
Polyols to improve quality and shelf life of baked products: A review

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Abstract

Mushrooming growth of fast food joints serving fancy bakery product like bread-butter, pizza, burger, puff, hotdog, pastries etc. alongwith traditional bakery product like biscuits, cookies, cakes etc. is the indication that bakery industry has developed its own remarkable position in industrial map of India. Bakery is the third largest of Food Industries. The increase in the growth rate is due to setting of more automatic plants, increased availability of raw materials of consistent quality, adoption of introduction of newer bakery products and reduction of product cost. Shelf life of bakery product is mostly characterized by onset of staling and ropiness formed by microbial spoilage. Other factor affecting shelf life are rancidity, crystallization, grittiness, syneresis of jams and jellies, development of off flavors and odors other than rancidity, chocolate bloom, structural weakness, color, fade or moisture migration. To extend the shelf life of bakery products, these factors must be controlled by suitable preservation methods. Bakery products are an ideal matrix by which functionality (whatever its form) can be delivered to the consumer in an acceptable food ranging from bread to biscuits, cakes and pastries. Preservation in bakery means the retardation of staling.

Keywords: Baking quality, organoleptic quality, polyols, shelf life

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Introduction

India's bakery and cereal market is worth \$1 billion, the 3rd largest in Asia Pacific after Japan and Australia. But still per capita per year consumption of bakery product in India is roughly 1 to 2 kg as compared to 10 to 50 kg in advanced countries. The gap is thus wide. There is ample scope for increasing production of bakery products. In our country, out of the 85,000 bakery units 75,000 operate in the unorganized small-scale sector occupying 65 per cent of the market share (Shraddha et al., 2008). The organized sector in bread industry consists of around 1800 small-scale bread manufacturers, 25 medium scale manufacturers and two large-scale industries. Biscuits and bread which are considered to be the major bakery product and they account for 82 per cent of all bakery productions. The unorganized sector accounts for about half of the total biscuit production estimated at 1.5 million tonnes. It also accounts for 85 per cent of the total bread production and around 90 per cent of the other bakery products estimated at 0.6 million tonnes. The last includes pastries, cakes, buns, rusks and others (www.indiastat.com).

Polyols are sugar-free sweeteners. Polyols are carbohydrates but they are not sugars. They are used cup-for-cup [volume-for-volume] in the same amount as sugar is used, unlike acesulfame potassium, aspartame, saccharin, and sucralose which are used in very small amounts. A sugar alcohol also known as a polyols, polyhydric alcohol, or polyalcohol is a hydrogenated form of carbohydrate whose carbonyl group (aldehyde or ketone, reducing sugar) has been reduced to a primary or secondary hydroxyl group (hence the *alcohol*). Sugar alcohols have the general formula $H(HCHO)_{n+1}H$, whereas sugars have $H(HCHO)_nHCO$. In commercial foodstuffs sugar alcohols are commonly used in place of table sugar, often in combination with high intensity artificial sweeteners to counter the low sweetness. Sugar alcohols do not contribute to tooth decay. "Polyols" is not a consumer friendly term, many nutritionists and health educators refer to polyols as "sugar replacers" when communicating with consumers. Scientists call them sugar alcohols because part of their structure chemically resembles sugar and part is similar to alcohols. Other terms used primarily by scientists are polyhydric alcohols and polyalcohols (Cammenga et al., 1996).

The present day consumer looks for new bakery products, better appeal, taste and convenience from bakery foods. With a population of 1 billion plus, India has the largest middle-income consumers, who demand varieties in food, clothing, transport and improved living standards, also wish to eat out. Opportunities, in abundance, exist in bakery, cafes and restaurants and who fast food enters which is another fastest growing sector in India. This is a new challenge to baker and he needs to update his information, technology, products and services to meet the changing needs of the Indian consumer.

