in baked, frozen, canned and dry foods. They are used in fruit pie fillings, tarts and gravies (Dias, Tekchandani, & Mehta, 1997). Succinate derivatives of starch have been recommended as binders and thickening agents in soups, snack, canned and refrigerated products.

A new specialty starch product, amylopectin potato starch, developed with the aid of modern biotechnology, containing only amylopectin can be used as a thickener/-stabilizer in a wide range of sectors of the food industry (Vries, 1995). A dual esterified starch with low gelatinization point and a high peak viscosity in noodles improves their consistency and mouth feel. The starch will gelatinize and absorb water before the wheat flour takes over and dominates the viscosity profile. Pregelatinized starch is used as a bodying agent for caramels and marshmallows.

A no sugar or reduced sugar beverage or beverage concentrate with an intense sweetener usually contains a gelatinized starch; it compensates for the lack of body, texture and viscosity that is traditionally provided by added sugar (Mills & Gristwood, 1999).

3.5.1. Sauce, ketchup, jams, jellies

A thermally inhibited, subsequently hydrolyzed by glucoamylase to split α-D-glucosidic linkages in ungelatinized granular starch has been shown to be a useful food ingredient, particularly fruit or vegetable-based products. The resultant starch of DE 20–30 reduces the amount of tomato solids in tomato-based products such as ketchup, barbecue sauce, tomato sauce and salsa without loss of viscosity or texture (Senkeleski, Zallie, & Hendrikx, 1999). The starch is useful in fruit-based food products, particularly when a starch is desired which is relatively easy to cook out at high solids, provides a short texture, controls moisture migration, has a clean flavor and/or provides a relatively low hot viscosity during processing e.g. in fruit preparations, jams, jellies and fruit fillings to reduce the amount of pectin or even replace it in total without a loss in viscosity (Xu, Senkelski, Zallie, & Hendrikx, 1999). Pulpy texture can be introduced to sauces with the aid of highly cross-linked and specially processed corn or tapioca pregels (Langan, 1987).

A pizza sauce with improved eye appeal and mouth feel can be obtained from cold water swelling, cross-linked instant starch. Such starch is easy to disperse in cold mixtures or oil and adds a pulpy richer look to fruit based sauces. Cross-linking imparts the starch with resistance in acid foods, and even allows retorting. Maltodextrins add body to canned sauces. The use of a 10 DE starch hydrolyzate in a frozen pizza sauce results in more sheen, a brighter red color and a more desirable body and texture, compared to a control sauce (Murray & Luft, 1973).

3.5.2. Pie fillings, toppings

Starch obtained from plants with a triple recessive genotype with 2 dosages of waxy and one dosage of amylose extender (wxwxae) produces a strong resilient gel, which clears from the mouth uniquely fast. The unique and distinctive texture makes the starch suitable as a replacement for conventional gelling gums such as natural gums and gelatin in whole, or in part in bakery application e.g. cream or fruit fillings for pies such as lemon, banana cream and in low or reduced fat high solids fruit centers for cookie such as fig bars (Hauber, Friedman, & Katz, 1996). Pregelatinized starch is used as a thickening agent for pie fillings.

Cross-linked starch is used to produce viscous systems in acidic media such as in cherry pie filling. The acidity from the cherries speeds the hydrolysis of the α-1,4 glucosidic bonds in the starch during baking, and thus produces a thin pie filling. Cross-linking does not stabilize the bonds to the acid; however, with sufficient cross-linking, the starch swelling is greatly restricted and as the acid hydrolyses the bonds, viscosity increases instead of decreasing. Therefore, with the right degree of cross-linking, one can end up with a thick pie filling (Hoseney, 1994a). Pregelatinized starch from a cross-bonded waxy cereal starch if used, the filling is subjected to only the heating it receives during baking and even this can be eliminated if desired. The juice thickened without heating keeps the fruits suspended, and avoids the loss of the fresh flavor of the fruits (Osman, 1984). Hydroxypropyl distarch phosphate and/or starch acetate is used as thickening agents for paste-like foods such as toppings, fillings, fruit preserves (Hasegawa, 1984).

3.5.3. Soups

Corn potage soups with good viscosity have been obtained with starch phosphate (Nireki, Hayasaka, Kawamoto, & Yoshida, 1989), and also with highly cross-linked or substituted waxy maize or dent corn.

3.6. As substitutes for gum arabic (as tackifiers/edible films)

Roasted dextrin, oxidized starches, gelatinized starches, and cross-linked starch derivatives can be used as substitutes for natural gums especially gum arabic in food processing (Hanmo, 1986). Acid-thinned hydroxypropylated tapioca starch as a gum arabic replacement, lowers coating time, since the viscosity of the starch is low even at 50% vs. a maximum 40% for gum arabic. Lipophilic starches can successfully replace a large portion of gum Arabic offering advantages of excellent emulsion stability and finished beverage quality (Light, 1990).

3.6.1. As edible films/protective coatings/glaze

Edible high-amylose corn starch films are permeable to air, oxygen and nitrogen, and have been proposed for packaging. They require plasticization to prevent brittleness and approach the strength of cellophane. Starch derivatives are also used as protective coatings on candies, nuts and chocolate candies.

Clear films obtained by dehydration of tapioca dextrin solutions are often used as protective coatings (as a replacement for gum arabic) such as in pan coating of confections (Langan, 1987) as a non-tacky glaze for cakes, donuts, fruit, nuts and candies. Tapioca specialty dextrins replace from 20 to 40% of gum arabic in some hard gum candies. Coating the hot surface of a freshly baked item with a high concentration of tapioca dextrin forms a film that retards moisture migration. A sealant for baked goods for reducing the moisture migration into and out of the baked good comprises sucrose 40–72%, starch hydrolyzate of DE < 38, 8–30 and water 20–30 weight % (Huang, Timm-Brock, Sward, Abrams, & Gaertner, 1993).

Almonds may be coated with a 50% solution of a 10 DE-hydrolyzate. The solution is heated to 160 °F and sprayed onto nutmeats in a revolving pan coater. The nutmeats are then dried in an oven at 120 °F. The coated almonds are found to be crisper after 3 weeks of storage. It is well known that a continuous starch film is about 98% effective in barring the transfer of O_2 and these low DE hydrolyzates may have some of these barrier properties. Hydroxypropylated starches are used as edible films.

3.6.2. As tackifiers

The new starch-based hot-melt system is a water-free free flowing oil preblended dry powder, which melts in < 30 s when applied to the hot snack (121–150 °C). The seasonings adhere to the products. The powder is very stable at temperatures below 93 °C. The starch-based hot-melt system provides greater tackiness than canola and other vegetable oils. It outperforms oil alone as an adhesive for seasonings. It also allows friendly labeling as corn syrup solids.

A dextrin coating at 30% solution in water or glycerine can be sprayed onto snacks to adhere seasonings. The solution is easy to spray at a high solids concentration (30–40%) due to its low viscosity characteristics (Huang, 1995; Huang & Rooney, 2001). Dextrins are used to tack water-soluble flavors to low-fat baked snacks. They are made by pyroconversion-controlled heating of dry acidified starch in a reactor with good agitation. The products have high water solubility, low viscosity and good film-forming ability (Huang & Rooney). As adhesives, they are used in pan coating to prevent separation of the sugar shell from the base center material (Moore et al., 1984).

3.7. As dusting agent

Pregelatinized starch is used as a dusting agent perhaps mixed with powdered sugar for candy gums (Mitch, 1984). Cornstarch can be modified to make it completely unwettable. This water-resistant starch is put to use in dusting applications (Langan, 1987). The more powder-like consistency of oxidized starches makes them ideal for dusting foods such as marshmallows and chewing gums (Brown, 2000).

