keep the wax mainly at the surface. The quantity of alginate used is usually 5-10% of the weight of starch in the size.

Alginate is also used in starch adhesives for making corrugated boards because it stabilizes the viscosity of the adhesive and allows control of its rate of penetration. One percent sodium alginate, based on the weight of starch used, is usually sufficient.

Cottrell and Kovacs (1980) give examples of formulations for a kraft lineboard sizing and for corrugating adhesives. An improved sizing with alginate has been obtained by using a paper containing 5-25% of calcium carbonate filler; the calcium alginate film which forms gives better solvent resistance and lower Bendtsen porosity. The alginate is blended with 6-20 parts of starch or it may be combined with polyvinyl alcohol (Kelco, 1985).

Paper coating methods and equipment have developed significantly since the late 1950s as the demand for a moderately priced coated paper for high quality printing. Trailing blade coating equipment runs at 1 000 metres per minute or more so the coating material, usually clay plus a synthetic latex binder, must have consistent rheological properties under the conditions of coating. Up to 1% alginate will prevent change in viscosity of the coating suspension under the high shear conditions where it contacts the roller. The alginate also helps to control water loss from the coating suspension into the paper, between the point where the coating is applied and the point where the excess is removed by the trailing blade. The viscosity of the coating suspension must not be allowed to increase by loss of water into the paper because this leads to uneven removal by the trailing blade and streaking of the coating. Medium to high viscosity alginates are used, at a rate of 0.4-0.8% of the clay solids. A new modified form of sodium alginate has been reported to be more effective than existing alginate and results in lower processing costs (Yin and Grishaber, 1979).

A useful discussion of the evolution of paper coating methods and the use of alginate has been prepared by Blood (1968). Other more general discussions of coating, which also refer to the use of alginates, have been published by Paper (Anon., 1976), Bergmann and Hunger (1978), and Delaplace, Laraillet and Isoard (1985).

Sergeant (1981) has prepared a general review of the applications of alginates in paper converting. He has also described the use of zinc ammonium alginate as a flame retardant in paper (Sergeant, 1980).

WELDING RODS

Coatings are applied to welding rods or electrodes to act as a flux and to control the conditions in the immediate vicinity of the weld, such as temperature or oxygen and hydrogen availability. The dry ingredients of the coating are mixed with sodium silicate (water glass) which gives some of the plasticity necessary for extrusion of the coating onto the rod and which also acts as the binder for the dried coating on the rod. However the wet silicate has no binding action and does not provide sufficient lubrication to allow effective and smooth extrusion. An additional lubricant is needed, and a binder which will hold the damp mass together before extrusion and maintain the shape of the coating on the rod during drying and baking. Alginates are used to meet these requirements.

Soluble alginates (sodium or potassium) are used in coatings on welding rods which are dried at moderate temperatures and in which the alginate remains after drying; this includes organic-type coatings with a high content of cellulosic material and mineral coatings of the "acid" type. Soluble alginates can be used in basic or low-hydrogen rods but calcium alginate, sometimes with a proportion of sodium alginate added, gives much better results. This is related to the high temperatures used to dry these rods (400-450°C) which produces low moisture contents so that only very low hydrogen levels are found in the deposited weld metals. Soluble alginates swell when wetted and as the water is driven out completely in this high-temperature drying, the alginates will contract and cracks will develop in the coating. When calcium alginate is mixed with sodium silicate, a small amount of sodium alginate forms around each particle of calcium alginate. This mixture is thixotropic, its viscosity is lowered when extrusion pressure is applied; it therefore acts as a good binder and extrusion lubricant. During the drying process, because the calcium alginate did not previously swell very much, it does not shrink appreciably and a more uniform coating results.