Used in Blended Form

Sweetness varies among the sugar replacers (polyols) and depends in part on the products in which they are used. They vary in sweetness from about half as sweet as the same amount of sugar to equally as sweet as sugar (Table 1). Sometimes combining sugar replacers (polyols) gives a more pleasant taste. Sugar replacers (polyols) are frequently combined with other alternative sweeteners, such as acesulfame potassium, aspartame, saccharin and sucralose, in sugar-free chewing gums, candies, frozen desserts and baked goods. The sugar replacer (polyol) gives these foods mild sweetness as well as the bulk and texture of sugar; the other

alternative sweeteners bring the sweetness up to the level consumers expect (McNutt and Sentko, 1996).

Tables

Table 1. Sweetness of different sugar alcohols

Polyols	Sweetness (sucrose = 1.0)	Caloric content (kcal/g)	Sweetness per caloric content
Arabitol	0.7	0.2	3.5
Erythritol	0.812	0.213	3.498
Glycerol	0.6	4.3	0.14
HSH	0.4–0.9	3.0	0.13–0.3
Isomalt	0.5	2.0	0.25
Lactitol	0.4	2.0	0.2
Maltitol	0.9	2.1	0.43
Mannitol	0.5	1.6	0.31
Sorbitol	0.6	2.6	0.23
Xylitol	1.0	2.4	0.42
Compare with: Sucrose	1.0	4.0	0.25

Clean sweet taste and unique functional properties, polyols offer important health benefits. They are reduced in calories and do not cause sudden increases in blood sugar levels. Importantly, polyols are not readily converted to acids by bacteria in the mouth and, therefore, do not promote tooth decay. Scientific research supports the fact that these low-calorie sweeteners, like polyols, do not promote tooth decay. The U.S. Food and Drug Administration has approved a "does not promote tooth decay" health claim for sugar-free foods and beverages sweetened with polyols. The American Dental Association has issued an official statement saying sugar-free foods do not promote dental caries. Polyols elicit a low glycemic response beneficial to all consumers, including those with diabetes.

Metabolism of Polyols

Polyols are slowly and incompletely absorbed from the small intestine. The portion of polyols that is absorbed is metabolized by processes that require a minimal amount or no insulin. The portion that is not absorbed into the blood is broken down into smaller segments in the large intestine. Due to the incomplete absorption, a large amount of polyols consumed at one time may cause gastrointestinal effects, such as gas or laxative effects similar to reactions to beans and certain high-fiber foods. Absorbed portions are either metabolized (generally by insulin-independent mechanisms) or excreted via urine. A significant amount of the unabsorbed portion is metabolized to short chain fatty acids and gases by bacteria in the large intestine (Nabors, 2007). The severity of the symptoms depends on the individual, amount of the food that is consumed in one time, type of polyols, and existence of any prior period of adaptation. Gastrointestinal symptoms, if they occur, are usually mild and transient. Most people will adapt

to the mild gastrointestinal effects within a few days (Ellis and Krantz, 1941). The FDA is aware of the potential laxative effect of polyols. Therefore, they require the informational food label statement on foods whose daily consumption may result in 50 grams of sorbitol or 20 grams of mannitol: "Excess consumption may have a laxative effect."

Hurdle technology for baked products

Use of hurdles which were difficult to overcome by the micro-organisms causing food spoilage and poisoning provided shelf stability to products (Leistner and Rodel, 1976). The parameters like water activity (a_w), high temperature (F value), low temperature (T value), water activity, pH, redox potential (Eh), some preservatives and competitive flora are commonly applied hurdles. However, more than 50 factors or hurdles of potential use for improving the stability and quality of foods have been developed. Their synergetic effects have been called as hurdle effect.

Food preserved by combined methods remains stable and safe even without refrigeration and are high in sensory and nutritive properties due to the gentle process applied (Leistner, 1992). Homeostasis was the constant tendency of microorganism to maintain a stable and balanced (uniform) internal environment. Food preservation was achieved by disturbing the homeostasis mechanisms, simultaneously. The influence of food preservation method on physiology and behaviour of microorganisms in food i.e. their homeostasis, metabolic exhaustion, stress reactions, were taken into account, and novel concept of multitarget food preservation emerged (Leistner, 2000).