3.8. For puffed/expanded products

Pregel starches contribute to the puffing properties of baked snack (Moore et al., 1984). Waxy starches usually produce the greatest expansion, but tend to give a tacky mouth feel. Cross-linking reduces the tackiness, but also tends to decrease expansion (Langan, 1987). Excessive cross-linking lowers the swelling capacity of the starch, resulting in a snack that has reduced expansion with non-uniform poor texture. Proper cross-linked waxy cornstarch controls the expansion of snacks (Huang & Rooney, 2001). A cross-linked waxy starch can be combined with a cross-linked non-waxy starch to make a puffed fat-fried snack. The mix with salt and flavoring is formed into dough and gelatinized, shaped and dehydrated to 10–14% moisture, deep-fried and puffed (Radley, 1976).

Foods that expand greatly upon microwave baking without surface breakage is obtained by coating the surface of the dough with α-amylase or acid-hydrolyzed starch prior to baking (Kanbara & Mori, 1989).

Expandable starch can be prepared by acidification of native cassava starch suspension with 0.08–2% of dry starch organic acids such as lactic acid, citric acid, acetic acid and tartaric acid, addition of iron ions and oxidation with 0.03–0.9% hydrogen peroxide at temperatures below gelation temperature (20–45 °C) for 1–48 h. The expandable starch thus obtained is suitable for preparation of breads; oven roasted or fried products having expanded surface and croquette texture (Oviedo & Manuel, 2001).

For hollow puffed foods, cream puff shells, snacks and fried foods, the dough contains 100 weight parts starch materials selected from starch (amylose content $<$ or $=25$ weight %), cereal flours and their gelatinized, acetylated and etherified products and 10–150 weight parts milk products which are coagulated unripened and added to water 35–60 weight % (Nakano & Sato, 1998).

A baked, wheat-based, chip-like snack food with surface air bubbles is made from pregelatinized waxy cornstarch (approx. 3–20%, by weight), pregelatinized potato starch (approx. 1.5–20%, by weight) and, optionally, modified potato starch. The ratio of the amount of pregelatinized waxy starch to the total amount of potato starches may be from 0.45–1.00:1.00. The pregelatinized waxy starch and potato starch are at least substantially hydrated prior to baking; this allows bubbles to be produced and retained, and controls the crisp, crunchy texture of the snack food (Carey, Moisey, Levine, & Slade, 1998).

A shelf-life snack food can be produced from fruit or vegetable juices or juice concentrates. Mixing of juice and/or its concentrate with a starch hydrolysis product and pregelatinized starch can form dough, which on heating expands due to evaporation of water and producing products with cracker or cookie-like appearance and texture (Gimmler, Levine, Slade, Faridi, & Sauer, 1996). Kerapok or fish crackers made from slurry with water: tapioca starch ratio of 70: 30 pregelatinized at 133.5, 143.6 and 151.8 °C had linear expansion greater than the minimum acceptable value of 77% (Yu & Low, 1992).

3.9. Starches for free-flowing high-fat foods

High-fat or oily foods such as peanut butter or chocolate liquor can be made free-flowing for dry packaging by plating onto extremely low-density modified tapioca or waxy corn dextrins. The density is reduced through special techniques of gassing with ammonia or CO_2 and spray drying (Langan, 1987).

3.10. As drying aids

Low DE SHP s are well known drying aids through their elevating effect on sub-zero glass transition temperature and reducing the fraction of unfrozen water. The combination of low solubility and low hygroscopicity makes the low-DE carbohydrates especially useful as a carrier and drying aid for many dehydrated foods such as dry peanut butter, dried citrus powders, spray-dried oils, wine flavors, apple juice powder, vegetable powders and sweetening agents. Citrus purees can be successfully spray dried with 30–40% of a 10 DE hydrolyzate (Murray & Luft, 1973).

3.11. As extrusion aids

Carboxymethyl starch from waxy amaranth starch is shown to be useful as extrusion aids in ready-to-eat extruded snacks prepared from semolina (Bhattacharyya, Singhal, & Kulkarni, 1996). Pregel starches are used to control cold flow and slumping of extruded shapes (Moore et al., 1984).

3.12. As texture improvers

Texturizing agent in low-fat and fat-free foods such as mayonnaise, margarine, salad dressing, mousse, cottage cheese dressing, sour cream, ice cream, yogurt and cream cheese comprises an insoluble micro particle such as TiO_2, xanthan gum and pregelatinized starch in the form of a complex in which the insoluble micro particle has been stabilized or entrapped. (Finocchiaro, 1995).

High amylose cornstarch is used in extruded and fried snack products to obtain crisp, evenly browned product. Crunchy or crispy mouth feel can be obtained with the use of high amylose starches or slightly degraded waxy pregels that expand to tender structures when heated and dried. Snacks have a high degree of mouth melt, less waxiness, improved texture and increased crispness by incorporating a modified starch and/or high amylopectin flour or starch into the dough composition and by controlling the water absorption index of the starch-based materials. 50–70% of the starch-based material must contain at least about 3.2% modified starch comprising at least about 3% hydrolyzed starches having a DE 5–30 and WAI 0.4–8 g per gram of modified starch (Villagran, Dolores, Villagran, Lanner, & Hsieh, 2002).

Cross-linked acetylated starches are used in canned, frozen, baked and dry foods; also in fruit and cream pie fillings in cans and jars to provide desired textural properties and viscosity breakdown resistance (Rutenberg and Solarek, 1984).

Food products such as baked goods (cone, cookie, wafer), use either a high-molecular weight starch hydrolyzate of DE 5–30 or a crystallite hydrate producing sugar such as raffinose or trehalose or combination thereof to increase the crispness of the product at higher moisture levels (Huang, Pnada, Rosenwald, & Chida, 2002).

Chewiness can be introduced with highly cross-linked waxy corn starch used at relatively high levels. Cornstarch tends to release with relative ease from the mouth as compared to waxy corn. Tapioca is often chosen over corn for release of flavor. Cross-linking helps mouth release because it shortens the consistency and lowers levels of usage (Wurzburg, 1987).

Adding modified waxy cornstarch to oat flour improves the quality of extruded snack foods (Karam, Grossmann, & Silva, 2001), and also for improving the texture and crispness of sheeted snack foods and crackers (Anon, 2001). Starch esters such as hydroxypropylated di-starch phosphates can impart stability and textural properties to dairy products (Dorp, 1996a)

3.12.1. Microwave cooking

One of the major problems associated with microwave cooking is the sogginess that occurs at the interface of wet and dry surfaces such as in pizza pies and breaded meat or fish. Predusting the surface with high amylose starches and flours with a slow hydrating pregel controls the moisture at the intersurface (Light, 1990).

3.12.2. Pasta cocktail snack foods (Cock, 1995)

Pasta cocktail snack foods, made from potato starch and granules, pregelatinized starch and salt, are produced by extrusion followed by drying, frying, flavoring and packaging. Effects of incorporation of 7% pregelatinized starches and maltodextrins from different origins (corn, waxy corn and potato) on texture of pasta cocktail snack foods showed waxy cornstarch to give a harder, crisper and denser product, and incorporation of potato starch to give a softer and less dense texture. Using corn maltodextrins, the extrusion capacity, crispness, chewability and brittleness increase with an increased DE value of the maltodextrins. Cross-linked starch ether (cross-linking degree 0.01–1) to the dough markedly improves reconstitution and texture of dried pasta (Nippon, 1984).

3.12.3. Fruit preparations

Cross-linked highly stabilized waxy maize starches can result in high viscosity even at 60% sugar concentration (Anon, 1992b).

