
REVIEW ON - INGREDIENTS USED IN TOOTHPASTE FORMULATION

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Abstract

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Different ingredients are used in toothpaste formulation to keep the oral health and to achieve multi claim products. We have variety of toothpaste available in market like anti-cavity, extra-whitening and toothpaste for sensitive teeth, toothpastes with stripes, clear etc. At Current scenario, toothpaste contains different ingredients like abrasives which help to wash off bacterial films and fluorides to harden the teeth against caries and have thickeners that will give the ribbon stand up. The role of foaming agents is to remove the fatty films. The sweeteners play the role as a non-nutritive which may help stop the attraction of bacteria. Toothpaste contains both active and inactive ingredients which have their role and will be proposed in accordance to the oral condition of individuals.

Introduction

The idea of maintaining teeth looking clean and feeling healthy has been common for many decades. The way of doing this however has changed over periods, Initial types of toothpaste commonly used ingredients such as honey and oil along with other pleasant tasting ingredients. This early toothpaste formula was often harmful to teeth and gums. One of the former commonly used methods for cleaning teeth was tooth powder. Tooth powder was stored in tins. The toothbrush had to be dipped into the wetted powder before using. Often resulting in wastage. Also common in the first part of the 18th Century was brushing with the dry baking soda or salt. The taste of this mixture was not very appealing to most people.

In 1877, toothpaste was first mass produces in jars by The Colgate Company. And in 1892 the first collapsible toothpaste tube was produced. In 1914, there was breakthroughs in the history of the toothpaste- the introduction of fluoride. British patent GB3,304 describes "Improvements in or relating to densifiers' and therein toothpaste contains sodium fluoride. Crest toothpaste from P&G is the first fluoride containing toothpaste world and is marketed in entire USA in the year 1955-1956.

The development of synthetic surfactant after 2nd world war led to the initiation of sodium lauryl sulfate, which is the commonly used surfactant in toothpaste. Gradually innovators have improved the formulation for better fluoride bioavailability, lower abrasivity, better stain removal and breath freshening etc. Also, toothpaste have become multclaim's do the addition of active ingredients in the formulation to combat a variety of oral diseases and condition to provide the health benefits.

Ingredients of toothpaste

- Abrasive
 - Calcium carbonate
 - Calcium Phosphate
 - Silica, Silica Hydrate
 - Other Abrasive
- Binders
 - Carboxymethylcellulose
 - Sodium alginate
 - Carrageenan

- Carbomers
- Xanthan gum
- Humectants
- Solvents
- Foaming agents
 - Sodium lauryl sulfate
- Flavoring agents
- Sweeteners
- Coloring agents
- Preservatives
- Active ingredients
 - Anticaries agents
 - i. Fluoride
 - ii. Xylitol
 - iii. Sodium bicarbonate
 - Anti-plaque agents
 - i. Triclosan
 - ii. Metal ions
 - iii. Essential oil
 - Anti-Calculus agent
 - i. Pyrophosphate
 - ii. Zinc ions
 - Anti-dentine hypersensitivity agents
 - i. Potassium salts
 - Anti-aphtous agents
 - i. Whitening agents
 - ii. Abrasives
 - iii. Dimethicones
 - iv. Sodium bicarbonate
 - Anti-halstosis agents
 - i. Zinc ions

Abrasive

Abrasive are the substance used for grinding or polishing. They remove element adhering to the teeth surface without scratching the teeth surface. The abrasivity of the substance depends on the hardness of the abrasive, morphology of the particles and concentration in formula. The hardness of an abrasive should be lesser than or equal to 3. Abrasives are found in toothpaste are most often found as crystals, small and smooth particles. RDA (Radioactive Dentine Abrasion) is the common method used for measuring the abrasive effect of powders used in toothpaste. In this method, an extracted human tooth is irradiated to convert the ^{31}P in its dentine to ^{32}P . The tooth is then put into an abrasion testing machine together with an abrasive and abrasion ^{32}P is used radioactive counter.

Some of following substance are wildly used abrasive,

Calcium carbonate

A fine, white, odorless powder, partially soluble in water. Its abrasiveness is higher than calcium phosphate. There are two types. Heavy and precipitated Calcium carbonate.