Lombard et al., (2000) examined hurdles: acid to lower pH, NaCl and glycerol to lower a_w , preservative to inhibit microbial growth, fat to retard staling, heat to destroy vegetative forms of heat sensitive microorganism and heat processing of final packaging material to inhibit microorganism regrowth. The hurdle technology approach was used to prevent fungal growth of common contaminants of bakery product including isolates belonging to the genera *Eurotium*, *Aspergillus* and *Penicillium* (Marin et al., 2002). Esteller et al., (2004) showed that different kinds of sugars alone or in combination could be used in bread making to improve products softness and shelf life. Potassium sorbate was found to be the most effective in preventing in fungal spoilage of bakery products at the maximum concentration tested (0.3 per cent) regardless of a_w (Guynot et al., 2005).

Polyols in baked products

Sodemann (1979) showed that mannitol was a highly soluble sugar alcohol, with a sweetness approximately 50 per cent that of sucrose. Consumption of mannitol does not increase blood glucose level, does not stimulate glucose secretion and has no effect on serum free fatty acid, lactate, pyruvate or urea concentration. It is preferable to fructose, xylitol or sorbitol as a sugar substitute in foods for diabetics. Petrizzelli (1988) developed shelf life of intermediate moisture dough or pastry made from 30-40 per cent native starch, 15-25 per cent fat, 5-10 per cent water and 2-5 per cent glycerol or 4-7 per cent sorbitol with emulsifier, salt and flavouring. The water activity of product was 0.6- 0.8.

Glycerol was reported to increase both shelf life and shelf stability of wheat and corn tortillas (Skarra et al., 1988). Glycerol (2-10 per cent by weight) increased the shelf stability by promoting softness and flexibility of tortillas by decreasing water activity. Glycerol decreased water activity, total titratable acidity of both crumb and crust, lowered volume and produced a firmer texture; shelf-life (absence of visible mould growth) of packaged bread was extended by

addition of glycerol by 1-2 days (7.5 per cent) or 7-8 days (15.0 per cent), using ethanol treatment by 3-4 days, or using propionic acid by 7-10 days (Ortola et al., 1989).

Blankers (1995) showed that lactitol was an ideal sweetening agent for formulation of sugar free products, in which it provides sweetness and bulking properties, and stable at high temperature. Application included use in chocolate and sugar confectionary, frozen desserts, and bakery products. The safety of lactitol had been approved by the joint FAO/WHO committee on food additives. Cauvain and Cyster (1996) also found that glycerol increased the volume of chocolate cakes and resulted in softer crumb structure. Glycerol levels of 150 and 180 g/kg flour produced a_w levels of 0.91 and 0.88, respectively. These levels were low enough to inhibit the growth and germination of *Clostridium botulinum* spores. Polyols are hydrogenated carbohydrates used as sugar replacers. Interest now arose because of their multiple potential health benefits. They were non-cariogenic (sugar-free tooth-friendly), low-glycemic (potentially helpful in diabetes and cardiovascular disease), low-energy and low-insulinaemic (potentially helpful in obesity), low-digestible (potentially helpful in the colon), osmotic (colon-hydrating, laxative and purifying) carbohydrates (Livesey, 2003). Xylitol increases the lag phase and stationary phase of *Zogoccharomyces bacilli*. Sorbate minimum inhibitory concentration concerning *Zogoccharomyces bacilli* acquired slightly lower growth values (Gliemmo et al., 2004). Sugar alcohols have influence in lowering the water activity of food and its high osmotic pressure lead to an increased preservative effect and extended shelf life. Low molecular weight would help in lowering the freezing point depression in frozen products.

The structure resembled sugar and part is alcohol. The common among these were hydrogenated starch hydrolysates, sorbitol, mannitol, xylitol, isomalt, maltitol, lactitol and erythritol. They provide many functional and health benefits (Dhiman et al., 2005). Best results were obtained with xylitol and maltitol, leading to sponge cakes more similar to the control manufactured with sucrose and with the highest acceptance level in sensory evaluations. Lower quality sponge cakes were those elaborated with mannitol (Ronda et al., 2004).