3.12.4. Cheese

Cheese is mixed with molten salt and $>$ or $=1$ compound selected from the group comprising oxidized starch, esterified starch and etherified starch, then melted with heating and emulsified to give a cheese resistant to freezing and resistant to crumbling in frying oil (Hisaku, 1994).

3.12.5. French fries

Potato products prior to deep fat frying may be coated with an aqueous dispersion of high amylose starch acetate (of DS 2.5) to give potato chips that are exceedingly crisp both when fresh as well as after prolonged storage. They are strong and rigid without being tough and have excellent flavor. A hydroxypropyl ether of amylose having a DS of 1.5 can also be used to get the same effects. Similarly, a thin boiling amylose product prepared by the treatment with sodium hypochlorite of cornstarch with a high amylose content of 65% by weight, the final product being converted to a degree known in the trade as 70 fluidity can also be used to coat the potato products (Gutcho, 1973a).

The physical properties and taste of cooked potato products may be markedly improved by contacting and reacting raw, peeled potatoes with an aqueous medium containing a suitable cross-linking agent to form cross-links between the labile hydrogen atoms on the alcohol moieties of the starch and sugar molecules on the surface of the raw potatoes. The potato products possess markedly superior and long lasting crispness and greatly improved color and flavor (Gutcho, 1973b).

3.12.6. Biscuits, cheese buns, cookies

Fermented tapioca starch termed 'sour starch' contributes unique flavor and texture in sour starch biscuits and cheese buns. A premixed unbaked dough preform containing a starch hydrolyzate of DE $<$ or $=42$ at $>$ or $=8\%$ of the total dough weight produces cookies that maintain their fresh texture for long (Evans, Dodson, & McConvis, 1967).

3.12.7. Milk-based products

Starch hydrolyzates increase the spreadability of milk solid-based spreads. It has also been used for micro-encapsulation of milk fat (Onwulata, Smith, Craige, & Holsinger, 1994). Frozen desserts made with a 10–15 DE hydrolyzate have a much slower meltdown and a better texture than desserts prepared with a 36 DE corn syrup. A marshmallow made with a 10 DE hydrolyzate for variegating ice cream retains a marshmallow consistency and texture after freezing and thawing because of its high molecular weight saccharide content (Murray & Luft, 1973).

3.12.8. Puddings, creamy desserts

Higher consistency and firmness of UHT puddings and higher creaminess of UHT creamy desserts is obtained with hydroxypropylated distarch phosphate derivative of a waxy maize starch (De Coninck, Vanhemeliujnck, & Peremans, 1995). For smooth pudding-like textures, tapiocas seem to do a slightly better job than waxy corn (Langan, 1987). Cross-linked waxy cornstarch significantly improves its appearance and texture in pie fillings (Brown, 2000).

3.12.9. Cakes

The cake mix industry has rapidly converted to the extra-moist cake formulas, where pregel starch softens the cake crumb and retains moisture in the baked product. Substitution for about 4% of the flour in cakes with pregelatinized starch has been reported to improve the eating quality (Osman, 1984).

Drum-dried cross-linked starches with low amylose content are claimed to improve cake volume, softness and keeping quality of cakes (Rutenberg & Solarek, 1984). Acid-modified starch has a greater tenderizing effect than an equal amount of unmodified wheat starch in angel cakes (Osman, 1984). Lightly inhibited and stabilized waxy corn and tapioca pregels are excellent for retaining moisture and softness in baked cakes and cookies (Langan, 1987). Sweet potato starch phosphate monoester improves cake quality markedly (Wu, Yang, & Tian, 1998).

3.12.10. Bread

Bread manufactured by partially substituting wheat flour with modified starch such as wheat starch acetate and activated gluten results in softer texture even after 3 days as compared to the control (Mizoguchi & Takayanagi, 1991). Breads manufactured by mixing 0.5–10 weight % α-cross-linked starch (swelling degree, 4–35) in grain powder containing wheat flour as a main raw material is improved in aging and gives soft feeling on eating (Mizoguchi, Yanetani, & Yamashita, 1992). Resistant starch (RS) can be used as a texture modifier, crisping agent in bread (Yue & Waring, 1998).

Breads manufactured using a composition containing wheat flour 62–92.5, hydroxypropyl starch and/or starch acetate 7–30, and α-starch 0.5–8 weight parts have glutinous texture. The addition of 5–7% of starch phosphates improves the volume and freshness retention of the finished loaf (Radley, 1976). Dextrins act as antifirming agents in bread (Hoseney, 1994b).

3.12.11. Farinaceous snacks

Low-calorie farinaceous snacks containing high amylopectin flour or starch in the dough results in snacks with a high degree of mouth melt and increased crispness (Gutcho, 1973a; Martines, Villagran, Villagran, Lanner, & Yen-Ping, 2002).

3.13. For stability to high shear, acid and high temperature conditions

Hydroxypropyl starches are usually cross-linked to obtain desired texture and resistance to the high temperatures, low pH and shear degradation often encountered in food processing. They may be used in granular or as pregelatinized, cold-water-soluble product. Cross-linked starches are resistant to low pH and shear, but they lose their clarity and water-holding capacity on prolonged low-temperature ageing. By acetylating cross-linked starches to an acetyl content of 0.5–2.5% the resistance to shear is retained and the cold ageing stability is improved. For high shear processes, moderate to highly cross-linked starches are normally required. Hydroxypropyl distarch phosphate shows good stability in retort foods.

Functions of potato starch can be improved by conjugating starch and whey protein isolate with a covalent bond (Yang, Hattori, & Takahashi, 1995; Hattori, Yang, & Takashi, 1995).

3.13.1. High temperature gelling starches

They are useful to provide a gel texture at temperatures significantly above those of conventional gelling starches e.g. 70 °C (Trzasko, Tessler, & Dirscherl, 1986).

3.13.2. Vegetable-based foods

A thermally inhibited, subsequently enzymatically hydrolyzed (glucoamylase to split α-D-glucosidic linkages, 0.1–1% by weight of starch) ungelatinized granular starch has been shown to be a useful ingredient in fruit or vegetable-based products. The resultant starch (DE 20–30) is useful in vegetable-based food products, particularly when a starch with relatively high process tolerance against heat, acid and/or shear, high viscosity, and stability against gelling, a clear flavor, and/or prevention against serum separation is desired (Senkeleski et al., 1999).

3.13.3. Salad mayonnaise/dressings

Salad mayonnaise produced with stabilized starches cross-linked with adipate group displays improved storage stability to high levels of shear, enabling the most modern equipment to be used without sacrificing end product quality (Doreau, 1994). Hydroxypropylated distarch phosphate derivative of waxy maize gives advantages of its use as a thickener in hot processed 30% oil dressings.

3.13.4. Fruit preparations

Modified waxy maize starches in fruit preparations such as acetylated starch adipate or hydropropoxylated starches show good acid and shear stability (Thys & Dorp, 1998).

3.13.5. Custard

An important component in bake-stable custards is the UHT-stable modified starch. Preferred starches are acetylated distarch adipate and hydroxypropyl distarch phosphate (Bilsen, Scholtes, Jacobus, & Van Zon, 1995).

3.13.6. Dairy desserts

Hydroxypropylated starches from tapioca and acetylated and hydroxypropylated starches from waxy corn show advantages in their use in UHT dairy desserts (Dorp, 1996c) or gelled desserts, distarch adipate or distarch phosphate or a native corn/waxy blend appears to be useful for the UHT process, but in order to obtain the desired texture, carrageenan must be added (Rapaille & Vanhemelrijck, 1984).