Calcium Phosphate

These are available in dihydrate form and an anhydride form. As the anhydride form is harder than the dihydrate form, it is not often used. The dihydrate form has a mild abrasive effect and feels good on use. However, when it is in toothpaste for a long period of time, it loses its water of crystallization, changes to the anhydride form and makes the toothpaste hard. Because of this reason, a magnesium salt or other stabilizer is added.

Silica, Silica Hydrate

The main ingredient of the silica used in abrasives is amorphous silicon dioxide and there are varieties of different types whose properties vary with the method of production. Silica is very suitable for use in toothpastes containing fluoride because of no insoluble salt is formed when it reacts with fluoride.

Other Abrasive

Aluminum hydroxide is also used as an alternative to calcium phosphate, dibasic, because it is cheaper. Other abrasives such as calcium pyrophosphate, insoluble sodium metaphosphate, magnesium carbonate, alumina.

Binders

Binders are also known as Viscosity and Rheology Modifiers. Primary function of this binders is to produce the gel phase containing a homogenous distribution of all ingredients and to prevent the components from separation during its shelf life. Separation is referred as syneresis which is defined as the separation of a liquid from a gel or suspension. The binders also contribute towards viscosity build and responsible for an easy flow of toothpaste from the tube and to form a good ribbon stand up.

Carboxymethylcellulose

Carboxymethylcellulose inactive, it dissolves in water and compatible with other ingredients. There are many types of CMC having a variety of different characteristics which is different degrees of hydroxy group substitution and polymerisation. Other known cellulose derivatives include methylcellulose, hydroxyethyl cellulose and hydroxypropyl cellulose.

Carbomers

These are synthetic high molecular weight polymer of acrylic acid cross linked with poly alkenyl esters of poly alcohol. They are produced in different grades characterized by the viscosity of a defined solution, these are white, hygroscopic powders with slight characteristic odor. They swell in water and in other polar solvents after dispersion and neutralization with sodium hydroxide solution. It also soluble in water, alcohol, glycerol.

Xanthan gum

Xanthan gum is high molecular weight anionic polysaccharide. It exists as the sodium, potassium, or calcium salt. This gum is produced by a bacterial culture or correctly buffered and aerated media containing carbohydrates with xanthomas campestris. After completion of the fermentation, the polymer is recovered by precipitation with isopropanol, filtered, dried, and crushed. It is cream colored powder, Soluble in hot water and cold water, it forms aqueous solution of which the viscosity remains practically unchanged by temperature changes as well as pH. The behavior of these solution is of the pseudoplastic. Means it decreases in viscosity proportional to shearing and instant recovery of the initial viscosity after discontinuation of shearing. The gum is compatible with most of the salts, moderate surfactant concentration, and preservatives.

Sodium alginate

Sodium alginate is the sodium salt of alginic acid. It is a white to pale yellowish powder which is odorless and tasteless. Soluble in water, forming a viscous, colloidal solution, partially insoluble in alcohol and ether. It has less surface activity and its emulsifying power is achieved by increasing of the aqueous phase.

Carrageenan

A white to yellowish coarse or fine, odorless powder with mucilaginous taste. Soluble in 1 in 100 water at 85°C. It disperses more rapidly if first mixed with alcohol. These are galactans or polymers of D galactose, are heavily sulfated and are anions with multiple electrolytes of molecular weight ranging from 105 to 106 and all are having a linear structure of (AB)_n type, with alternating 1,3 and 1,4 bonds.

Humectants

Humectants play mainly to help retention of water within the formulation over time. Also affect shelf life stability and consistency during the use. It also provides the creamy texture to the formulation. There are short chained poly alcohols such as Glycerin, sorbitol, Propylene glycol and Polyethylene glycol.

Solvents

Water is the most common solvent used in toothpaste. It dissolves the ingredients and allows them to be mixed.

Foaming agents

The foaming agents which helps dispersion of the toothpaste in the oral cavity to enhance the cleaning property by acting as surfactant and removes the debris and plaque from oral cavity. The selection of surfactant type and concentration in formulation is very important to minimize any possible irritation in oral tissue and to reduce any negative impact on fluoride availability. As they go into mouth, attention is also paid to the taste and smell. The frequently used at present is sodium lauryl sulfate. Other examples are cocamidopropyl betaine, cocoyl taurate, sodium lauryl sarcosinate and sucrose fatty acid esters.