Many properties of foods and beverages depended upon proper pH. Glycerol appeared to have no effect on the apparent pK_a value of phosphate buffer while causing a slight increase in the values for citrate buffer. Potential pH changed from food additives should be recognized during product development in order to optimize product quality and shelf life (Chuy and Bell, 2006). Effectiveness of preservation ranked as follow: combination of citric acid, potassium sorbate, ethanol and pasteurization > combination of citric acid, potassium sorbate and ethanol > combinations of citric acid and potassium sorbate > combination of sodium diacetate and potassium sorbate > combination of tartaric acid and potassium sorbate (Doulia et al., 2006). Statistical associating fluid theory (SAFT) model had been able to model the water activity, oxygen solubility and density with very good accuracy, and the SAFT model could be taken as a suitable tool for describing sugar and sugar containing solutions (Peijun et al., 2006). Radowski (2006) reported that isomalt could be used in wide range of cereals, including extruded and coated breakfast cereals, cooked cereal products, soft or crunchy granola and cereal bars, and museli clusters. It was more stable than sucrose under higher temperature during processing. It absorbed little water which helped in increasing the shelf life and texture of stored cereal products.

Pasting properties of flour incorporated with polyols

Sucrose, shortening powder, and GMS had the most effect on the pasting properties of wheat flour extrudates. Pasting properties could be controlled by changing concentrations of

such ingredients (Ryu et al., 1993). Sorbitol and xylitol were highest on gelatinization but their retrogradation occurred faster than other sugar alcohols. Lactitol and maltitol decreased gel strength more than that did sucrose and the other sugar alcohols (In-Young-Shin et al., 2001).

Textural properties of baked products

The firmness method proposed for bread was applicable to cakes and could be used to differentiate cakes of different formulations and ages. They concluded that there were at least two forces contributing to the total firmness, a compression force related to the area of indenter and a tension/shear force related to the perimeter of the indenter (Walker et al., 1987). Bourne (1990) stated that probing could be much wider application to cereal based foods such as cookies and crackers. Probing is also known for penetrating, puncturing and punching, depending on the product to be tested and the degree of penetration. The results were given in various interpretations, including firmness, toughness, tenderness, ripeness, and hardness again depending on the product (Szczesniak, 1972). The technique measured the maximum force required to push a probe into or through a product. The depth of penetration was sometimes recorded as the hardness value. Texture was a major importance in extruded products where crispness being often a desirable attributes. Due to the high costs involved in sensory analysis, instrumental assessment of end-product texture, by fundamental and empirical techniques, had been a useful tool for food researchers and manufactures as it had been related to sensory evaluation (Anton and Luciano, 2007).

Staling of baked products

Self-diffusion coefficient (D) increased with added glycerol in breads of the same moisture content. D remained unchanged after storage without crust (with no moisture loss from crumb to crust). When stored with crust (with moisture loss), more mobile water was lost (probably from glycerol), resulting in a more rapid initial decrease of D in glycerol added bread. Competition of water may be a key influencing factor. Glycerol and loss of moisture (according to crumb-crust moisture gradient) triggered a shift in moisture redistribution from starch and gluten to glycerol (Baik and Chinachoti, 2003). Starch degrading enzymes acted by decreasing the structural strength of the starch phase by preventing the recrystallization of amylopectin or by reducing the connectivity between crystalline starch phases. Starch degrading enzymes might also promote the formation of a partly crystalline amylose network and by this contributed to a kinetic stabilization of the starch network. A model for bread staling was proposed by taking into account the biphasic nature of starch and the changes in both the amylose and amylopectin fraction (Hug-Iten et al., 2003). The study showed that breads produced with the sponge and dough (SPD) method was superior to those produced by the straight dough (SD) method with respect to their overall quality and resistance to staling. 50 per cent sponge gave bread with superior overall sensory quality to that obtained using 60 per cent sponge (Amr and Ajo, 2005).

Changes in the texture profile (TP) parameters were modelled and their initial values and their variation rate were obtained. In white and whole breads, the longer the fermentation time and the higher the yeast dose, the lower the firmness and the firming rate (Gomez et al., 2006). Bread containing trehalose had higher specific volume and performed better in sensory comparison than the control. Bread crumb hardness was reduced by adding trehalose. DSC studies showed that trehalose decreased the enthalpy of starch retrogradation and increased the glass transition temperature. Trehalose improved the quality and retarded the staling of bread effectively (Zhou et al., 2007).