3.13.7. Xanthan gum-modified starches (Cheng & Wintersdorff, 1981)

Xanthan gum-modified starches are characterized by increased acid stability, by heat and shear stability, and by increased resistance to dissolution in aqueous media. The novel process by which this is made comprises: heating to gelatinize an aqueous starch-xanthan gum blend below 100 °C, continuing heating to reduce the moisture content to about between 5 and 10%, then further drying the mixture (typically to below 7% moisture) above 100 °C long enough to cause interaction between the starch and xanthan gum. Drum drying that combines the heating and drying steps is preferred heating method. Another embodiment is a process comprising drying (preferably on a drum dryer) an aqueous mixture of xanthan gum and gelatinized starch in 1:5–50 parts above 140 °C so as to cause a modification of the precursor starch by the xanthan gum. The decomposition temperature of the precursor starch limits the maximum drying temperature. Typically 204 °C is the maximum drying temperature. Gelatinizing and co-drum drying an aqueous xanthan gum, unmodified tapioca starch mixture in a 1:5 weight ratio milled to a desirable particle size above 200-mesh (e.g. through 14-mesh, on 20-mesh) results in a finished product that exhibits a rapid hydration rate in water to form pregelatinized, texturized, swollen particles having a firm and crispy texture. Although commercial pregelatinized, texturized starches are grainy and pulpy, they are not as firm and crispy in texture compared to the xanthan gum-modified tapioca starch product. These starches can be used in tomato sauce mix, apple-sauce mix, instant dry mix vanilla pudding, instant imitation jelly, lemon pie filling, French type dressing, improved textured vegetable proteins or meat extenders. Other food uses include soups, spaghetti sauces, fruit drinks, meat sauces, gravies, and tapioca desserts, or instant foods. As such, they are used in the same manner as commercial pregelatinized modified starches.

3.14. For freeze-thaw stability/low temperature stability/prevention of syneresis

Waxy rice starch with 98% amylopectin is known for its creamy gel texture and natural heat and freeze-stability. Waxy rice starch is better than waxy maize or waxy sorghum starches in that the gels can withstand 6–7 number of freeze-thaw cycles without syneresis or irreversible setback compared to the gels of waxy corn or sorghum which are stable to only 3 cycles (Radley, 1976). In conjunction with waxy starches, high-amylose starches can produce gels of good strength and stability to syneresis. Tapioca, potato and waxy cornstarches, which have a relatively high degree of stability, require acetylation for low temperature stability (Rutenberg & Solarek, 1984). A non-gelling starch with good freeze-thaw stability and good mouthfeel is a waxy starch, which has greater than 30% by weight of short chains with a DP of 13 and converted to a water fluidity of 20–45. Particularly useful waxy starches are hybrid starches from a plant of wx su2 genotype and starches from waxy rice, barley and amaranth (Huang, Jeffcoat, & Mason, 1997).

3.14.1. Mayonnaise

Salad mayonnaise produced with acetylated distarch adipate or acetylated distarch phosphate displays improved storage stability to syneresis (Doreau, 1994; Rainer, 1984).

3.14.2. Pie fillings, gravies, puddings

To produce a stable sauce or pie filling, chemical modification of starch by adding blockers such as acetyl or hydroxypropyl groups separate amylose chains within the granule. This inhibits retrogradation, improves freeze-thaw stability and water holding capacity. Cross-linking tends to counter freeze-thaw stability so the best low-temperature storage stability is found in lightly cross-linked, highly stabilized waxy starches. Hydroxypropyl distarch phosphate shows good freeze-thaw stability (Jang, 1998).

The hydroxypropylated distarch phosphate derivative of a waxy maize starch shows perfect freeze-thaw stability even after 15 consecutive cycles and hence suitable in cooked pie fillings. Also, this starch specifically improves edibility, texture and taste of the cooked pie fillings (De Coninck et al., 1995).

Hydroxypropyl starches (of DS 0.05–0.10) are used as thickeners in gravies, sauces, fruit pie fillings and puddings where they must impart a smooth, thick, clear, non-granular texture that will hold up under various storage conditions including freezing and also impart no taste (Hjermstad, 1984). Starch monophosphates due to their superior freeze-thaw stability, are preferred to other starches as thickeners in frozen gravy and frozen cream pie preparations (Othmer, 1995).

3.14.3. Sauces

Sauces made with waxy corn flour gives no appearance of separation after 12 months of frozen storage (Radley, 1976). Stability to freeze-thaw cycles can be greatly improved by the introduction of acetyl or propionyl groups in combination with cross-linking.

Resistance to freeze-thaw deterioration of cross-linked starch derivatives is obtained by treating them with α-amylase (Radley, 1976). A thermally inhibited, subsequently enzymatically hydrolyzed to give a starch of DE 20–30 is useful in reducing serum separation in barbecue and tomato sauce during storage (Senkeleski et al., 1999).

3.14.4. Rice-cake like foods

Rice cake-like foods are manufactured by mixing more than 10 weight % starch acetate, carbohydrate sweeteners and water, heating, forming into a shape and coating with corn starch mainly comprising of amylopectin. The foods are stable at less than 10 °C and maintain rice-cake firm textures after defrosting or heating (Hatsuta, Makisako, & Hiroya, 1991).

3.14.5. Fruit preparations

Hydroxypropylated (HP) starches can be used for syneresis reduction in fruit preparations (used for yogurts, dairy desserts etc.) (Watter, 1996). A thermally inhibited, subsequently enzymatically hydrolyzed ungelatinized granular starch, when used in fruit preparations for use in yogurts significantly reduces the interface that occurs between the fruit and the white mass, and also the color bleed from the fruit into the white mass (Senkeleski et al., 1999).

3.14.6. Non-freezing custard cream

A milk product, sugar and one or more modified starch (selected from the group comprising etherified starch, esterified starch and cross-linked starch) are mixed at a specific weight ratio, sterilized, combined with frozen, sugar-treated egg yolk to give custard cream not freezing in the refrigerator. The custard is preserved for a long time at low temperature (Nojiri, Nakai, Nakani, & Nakagome, 1994).

3.15. For encapsulation of flavor oils

Extrusion of hydroxypropyl distarch phosphate, acetylated distarch adipate or acetylated distarch phosphate (prepared from tapioca starch or corn amylopectin) along with an essential oil flavor (2–10% w/w) and emulsifier (4–20% w/w), mixed with a weighting agent and sweetener and/or acidulant (0.1–4.0% w/w) is reported prepared for use as a soft drink flavor component (Gonze, Van, Freddy, & Wastijn, 1990).

Sodium starch octenyl succinates are characterized by good filming properties and the ability to form very fine, stable emulsions, two key factors for very effective encapsulation of flavor oils by spray-drying (Trubiano, 1995a). They are superior in performance over other encapsulating agents or carriers, such as powdered gum arabic and maltodextrins. Dextrins can also replace gum arabic in the encapsulation of flavor, oils (Moore et al., 1984).

3.16. For clarity

Clarity is best obtained through the use of waxy starches. Cross-linked waxy cereal or root starches have proved excellent for use in fruit pie fillings in which clarity of the paste is a particular asset (Osman, 1984). In canned specialty products such as Chinese style foods, where clarity is exceptionally important to maintain the attractive appearance of vegetables, special cross-linked waxy maize starches perform satisfactorily (Glicksman, 1984).

Lightly derivatized starch acetates give clear gels of good stability, and are employed in frozen fruit pies and gravies, baked goods, instant puddings and pie fillings (Othmer, 1995).

3.17. As suspending agents

Cross-linked starches are superior to native starches in their ability to keep food particles in suspension after cooking (Othmer, 1995). To suspend particulate matter, moderate to lightly cross-linked waxies are recommended. These starches have high hot viscosities, which will hold the particulate in place until the paste has a chance to cool. Pregelatinized waxy or tapioca starches are sometimes used to suspend uncooked or partially cooked starch particles in cold aqueous systems so that the starch will not settle out during a cooking stage. This technique is used where agitation during cooking presents problems (Langan, 1987).