Sodium lauryl sulfate (SLS)

SLS is a combination of Sodium alkyl sulfates, consisting mainly of sodium dodecyl sulfate. It is white powder or crystals with slight characteristic odor. Freely soluble in water. It shows high attraction towards proteins and is a strong denaturing agent. It may be highly irritant to skin and mucosa and it may be also damaging the mucosal mucin layer by denaturing its proteins. The epithelium layer will be more exposed for irritants and this can lead in apthous ulceration in some patients. It has also been said that there is a connection between the use of toothpaste containing SLS, an increased frequency of recurrent apthous ulcers in some patients.

Flavoring agents

They get free of the unpleasant smell and taste of the other raw materials and give a refreshing taste. Combinations of water-insoluble essential oils, such as spearmint, peppermint, eucalyptus, and menthol are often used as flavoring agents in toothpastes.

Sweeteners

Sweeteners also improve the taste of toothpastes and mouthwashes and give them a mild and sweet taste. The most common used sweeteners are sodium saccharin, Sucralose, stevia glycosides etc.

Coloring agents

Most toothpastes contain colour which give them an attractive appearance. The color-substances are classified by the Colour Index (CI), published by the Society of Dyers and Colourists and the American Association of Textile Chemists and Colourists, or by a system called the FD&C Colours. Titanium dioxide is often as opacifiers.

Preservatives

Preservatives prevent the growth of micro-organisms in toothpastes. Mostly, they include sodium benzoate, methylparaben and Propyl paraben.

Active ingredients

One or more active ingredients are usually added toothpastes. At present most of the toothpaste contain fluorides, Triclosan, Sodium tri poly phosphate, Potassium nitrate etc
Anticaries agents

Fluoride

Fluoride is the most effective caries-inhibiting agent, and almost all toothpastes currently contain fluoride. The most common form is sodium fluoride (NaF), but mono-fluoro-phosphate (MFP) and stannous fluoride (SnF) are also available. Toothpastes are the main vehicle for fluoride. The combined therapeutic and cosmetic mouthwashes usually also contain fluoride, but in a non-therapeutic dose. The mechanism by which fluoride prevents caries is not clearly understood. It is known that the fluoride ion (F⁻) can replace the hydroxyl ion (OH⁻) in hydroxyapatite, the major

crystalline structure of enamel. The substituted crystal, called fluorapatite, is more resistant to acids, such as those produced by plaque bacteria, than the original hydroxyapatite. As the tooth develops and enamel is formed, ingested fluoride is incorporated into the enamel. Therefore, because enamel develops its outer layer first, more fluoride can be expected to be deposited on the outer layers as compared to the inner layers. It is this surface enamel layer containing fluoride that imports caries resistance to a tooth. It is also suggested that fluoride has anti-bacterial actions. In an acidic environment, if fluoride is present, hydrogen fluoride (HF) is formed. HF is an undissociated, weak acid that can penetrate the bacterial cell membrane. The entry of HF into the alkaline cytoplasmic compartments results in dissociation of HF to H^+ and F^- . This has two separate, major effects on the physiology of the cell. The first is that the released F^- interacts with cellular constituents, including various F^- -sensitive enzymes. The second effect is an acidification of the cytoplasmic compartment caused by the released protons. Normally protons are pumped out of the cell, but fluoride inhibits these processes. The decreased intracellular pH will make the environment less favourable for many of the essential enzymes required for cell growth. As the most important anti-caries effect is claimed to be due to the formation of calcium fluoride (CaF_2) in plaque and on the enamel surface during and after rinsing or brushing with fluoride. CaF_2 serves as a fluoride reservoir. When the pH drops, fluoride and calcium are released into the plaque fluid. Fluoride diffuses with the acid from plaque into the enamel pores and forms fluorapatite (FAP). FAP incorporated in the enamel surface is more resistant to a subsequent acid attack since the critical pH of FAP (pH=4.5) is lower than that of hydroxyapatite (HA) (pH=5.5). Fluoride decreases the demineralisation and increases the remineralisation of the enamel between pH 4.5-5.5, and consequently the demineralisation period is reduced.