The quantities of alginates used are very dependent on the type of welding rod being coated and the extrusion equipment being used. For soluble alginates it may be 0.4-1.2% for low-hydrogen welding rods and 0.15-0.25% for acid and organic types. For the thixotropic alginates, manufacturers often find it more effective to use a mixture of calcium alginate and sodium alginate with a total alginate content of 0.4-0.6% for low hydrogen electrodes. Alginate manufacturers are the best source of information for using alginates in welding rod applications, for example Protan (1984).

PHARMACEUTICAL

Alginic acid is insoluble in water but swells when placed in water. This property makes it a useful disintegrating agent in tablets. It is more expensive than the traditional disintegrating agent, starch, but its overall addition to the cost of the tablet is still usually very low. It is a better disintegrant than starch so less is required. It can be added during the granulating process, rather than as a powder after granulation, so the processing is easier. The mechanical strength of the final tablet is greater, compared to using starch.

Sodium alginate is used in some liquid medicines to increase viscosity and improve the suspension of solids. Propylene glycol alginate can improve the stability of emulsions. Capsules containing sodium alginate and calcium carbonate are used to protect inflamed areas near the entrance to the stomach. The acidity of the stomach causes formation of insoluble alginic acid and carbon dioxide; the alginic acid rises to the top of the stomach contents and forms a protective layer.

Very useful dental impression compounds are based on alginate cold-setting gels; some recent examples can be found in Pellico (1983) and Scheuble and Munsch (1983). Alginates are the basis of many slimming or diet foods, particularly biscuits; alginic acid swells in the stomach and fills it so that the dieter no longer feels hungry; the body cannot assimilate the alginic acid so no calories are absorbed.

These uses have been discussed in earlier reviews such as McNeely and Pettitt (1973).

OTHER USES

MEDICAL DRESSINGS

Courtaulds (UK) has patented a wound dressing which combines aspects of alginate filament formation with those of spunbonding to produce a good quality staple fibre (Aldred and Mosely, 1983). This fibre can be easily processed into nonwoven fabrics. The sodium calcium alginate fibres are useful as haemostatic wound dressings which can be absorbed by body fluids, as the calcium in the fibre is exchanged for sodium from the body fluids (Burrow and Welch, 1983).

A new "biopaper" has been made by the Japan Institute of Industrial Research (1985). The papers, made from alginic acid or a mixture of the acid and its calcium salt, are expected to be of value for bandages and similar medical uses where the haemostatic properties of alginates are useful. Bioactive papers have been made from staple fibres in which enzymes have been entrapped (Kobayashi, 1986; Kobayashi and Matsuo, 1986; Kobayashi, Matsuo and Kawakatsu, 1986).

CONTROLLED RELEASE OF CHEMICALS

This use has some similarities to the methods used for immobilization of cells. In this application the cells in the alginate gel beads are replaced by materials having biological activity, such as biological and chemical herbicides. The rate of release of the herbicides into soil or water can be controlled by the properties of the gel beads; the beads can be air dried and become hard granules. By incorporating air into the beads they can be made to float. The patent suggests their use for herbicides, pesticides, algicides and most biologically active substances (Connick, 1983; Connick, Lee and Rawson, 1984).

An alginate-clay mixture and calcium ions have been used to encapsulate microorganisms (chiefly fungi) which have potential to control plant diseases (Fravel et al., 1985). A sustained release system for pharmaceuticals, using calcium alginate beads, has been reported by Badwan et al. (1985).

BINDERS FOR FISH FEEDS

The worldwide growth in aquaculture has led Protan (1978) to investigate the use of alginate as a binder in fish feeds, especially moist feed made from fresh waste fish mixed with various dry components. Alginate binding can lower consumption by up to 40% and pollution of culture ponds is sharply reduced. More recent technical information is available from the authors.

CONFECTIONERY

Alginate gels find a small application in confectionery. Recently the incorporation of fruit pulp has been suggested and a method for making Turkish delight is described (Anon., 1983a).