3.18. In coating batters for adhesion, crispness, low fat absorption

Oxidized starch is known to give better adhesion of the batter coating to the foodstuff (Lachmann, 1969a) such as fish and meat, and is widely used in breaded foods (Rutenberg & Solarek, 1984). The use of oxidized amylaceous materials provides a batter mix for breaded, deep fried foods which is vastly superior in all respects to batter mixes prepared from ordinary starches or flours. The batter mix components display a degree of adhesion to deep-fried foods, which is so tenacious as to actually render the breaded batter coating into an integral component of the foodstuff (Lachmann, 1969a). Use of oxidized starch batter mixes in the preparation of deep-fried scallops, which are suitable for immediate consumption, or subsequent freezing results in breaded coatings with a pleasant, firm texture, golden brown color with no crumbing. Cross-linked waxy cereal or root starches can form the base of a batter mix for coating foods for deep fat frying (Osman, 1984).

Adhesion of breaded coatings for baked or fried meat or fish is greatly improved with the inclusion of lightly inhibited and bleached cornstarch in the batter (Langan, 1987). The batter mix consists of a mix of 210 parts of water and 90 parts of cornstarch, which had been treated for 30 min with 5% of chlorine, as, based on the weight of corn starch (Lachmann, 1969a). Coating crispness is further enhanced with the inclusion of modified high amylose starches. Modified high-amylose starch used in batters for breaded products form films when cooked retarding moisture movement. Rice flour based batter formulations with 15% oxidized cornstarch and MCC can be used as an alternative to traditional wheat flour-based batter for chicken drumstick coating. This results in a healthier product due to lower fat absorption (Mukjprasirt, Herald, Boyle and Boyyle, 2001). French fries coated with batter containing 60–90% wheat flour and 10–30% high amylose starch imparts a very smooth appearance with firm crispness (Anon, 1994).

Deep-fried foods such as shrimps manufactured by covering with wheat flour batter containing starch phosphate (swelling ratio 53) (21% w/w), egg white powders (11% w/w) and calcium phosphate (3% w/w) show no deformation or taste deterioration when sealed in a retort pouch and heated at 121 °C for 30 min (Kawana, Yamana, Inaguma, & Ishiguro, 1992).

An esterified starch batter (at solids content content 40%) provides good adhesion and produces a crunchy and crispy breaded batter coating (Furcsik & DeBoer, 1992) for foodstuffs that are subjected to deep fat frying and then served immediately after frying; or foodstuffs that are prefried, frozen and then reheated after freezing.

3.19. For canned foods

A can-filling starch which has an initial high viscosity to facilitate uniform can filling, and exhibits viscosity breakdown on heating to increase heat penetration for sterilization, and a thin final viscosity is claimed for cross-linked acetylated tapioca, potato and waxy corn starches. FDA regulations permit up to 2.5% acetyl content in starches used in foods (Rutenberg & Solarek, 1984).

3.20. As binders/for WHC

Modified tapioca starches give higher viscosity than corn, waxy maize or wheat starches to bind a certain amount of water in meat giving a more succulent and juicy final product (Pszczola, 1999). Treatment of a suspension of 1:5 parts of starch: water at pH 9.4 with ultrasound for 35 min, followed by neutralization, washing and drying is reported to give storage-stable particles for sausage manufacture (Ajinomoto, 1983). Pregelatinized potato starch improves water-binding capacity in paneer (Sethi, Thind, Padda, & Bakshi, 2003).

3.21. As emulsifiers/starches for eggless products

Enzymic degradation carried out before or after preparation of the starch derivative (containing a hydrophobic group) provides an emulsifier with improved shelf stability, and has applications as a replacement for gum arabic (Chiu, 1993; Trubiano, 1995b). Hydrolysis of the starches with glucoamylase after derivatization are useful as emulsifying and/or encapsulating agents, particularly in systems where high load and retention of the active ingredients, low surface oil exposure and good oxidation resistance is desired (Keller et al., 1999).

In low-viscosity pourable dressings or flavored beverages, the oil-in-water emulsions are best protected through the use of lipophilic substituted starches or dextrins.

3.21.1. Beverages

Lipophilic groups attached to dextrin or starch help stabilize emulsions (Langan, 1987). Sodium starch octenyl succinates are unique specialty food starches characterized by emulsion-stabilizing properties in soft drink beverages over spray-dried gum arabic in terms of lower use level. An emulsifying agent as a substitute of arabic gum consists of lecithin 3 parts and tetra glycerin pentaoleate 5 parts by weight added to 1000 parts of starch hydrolyzates to make an emulsion and then mixed with hydroxy propyl distarch phosphate 25 and xanthan gum 0.5 parts by weight (Hanno, Okuma, & Hoshii, 1988).

3.21.2. Mayonnaise and dressings

An eggless mayonnaise can be formulated using starch octenyl succinate or cornstarch phosphate (Dias, 1997). Octenyl succinate starches are used as salad dressing stabilizers. These are added in the processing or storage of fat- and oil-containing food products to improve the stability of fats and oils and the appearance, flavor and taste of the products (Hiroaki, Hozumi, & Kazuyuki, 1994)

A combination of starch phosphate, guar gum and propylene glycol (for control of thixotropic effects) can be used as an emulsion stabilizer for vinegar and vegetable oil in water.

3.22. As stabilizers

3.22.1. Ice cream

Carboxymethyl starch added to plain ice cream (0.3–0.5%) or fruit-berry ice cream (0.5–0.75%) results in superior taste, aroma, structure and consistency, color and appearance (Olenev, Zhizhin, Borisova, & Ustinova, 1984). Lower DE starch syrup contains more dextrins, which tie up more water in the mixture exerts a greater stabilizing effect against coarse texture in ice creams.

3.22.2. To prevent crystal formation in cheese

Hydroxypropyl distarch phosphate from waxy maize starch at 0.5–1% serves as a binding agent and also halves the added processing salts in comparison with known recipes of cheese, thereby preventing crystal formation efflorescence on the cheese surface (Merkenich, Maurer, Walter, Scheurer, & Klostermeyer, 1992; Merkenich, Maurer, Walter, Scheurer, & Klostermeyer, 1993).

3.22.3. As low-calorie sweeteners

Hydrolyzates of hydroxypropyl starches containing >15 weight % of polymers of 2–6 DP, prepared enzymatically or by acid hydrolysis are suitable as low-calorie sweetener composition in bakery products (Quarles, 1992).

3.22.4. Starches as casein replacers/dairy-food substitutes

Modified starches and dextrins have been used successfully to replace caseinates in meat emulsions, coffee whiteners and imitation cheese (Yoder, Chang, Xu, & Domoras, 1996). Total or a partial caseinate replacement composition for imitation cheese can be made from a granular hydroxy propylated high amylose starch having a DS >0.04, gelatin and a gum such as pectin and carrageenan. The gum is used to decrease the amount of gelatin necessary and to improve the texture of the overall cheese analog (Yoder et al., 1996). Pregelatinized modified high amylose ($>40\%$) starches, preferably converted and/or derivatized is another alternative for a similar purpose. Short chain amylose prepared by enzymatic debranching of starch is useful in imitation cheese as caseinate replacer (Zallie & Chiu, 1990).

Oxidized starches prepared by acid- or enzyme-conversion, oxidized starch prepared by treatment with less than 5% active chlorine and dextrins having fluidity of 50 are also suitable. Derivatives prepared by treatment with $<25\%$ propylene oxide, 5% succinic anhydride and 10% octenyl succinic anhydride or with a sufficient amount of acetic anhydride or sodium or potassium *ortho*- or tripolyphosphate as well as unmodified high-amylose starches (up to 80%) are also useful (Zusiercan, Lacourse, & Lenchin, 1986).