Storage studies of baked products

Water activity was more closely related to the physical, chemical and biological properties of foods and other natural products than the total moisture content. Specific changes in colour, aroma, flavour, texture, stability and acceptability of raw and processed food products were associated with relatively narrow water activity ranges (Rockland and Nishi, 1980). The addition of hydrogenated vegetable oils in convenience foods was found to improve their storage stability (Patki and Arya, 1994). The lower fungal contamination was found inside the products than on the surface. The most important point to control a_w on the cake surfaces (Abellana et al., 1999).

Manley (2000) stated that the low moisture content and low water activity of bakery products imparted them a long mold free shelf-life, typically many months. Organoleptic shelf-life was also very long since the product staling and usually moisture loss was not a problem. One problem was the potential to absorb moisture from the surrounding atmosphere, which could lead to softening of products and loss of crisp eating characteristics (staling). The second was the risk of fat rancidity arising from the combination of long storage time with low water activity. The baked products would remain soft with increased resilience, improved texture and desirable toasting qualities. With extended shelf life of products were aid in reducing the stale returns would be reduced which opened a new distribution avenue and ultimately create superior products.

Nutritional importance of polyols in baked products

The primary advantage of the multiple sweeteners was that low calorie sweeteners, when used together, had a synergistic effect. Such synergistic combinations reduced cost and improved product taste and stability. Since, the combination often overcomes the limitations of the individual sweetener (Robert, 1987). Levin et al., (1995) reported that zero or low energy, full-bulk, alternative carbohydrate sweeteners could play a useful role as one factor in helping to make several energy restricted diets. The 85 per cent of diabetics were type 2 diabetics (Non-insulin dependent) and their diabetes could be controlled by a healthy diet and exercise and by losing weight (Roberts et al., 1995).

Table 2. Dietary regulation for sugar alcohols

Polyols	Laxication threshold (g/day)	Glycemic index	Degree of hygroscopy	USA regulatory status	EU regulatory approval
Sorbitol	50	Low	Medium	GRAS	Yes
Mannitol	20	Low	Very low	Food additive	Yes
Polyglycitol syrups	>100	Low	Medium	Variable	Pending
Maltitol syrups	>100	Low	Medium	GRAS	Pending
Maltitol	90	Low	Low	Food additive	Yes
Xylitol	50-90	Low	Low	GRAS	Yes
Erythritol	125	Low	Very low	GRAS	Pending

Safety and regulatory Aspect

Most polyols in use today are in a category of ingredients referred to as GRAS (Generally Recognized as Safe). Erythritol, hydrogenated starch hydrolysates, isomalt, lactitol, maltitol and sorbitol are considered GRAS. Mannitol has interim food additive status and xylitol is a food additive approved for special dietary purposes. Dietary regulation for sugar alcohols are given in Table 2.

Conclusion and future trends

The bakery industry is the largest among the processed food industries in India with significant growth of 40 per cent. Bread and biscuits are the two major bakery industries account for about 82 per cent of the total bakery products. Bread is the cheapest and ready to eat convenience food taken by large section of population of urban as well as rural. Bread is generally a highly perishable item which has a shelf life of 72 hours in a tropical country like India. Muffins are also ready to eat food. Muffins are perishable item which has a shelf life of 20 days. These are fresh when just out of the oven but started to age, firm up and become progressively stale thereafter. From the production point, these are transported to various cities nearby and even to other states. The time gap between production and actual consumption for bread is estimated to be 18.36 hour or more. By that time the product may have lost its freshness due to staling which is the result of the changes other than those resulting from action of a spoilage organism namely spores of rope mold. These lead to the loss of palatability. The important changes due to staling are increase in the firmness of the crumb, evaporations of moisture from the crumb; loss of bread flavor; and microbial deterioration. Among these, increase in crumb firmness, which is considered as the most important aspect of staling is recognized by the consumer a long time before the bread products has become unsuitable for consumption. It results in decreased consumer acceptance and great economic losses. Hence much attention has to be focused on this problem, because people never prefer stale products.

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