RELEASE AGENTS

The poor adhesion of films of alginate to many surfaces, together with their insolubility in non-aqueous solvents, have led to their use as mould release agents, originally for plaster moulds and later in the forming of fibreglass plastics. Sodium alginate also makes a good coating for anti-tack paper which is used as a release agent in the manufacture of synthetic resin decorative boards (Cheetham, 1976; Sumitomo Bakelite, 1981). Films of calcium alginate, formed in situ on a paper, have been used to separate decorative laminates after they have been formed in a hot-pressing system (Jaisle and Bunkowski, 1981; Jaisle and Schiermeier, 1981).

MARKETING

There are difficulties and costs in the marketing of seaweed colloids, such as alginate, agar and carrageenan, which are not always apparent to those outside the industry. In some markets one colloid may compete with another, in others one might be the only real choice. They must all compete, in at least some of their uses, with plant gums (such as guar and locust bean) and cellulose derivatives (such as CMC and methyl cellulose) which are often cheaper. It is important to realize that price may not be the determining factor in a buyer's choice of a seaweed colloid; quality and its reproducibility from one batch to another may be more important. Frequently a buyer uses less than 1% of the colloid in his product so a 20% price difference may be inconsequential in the total cost of his product. Many a buyer of seaweed colloids, satisfied with one particular brand or grade, will, despite a higher price, stay with it because the risks of changing may not seem to be worth the saving. So in seaweed colloids, those brands already established in the market often hold a very strong, entrenched position. To dislodge them, a marketing group should include a strong technical team which can run tests and trials to convince the buyer of the equivalence of the new product; sometimes this requires a detailed knowledge of the buyer's industry. In promoting new sales, the colloid producer may have to provide complete formulations and technical know-how to potential buyers. Therefore selling costs of the seaweed colloids can be high and account must be taken of this by the potential producer.

The buyers of alginates fall into two groups. The first is a number of large buyers who know exactly what they want and who require little servicing because they have their own resources. This group includes those specialty gum companies who service smaller users by preparing their own blends of seaweed colloids and other colloids, according to the requirements of a particular customer.

The second and larger group are the smaller users who need some technical service support. Frequently this group yields more profitable sales in the long term because they may be sold specifically formulated products at a premium price and they are generally more reluctant to change to a competitor's product. On the other hand it takes more time and expense to establish such sales. Many of the major producers have such specialty products, shown by the large range of products listed by them.

Alginate manufacturers usually sell direct to the major markets but in minor markets it is more economical to sell through an agent, leaving the task of market penetration to him but providing technical support where necessary. Agents need to have an appreciation of the application of colloids and a knowledge of the client's industry. This ideal might be achieved by an agent selling a variety of chemicals to just one industry, like the food industry, but an agent who deals principally in colloids over a range of industries, which is a not uncommon situation, usually needs more backup from the producer. Large wholesalers/agents may buy from the producer and resell; otherwise they operate on a commission of 5-15%, depending partly on the degree of assistance required from the producer.

The world market for alginates is estimated at 20 000-24 000 tonnes per year (Kjemi, February 1986; Inf.Chim., (265), October 1985) which is similar to estimates made in 1980 (ITC, 1981). Demand for sodium alginate is steady with plentiful supplies.

Three principal grades are available but there are variations of viscosity, and many specially formulated mixtures with additives, within each grade. The highest grades meet the requirements of the National Formulary (USA), food grades generally meet the quality standards of the Food Chemicals Codex (USA) and technical grades vary considerably in their colour and water-insoluble solids (such as cellulose). Other countries or groups (EEC) have similar specifications to the NF and FCC.

Prices have shown little change between 1986 and 1987 and lie in the following ranges: Sodium alginate: pharmaceutical (NF) grade, US$ 6-7 per pound; food (FCC) grade, US$ 3-5 per pound; technical grade, US$ 2.50-3.50 per pound. Propylene glycol alginate, US$ 6-7 per pound (Chemical Marketing Reporter, 27 January 1986, 11 August 1986, 23 February 1987).

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