A specialty starch produced from modified waxy maize has good gelling and water binding properties and a low gelation temperature. Its inclusion in meat products such as frankfurters and cooked chicken joints as a casein replacer results in low drip loss, firm texture and greater succulence (Anon, 1992a).

A dairy-food substitute composition comprising of 6–10 parts by weight of oil in a carbohydrate matrix, 4–8 parts of maltodextrin of DE 2–5, emulsifier and antioxidant with optional addition of vitamin and minerals, can be used to prepare an instant custard mix (Strong, 1989).

3.23. As clouding agents

Octenyl succinate starches can be used as clouding agents for direct use in soft drink beverages or spray-dried drink mixes (Wurzburg, 1987).

3.24. Starches for fish, meat pastes

Seafood pastes are manufactured by mixing paste materials (e.g. frozen ground meat or fish meat) with 0.5–12% modified starch and 0.001–0.2% cystine. The pastes have good mold-releasing properties, firm texture and high quality even after freezing. Frozen ground meat is kneaded with sodium chloride, 0.5% acetylated starch and 0.05% cystine, packed in cases and heated at 90 °C for 40 min in water to manufacture kamaboko (Myabe, Nakajima, & Kokai, 1989).

Addition of cross-linked hydroxypropyl starch and/or cross-linked starch acetic acid ester, cross-linked starch phosphoric acid ester, cross-linked starch octenyl succinic acid markedly increases elasticity and organoleptic test scores of kamaboko and other fish paste products (Ichiro, Naoyuki, Norishige, Yasuo, & Toru, 1987; Nippon, 1984).

3.25. Starches with low adhesion properties

Noodles manufactured with acetylated tapioca or potato starch showed excellent taste (Nakamura, 1996). Addition of starch acetyl ester to dough at 0.2–3.0% markedly increases the shelf life of cooked noodles (Shimadaya, 1984). The inner surface of cellulose sausage casings is coated with a mix of starch ether, a wax and optionally a silicone or plant oil prevents adhesion between the food and cellulose film/casing (Hammer, Winter, Kindl, & Luchterhand, 1984). Rice cooked with oxidized waxy cornstarch hydroxypropyl ether prevents sticking of cooked rice (Masuda, Sato, Kato, & Yamazaki, 2002).

3.26. Starches for use in plate heat exchangers

Cross-linked waxies produce higher viscosities than cross-linked corns, which is of particular importance when selecting a blend for processing in plate heat exchangers. High-viscosity pastes strain heat exchanger gaskets and lower product throughput. Lowering total starch concentration will lower gasket strain and increase throughput, but will produce a weak-bodied dressing. Lowering the waxy-to-corn ratio will relieve back pressure on the heat exchanger, but will also bring about changes in finished texture. As the corn portion is increased, the smooth salve-like texture is decreased. If the corn portion is allowed to get too high, there can also be problems with tailing at the filler causing stringing of the product to the outside of the containers. Obviously, the proper starch selection is a balance blend to produce a satisfactory consistency and texture (Langan, 1987).

3.27. Starches for high fiber nutritional claims

Resistant starch, billed as a functional fiber, is well suited for snack applications, since it allows high fiber nutritional claims. It also imparts excellent texture without compromising quality. The RS crystallites are much smaller than those in traditional sources of fiber, and therefore do not adversely affect texture (Huang, 1995). Unlike traditional sources of dietary fiber, which hold significant moisture and impart a gritty mouth feel and characteristic fiber taste, RS has low water-holding capacity, small particle size and bland flavor. Commercial RS is a special high-amylose starch that has been modified by biochemical and/or physical processing to maximize its total dietary fiber content. RS provides snack processors the opportunity to produce high-quality fiber-fortified snacks for health conscious customers (Huang & Rooney, 2001).

A microcrystalline starch-based product comprising glucose and short chain glucooligosaccharides and having an average particle size of less than 10 mu can be used as a dietary fiber supplement (Gross & Haralampu, 1999). A high amylose starch with greater than 40% by weight amylose content and a water content of 10–80% by weight is heated to a temperature of about 60–160 °C to provide a granular starch which retains the granular structure and has a total DF content of greater than 12% (Yong & Trzasko, 1997). Any native or pregelatinized high amylose starches containing at least 30% amylose is hydrated to allow for sufficient molecular mobility for retrogradation to occur. Prior to or during retrogradation, the starch may be debranched by enzymes, to enhance retrogradation. The retrograded starch is further modified by hydrolysis of the amorphous non-crystalline regions with α-amylase or glucoamylase to produce glucose and short chain glucooligosaccharides while leaving the resistant microcrystalline regions intact. This may be dried to a powdered form. Gums, hydrocolloids may be added to change the rheology or increase the water-binding capacity of the product. This product can be incorporated into food and beverage formulations in either the aqueous or dried form.

Indigestible dextrins rich in dietary fiber are obtained by roasting cornstarch in the presence of HCl, followed by hydrolyzing the roasted products with α-amylase and glucoamylase, then removing most of the glucose fractions (Matsutani, 1994).

Chemically modified starch, which is resistant to α-amylase and may serve as a low calorie additive to breads or crackers, so that it may act as a source of dietary fiber. The modified starch may be prepared from any type of food grade starch and preferably takes the form of a phosphorylated di-starch phospho-diester, with a mixture of sodium trimetaphosphate and sodium tripolyphosphate in the presence of a sodium salt acting as the phosphorylating agent (Seib & Kungsoo, 1999).

3.28. Starches for gum confections

A major requirement for use of starch in jelly gums is that it be thin-boiling. This is often achieved by acid conversion or oxidation. Thin-boiling starches can be successfully cooked in the presence of high concentrations of sugar to form strong gels (Evans & Wurzburg, 1967). In starch gum candy production, non-waxy cereal starches with acid modification are advantageous owing to their ability to produce highly concentrated fluid paste, which form gels upon cooling and ageing. Acid-hydrolyzed fluidity starches are used as gelling agents in the manufacture of gum jellies such as jellybeans, gummy bears and orange slices (Dias, Tekchandani, & Mehta, 1997). A typical composition of starch gum candy is 100 lb-granulated sugar, 150 lb of 63 DE corn syrup, and 40 lb of 70-fluidity acid-modified starch, 7 gal of water and

Table 3
Preparation of chip-like products

Ingredients	1	2	3	4	5	6
Waxy maize starch, inhibited and acetylated with 4.6% by weight of adipic–acetic mixed anhydride containing 1 part adipic acid and 50 parts acetic anhydride					260	440
Tapioca starch			400			
Waxy maize starch				400		
Bran-free enriched white wheat meal	3750					
Whole wheat, quick cooking brown wheat meal		500				
Acetate ester of a high amylose corn starch resulting from treatment of a high amylose cornstarch containing 55% by weight amylose with 5% by weight acetic anhydride	3750	500			260	60
High amylose corn starch containing 55% by weight amylose		600				
Acetate ester of high amylose corn starch resulting from treatment of high amylose corn starch containing 70% by weight amylose with 5% by weight acetic anhydride			600			
Dried cheese powder	100				51	105
Onion powder	10				8	5
Caraway seed	20					
Sal	30				22	22
Paprika					5	
Pizza flavor					2	
Monosodium glutamate						2
Water	7600	1000	1050	1000	392	366