Xylitol

A polyol related to the pentose sugar, xylose. White crystals or crystalline powder. Very soluble in water. It has a sweet taste and produces a cooling sensation in the mouth. Xylitol cannot be fermented by oral microorganisms. It is a cariostatic agent since it can inhibit the carbohydrate metabolism in different oral micro-organisms. Xylitol seems to be unique among the sugar alcohols in its inhibitory effect on glycolysis. The inhibitory effect on glycolysis has been related to the uptake of xylitol via a constitutive fructose specific phosphotransferase system and subsequent intracellular accumulation of xylitol-5-phosphate. Such a mechanism leads to reduction in acid formation from glucose, and a reduction in the *Streptococcus mutans* content in both plaque and saliva

Anti-plaque agents

Triclosan

Triclosan is a non-ionic chlorinated phenolic compound with antiseptic property. It has a broad-spectrum activity on Gram + ve and Gram – ve bacteria and effective against anaerobic bacteria, spores and fungi. Clinical studies revealed it has moderate level of antiplaque activity. Triclosan to be used with other ingredients to get increased antibacterial effect. Commonly used are copolymer PVM/MA and zinc citrate. Triclosan also has anti-inflammatory effect by acting on the eicosanoid cascade and by inhibiting both cyclooxygenase and lipoxygenase thereby inhibits the production of prostaglandins and leukotrienes.

Metal ions

Commonly used metal ions in dental formulations are Zinc (Zn^{2+}) and Stannous (Sn^{2+}). These are having the ability to inhibit the bacterial growth, inhibit the plaque formation and restrict the plaque bacteria to convert urea to ammonia. They can also inhibit some of the bacterial enzymes and reduce the bacteria's ability to colonise the tooth surfaces.

Essential oil

The essential oils like thymol, menthol and methyl salicylate are thought to have anti-bacterial activity by altering the bacterial cell wall. Presence of these active ingredients have been reported to reduce plaque and gingivitis significantly.

Anti-Calculus agent

Pyrophosphate

Pyrophosphate is added as Sodium tri poly phosphate, tetrasodium pyrophosphate and disodium pyrophosphate. It has been shown that pyrophosphate has high affinity to hydroxyapatite (HA) surfaces, probably by an interaction with Ca^{2+} in the hydration layer. By interacting with HA and the enamel surface, pyrophosphate reduces their protein-

binding capacity. It can inhibit calcium phosphate formation. The PO- P bond of pyrophosphate is known to be susceptible to enzymatic hydrolysis by plaque and salivary phosphatases, and the effect may thus be of limited duration in the oral cavity. Consequently, the tartar control toothpastes that contains pyrophosphate as a calculus inhibitor.

Zinc ions

Zinc is added as Zinc chloride or Zinc citrate. Zinc ions inhibit the PTS pathway of glucose uptake by streptococcus mutans, Streptococcus sanguis and Actinomyces naeslundii, and the metabolism of glucose to lactic acid. The effects of zinc are intracellular, resulting from the inhibition of sulfhydryl enzymes, specifically enzyme I in the phosphotransferase transport system and aldolase and glyceraldehyde dehydrogenase in the glycolytic pathway. Zinc also inhibits the trypsin-like protease activity of Porphyromonas gingivalis and of Capnocytophaga gingivalis. The role of zinc in plaque inhibition or as a calculus inhibitor.

Anti-dentine hypersensitivity agents

Potassium salts

Potassium ions acting by blocking the action of potential generation in interdental nerves. It is claimed that potassium salts in dental formulation increase the concentration of potassium ions around the pulpal nerves, and thereby depolarizes the nerve. This can inhibit a nerve response from different stimuli.

Whitening agents

Whitening toothpastes do not lighten the color of the tooth, they just remove surface stains with abrasives or special chemical or prevent stain formation.

Anti-halitosis agents

Zinc ions

Halitosis originates mainly from the oral cavity. This unpleasant odor is because of the retention of anaerobic, Gram-negative bacteria. These bacteria use Sulphur containing amino acids as substrates in their production of volatile Sulphur-containing compounds. Volatile Sulphur-containing compounds have a distinctly unpleasant odor in low concentrations. Zinc inhibits the production of volatile Sulphur-containing compounds in the oral cavity by interacting with Sulphur in the amino acids or in their metabolism.

Conclusion

To achieve the multi-claim dental products in basket, it is necessary for the innovators or formulator to use a variety of ingredients. Innovations in pharmaceutical technology have contributed to the formulation of the products having improved efficacy as well as other qualities aspects that may provide to clinical response and patient compliance. This enhanced clinical efficacy and permissibility, should encourage patient compliance with oral hygiene to prevention of the oral disease.

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