Table 4
Commercial specialty starches

Trade name of the commercial specialty starch	Name of the company	Description and uses
Remygel 663-B-P	A and B Ingredients, USA	Precooked, acetylated and cross-linked rice starch that reduces oil uptake of wheat donuts at 25% wheat flour replacement; also increase firmness.
Remyflo R 500P		Gelatinized long grain rice flour that reduces oil uptake up to 64% at 50% replacement of wheat flour in wheat donuts.
HP starch C Cream 06718	Cerestar Euro Centre Food, Belgium	Hydroxypropylated distarch derivative of waxy maize starch (DS-0.08) with well-defined advantages under severe processing conditions such as UHT, high shear, acid conditions; also has good freeze-thaw stability;
C*(AraTex 75701)		A gum arabic replacement in the sugar-free gum application. This acid thinned hydroxypropylated tapioca starch lowers coating time, since the viscosity of this starch is low even at 50% of the total amount vs. a maximum 40% concentration for gum arabic.
C*Pulp tex		Pregelatinized starch, which can replace expensive tomato- and potato-based ingredients.
C*Tex		Waxy maize starch esters for stabilizing fruit preparations
C*Polar tex		Hydroxypropylated waxy maize starch ether to manufacture high quality chilled sauces without syneresis on storage.
C*Cream tex		Stabilized, high cross-linked, tapioca starch that has a short, creamy texture in finished products and a bland flavor; also has good heat and shear resistance, paste clarity and cold storage and freeze-thaw stability.
Staley mira-sperse 622	Tate and Lyle Food Ingredients, Decatur	Agglomerated instant starch and maltodextrin for easy maximum dispersion. Even in cold water, it starts to disperse immediately.
Staley mira-sperse 626		Modified food starch—instant starch—for soups and dry mixes requiring starches that disperse readily in hot water. It is agglomerated for superior mixing and flow and for lump-free end-results in dry mixes.
Staley soft set		Modified food starch, enables the no-cook preparation of spoonable, textured salad dressings. It sets to a soft gel without the need for heat or refrigeration.
Staley Lo temp- 452		Waxy modified starch makes cook-up quality possible in gravies and other products where high temperatures would harm the product formation.
Granular starch		Instantized without gelatinization by means of a novel manufacturing process to physically disrupt internal granular structure for gelling, thickening, easy-dispersing and low pasting temperature; used for dry mixes, gravies and sauces.
Staley's instant stellar		Modified corn starch that has been acid hydrolyzed to produce a loose association of crystallites; xanthan gum is added to aid dispersion and hydration of these crystallites. Used as a fat replacement system for baked goods, frostings and fillings, dairy products, salad dressings, cheese products, table spreads, meat products, confections and frozen dairy desserts. Can endure moderate heat processing with not much loss of quality.
Novation 9330, 9360	National Starch and Chemical Company, Bridgewater, NJ	Functional native tapioca starch for improving texture and mouthfeel of soy yogurt. Suitable for products labeled 100% organic.
Novation 8600		For moderate temperature/neutral pH applications
Novation 8300		For high temperature/low pH applications
Novation 3300		For high temperature/high shear systems
Novation 3600		For moderate temperature/high shear applications
N-surance		A blend of food starch and maltodextrin to provide ice-cream and frozen desserts with an improved texture and slower melt rate
Slenderlean		Modified tapioca starch in combination with sodium alginate. Provides improvement in tenderness, juiciness and cooking yields without affecting beef flavor in low-fat beef patties
Novelose 330		30% total dietary fiber, white in color, neutral in flavor, with less than 1% fat; contributes to good eating quality and high fiber claims.
Novelose 260		Contains 60% TDF, the highest level available in a resistant starch. It can be formulated into a broad range of foods such as pasta, cereals and snack foods that can carry a rich-in-fiber labeling.
N-lite		Fat replacer for liquid systems such as spoonable salad dressings, soups and microwavable cheese sauces; provides lubricity without gelling
N-tack		Waxy cornstarch as an adhesive for cereal-based snack foods. At 30% solids, it exhibits a significantly higher tensile strength than other adhesives. It can be sprayed on at 30–40% solids and develops a tacky texture that dries very quickly.
Dry tack		Adhere seasonings to snacks without the use of oil or water. It is a free-flowing powder preblended with seasonings and applied while the substrate is hot (250–300 °F). The powder melts in less than 30 s, providing a high degree of tackiness and keeps seasonings attached to the snack.

(*continued on next page*)

Table 4 (*continued*)

Trade name of the commercial specialty starch	Name of the company	Description and uses
Textra		Used in hot chocolate to prevent chocolate powder from settling to the bottom of the beverages. It is a tapioca-based specialty starch texturising agent designed to increase body in very thin liquids.
Ultra tex1, ultra sperse		Cold-water swelling native maize starches the reconstitution of which have a smooth short texture, good viscosity and creamy mouthfeel. Food applications of Ultra Tex 1 include bakery food fillings, desserts, gravies, soups, sauces and food products subject to frozen storage. Food applications of Ultra-Sperse include refrigerated, frozen and dry food mixes.
HiCap 100		Modified food starch derived from waxy maize, specially suited for the encapsulation of flavors, clouds, vitamins and spices at high oil loading. It is a white fine powder, characterized by excellent resistance to oxidation.
Hylon VII and micro-crisp		High amylose maize flour used in the formulation of breaded foods for deep-frying, oven or microwave cooking.
N-lok		It is a low-viscosity fine, white powder especially designed for the encapsulation of flavors, fats oils and vitamins, characterized by excellent resistance to oxidation.
Colflo 67		Cross-linked and stabilized starch used in frozen cherry pie filling due to its good freeze-thaw stability.
Ultra set LT		Modified high amylose starch for use in confections, suitable for low temperature processes (140–145 °C).
Hi-set		Modified high amylose starch for use in confections, suitable for use in confections, suitable for jet cooking.
Purity 420 A		Cross-linked and stabilized cornstarch for use in reduced fat spoonable salad dressing formulations.
Struct-sure		Gelatin-replacing starch, to stabilize regular low-fat, no-fat and light yogurts, yielding products with a smooth, creamy texture. Also used to replace milk solids.
Clintose	ADM Food Ingredients	Combination of a pure and stable maltodextrin and crystalline fructose to reduce calories and maintain sweetness in snack foods.
Paselli excel	Avebe America Inc., NJ	Potato-based enzymatically converted product i.e. maltodextrin which forms gels composed of microparticles of 1–2 $\propto$m, that are smooth and creamy. A minimum of 18% is required to form a gel; DE <3 is used for frozen desserts, soups, sauces, dressings and dips, dairy products and bakery products.
Pure cote	Grain Processing Corporation, Muscatine, IA	Corn-based modified starch that acts as an undercoat in panned candies or as a surface shine on chocolate. Preparations of 15–25% in water, cooked at 180 °F for 10 min, and then cooled are required. Maltodextrin, sugar and possibly corn syrups are added to increase solids and facilitate drying.
Pure cote B792		Pregelatinized aqueous-based coating starch that produces clear, flexible films without heating to hydrate the starch, so delicate seasonings and flavors may be added without loss of flavor. The starch has an ability to adhere to large particulates such as sesame, caraway and poppy seeds.
Inscosity		A cold-water swelling starch that provides viscosity without heating/cooking and without forming undesirable lumps or fish-eyes. It is a fine, off-white to cream color powder, that provides freeze-thaw stability without syneresis.
Pen plus 205	Penford Food Ingredients Co., Englewood	Extends shelf life of baked goods due to high moisture-binding properties.
Pen BIND 1000, PenCling 510		Starches are designed for foods requiring a cook-up starch
Hi-Maize	(Starch Australasia) Penford Australia Ltd	Rich in resistant starch, added to foods such as bread, buns, breakfast cereals, pasta, extruded foods, snack, biscuits and drinks without adversely affecting the organoleptic properties. Results in a soft high fiber white bread (Wonder White™) with excellent keeping qualities.
Inamalt 110	Industrializadora de Maiz, S.A. de C.V.	Maltodextrin of DE 10, for use in dry mixes. It is a fine white powder obtained by enzymatic hydrolysis of gelatinized starch suspensions used as fillers/carriers/bulking agents in confectionery products, desserts, bread products, and meat products.
Waxysol		Modified waxy corn starch used as a thickening agent in foods, with great deal of stability under medium and extreme process conditions. The gels of this product present resistance to syneresis during freeze-thaw cycles and minimum opacity; used as a stabilizing agent in formulas for pastry creams, ketchups, puddings, spaghetti sauce, pie filling, bake resistant jellies.
Midsol adhere	Midwest Grain Products, Inc., Atchison	Modified wheat starch with superior binding characteristics for use in batter mixes for breaded, deep-fried foods.
Crysta lean	Opta Food Ingredients, Bedford, MA	Highly retrograded maltodextrin, containing 30% TDF used for reducing calories or increasing fiber especially in baked and extruded products.

(*continued on next page*)

Table 4 (*continued*)

Trade name of the commercial specialty starch	Name of the company	Description and uses
Styclor 60	African Products	A medium acid-modified edible maize starch, when heated in water thickens to a peak viscosity that thins with further cooking. On cooling, the solution thickens rapidly and sets to a firm gel; used in confectionery and desserts.
Stygel FS		Pregelatinized starch made from unmodified edible maize starch. It is cold water swelling and commonly used as a thickening agent in puddings, snack foods.
Yellow dextrin stydex specialty dextrin		A low moisture dextrin, derived from the catalytic treatment of maize starch, classed as a thin boiling yellow dextrin, for use in confectionery products.
Maisita 21.050	Agrana Zucker und Stärke AG, Gmuend	Organic corn starch that has very high thickening properties for use in puddings, dessert creams, soups and sauces
Maisita 21.057		Organic waxy maize starch that shows high freeze-thaw stability for use in pudding and dessert cream.
Quemina 21.204		Organic pregelatinized corn starch that yields opaque pastes with high viscosity, for use in instant dough mixes, baking products and pancakes.
Quemina 21.207		Organic pregelatinized waxy maize starch that yields clear smooth paste with high viscosity for use in instant drinks.
Starkina 20.001		Organic potato starch with good water binding capacity and consistency for use in noodles, pasta, bread and snack foods.
Starkina 20.002		Organic potato starch with low moisture content (6%). Due to its low moisture content, this starch is also hygroscopic making it useful as water absorbent in dry mixes. Used in dehydrated soups and sauces (water absorbent), powdered sugar (flow agent) and shredded cheese (for separation).

appropriate coloring and flavoring (Rohwer & Klem, 1984). Fat-free starches have useful properties making gum confections. Granular acid modified starch is treated with methyl alcohol under pressure at 115–150 °C for 30 min to reduce the fat content to 0.09%. It produces gumdrops of superior characteristics (Radley, 1976).

Oxidized starches increase paste clarity but have reduced gel strength; this makes it suitable for tender gum confection of high clarity (Osman, 1984).

High amylose cornstarch containing 70% amylose makes it a strong gelling agent in the manufacture of fine jelly gum candies. It is used in combination with normal fluidity cornstarch (thin boiling starch) in 1:1 ratio to obtain quick setting candy piece with an attractive texture. High amylose starches in jellies and gums result in fast setting that reduces drying time (Cowburn, 1991).

Jelly gum confections with high gel strength after setting comprises 25–99% acid- or enzyme-converted high

Table 5
Digestibility of various modified starches used in snack foods

Starches	Digestibility
WPI-CMS conjugate (Makoto et al., 1995)	Most indigestible with both α-amylase and β-amylase. The conjugation endows CMS with the characteristics of an indigestible polysaccharide
Oxidized starch (WHO, 1972)	Digestibility of hypochlorite-oxidized starch in vivo is similar to that of unmodified starch
Starch acetate (WHO, 1972)	Starch acetate containing 2.5% acetyl groups are only 93.7% as digestible as native starch. Digestibility by fungal amyloglucosidase is 68-81% of that of native starch. The digestibility of starch acetate containing 1.98% acetyl groups by pancreatin and porcine mucosal enzymes is 90% of that of the unmodified starch.
Hydroxypropyl starch (WHO, 1972)	At 0.04 DS, in vitro digestibility by pancreatin is found to be 80% of that of unmodified starch.
Hydroxypropyl distarch glycerol (WHO, 1972)	At 0.04 DS, in vitro digestibility by pancreatin is found to be 86% of that of unmodified starch.
Distarch phosphate (WHO, 1972)	In vitro digestibility by pancreatin of corn or potato starch modified with 0.05 or 0.1% $POCl_3$ is found to be similar to unmodified starch. The in vitro digestibility by amyloglucosidase of starch modified with 0.35, 0.07 or 0.1% $POCl_3$ varies between 96.4 and 98.3%.
Phosphated distarch phosphate (WHO, 1972)	In vitro digestibility by pancreatic amylase or by pancreatin and porcine intestinal mucosa is somewhat reduced compared with the unmodified starch.
Acetylated distarch phosphate (WHO, 1972)	In vitro digestibility by pancreatin and porcine mucosal enzymes of acetylated distarch phosphates, modified to 1.6 and 2.3% acetyl content are found to be 93 and 81%, respectively, of that of unmodified starch.
Distarch glycerol (WHO, 1972)	In vitro digestibility by amyloglucosidase is 98.3% of that of unmodified starch.
Acetylated distarch glycerol (WHO, 1972)	At 1.2% acetylation, some 82% of the modified starch is digestible, at 2.5, 68.5% is hydrolyzed enzymatically.
Acetylated distarch adipate (WHO, 1972)	In vitro digestibility by amyloglucosidase is 98.3%.
Starch octenyl succinate (Wolf, Thomas, Wolever, Bradley, Keith, & Jeffrey, 2001)	In vitro digestibility by α-amylase and glucoamylase is 70%.

amylose (65–80%) starch and 1–75% of a starch having greater than 25% amylose content, the latter starch being an unconverted starch or a converted starch other than acid- or enzyme-converted high amylose starch (Lacourse & Zallie, 1988). Tapioca specialty dextrins replace from 20–40% of gum arabic in some hard gum candies. Short chain amylose prepared by enzymatic debranching of starch is useful in jelly gum confections as improved gelling agents (Chiu, 1989).

3.29. Starches for chip-like fried snack snacks (Lachmann, 1969b)

Table 3 summarizes various combinations of starches to produce chip-like fried snacks.

4. Commercial specialty starches

A list of the commercially available modified starches suitable for snack foods is compiled in Table 4.

5. Biochemical aspects

This is mainly related to the digestibility of the starches. The information for the various modified starches is compiled in Table 5.

6. Conclusion

With the growth of the processed food industry, the demand for specialty starches should increase. Specialty starches can provide a number of functional benefits to snack foods, and that use is likely to increase due to demand for tasty and appealing reduced fat products. The starch-based coating provides a lot of benefits, including cost effectiveness due to low use level, good flavor release, compatibility with a range of processes, and friendly labeling as corn syrup solids. Commercially developed RS opens up new opportunities for snack manufacturers to develop high-quality fiber-fortified snack products.

The myriad functionality of starches today all but guarantees that—whatever the desired end result—a starch is available to meet the demand. But from the complex combination of applications, possible end-product attributes and processing demands, guidance is needed to exploit this ingredient to the fullest.

7. Future prospects

The future may see an emphasis on new methods of using starch rather than the proliferation of derivatives. That means a focus on physical processes or investigating possible synergistic relationships that alter the starch characteristics, rather than using chemical modification. Physical modification will become a popular approach to simplifying the label, while offering new functionality.

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