Food Chemistry **16** (1985) 259–269

The New Intense Sweetener Acesulfame K

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(Received: 12 November, 1984)

ABSTRACT

The use of Acesulfame K is permitted under the 'Sweeteners in Food Regulations 1983'. International acceptance of Acesulfame K was manifested by a favourable assessment and the allocation of an ADI by the WHO/FAO.

Acesulfame K is approximately 200 times sweeter than sucrose in diluted solutions. Its taste is generally considered to be good. Under most processing and storage conditions used for foods and beverages it seems to be virtually stable. No adverse reactions or unacceptable losses in sweetness have been observed. The high solubility is advantageous in preparing products with higher water content.

Acesulfame K appears to be suitable for all the usual fields of application of high-intensity sweeteners. Soft drinks of different types have been prepared and given favourable ratings. Tablets, granules, table-top powders and solutions of Acesulfame K have been prepared for household purposes. There are no problems in using Acesulfame K in combination with sorbitol, polydextrose or similar bulking compounds. Mixtures of Acesulfame K and bulking ingredients are suitable for many types of foodstuffs like jams and marmalades, desserts, baked goods and chewing gum.

INTRODUCTION

The use of Acesulfame K is permitted under the 'Sweeteners in Food Regulations 1983' (Anon., 1983*a*) in the United Kingdom. It can also be

Food Chemistry 0308-8146/85/$03·30

used in the Republic of Ireland. A first approval for table-top preparations containing Acesulfame K has been granted in Germany (Anon., 1984*a*). The Belgian authorities announced a new regulation including the approval of Acesulfame K for soft drinks (Anon., 1984*b*). Other countries are likely to follow soon. International acceptance of Acesulfame K was manifested by a favourable assessment and the allocation of an ADI of 0–9 mg kg^{-1} body weight by the Joint Expert Committee on Food Additives of the WHO and FAO (Anon. 1983*b*).

SENSORY PROPERTIES

Acesulfame K is about 200 times sweeter than sucrose in a three per cent solution. On a similar basis, the respective values for sodium saccharin are 450 times, for aspartame 200 times, and for sodium cyclamate 40 times. With increasing concentration the relative sweetness intensity of virtually all high intensity sweeteners decreases, while at the threshold level much higher intensities are generally found. An indication of the sweetness levels at different concentrations can be obtained from the sweetness intensity curve determined in still mineral water at a pH slightly above 7 (Fig. 1).

As a rule, using single sweeteners, 2–2·5 times more Acesulfame K than sodium saccharin, and 4–5 times more sodium cyclamate than

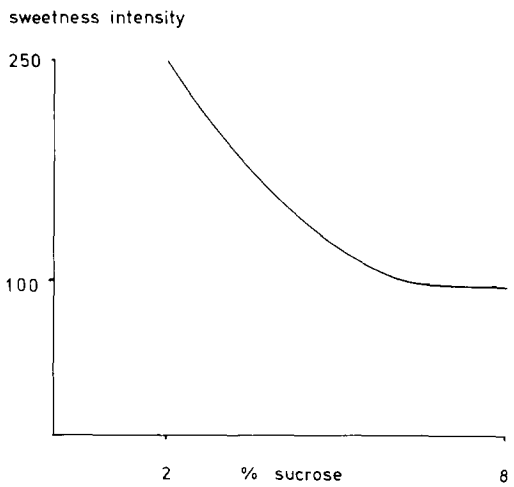

Fig. 1. Sweetness intensity of Acesulfame K compared to sucrose in aqueous solution.

Acesulfame K, is needed to achieve the same sweetness. This relation is probably valid for room temperature only, since at elevated temperatures reduced sweetness has been reported for sodium saccharin and sodium cyclamate as single sweeteners compared to Acesulfame K (Hoppe & Gassmann, 1980). Since the taste of sucrose is slightly masked by acids, in acid media the sweetness intensities of Acesulfame K seem to be higher than in neutral preparations and in water.

The taste characteristics of sweeteners are of greater importance for practical uses than sweetness intensities. Onset of Acesulfame K sweetness is fast, without unpleasant delay. It decreases slowly, without lingering unacceptably. The sweet taste may persist slightly longer than the sweet taste of sucrose.

The taste of Acesulfame K is generally considered to be superior to that of sodium saccharin. Up to medium concentrations and sweetness intensities, an aftertaste does not seem to be important, but it may be detected at elevated concentrations by some persons.

In mixtures of different sweeteners the time–intensity profiles are additive. Sometimes the taste of a mixture can come close to the taste of sucrose or even be more pleasant than the pure sucrose taste. The best combination of the different taste profiles often seems to be a 1:1 mixture on a sweetness basis, i.e. the mixtures contain sweeteners in the reciprocal ratio of the sweetness intensities. For mixtures with nutritive sweeteners this may be Acesulfame K and sorbitol in a ratio of roughly 1:150–200, Acesulfame K and sucrose in a ratio of roughly 1:100–150, Acesulfame K and maltitol in a ratio of approximately 1:150, and Acesulfame K and isomalt in a ratio of approximately 1:250–300. Of course, other ratios are possible, if a special weight–sweetness ratio has to be achieved.

In mixtures of Acesulfame K and other non-nutritive sweeteners, strong synergistic effects can sometimes be detected. In our sensory studies, synergistic effects were found in mixtures of Acesulfame K and aspartame, Acesulfame K and sodium cyclamate, but less pronounced, if any, in mixtures with saccharin. Again, the reciprocal ratio of the sweetness intensities seems to be the best combination.

PHYSICAL PROPERTIES

Acesulfame K is a white, crystalline material. The stability in the solid state appears to be virtually unlimited. Samples have been kept in our

laboratory for approximately ten years without detectable signs of decomposition. After 8–10 years' shelf life, they were comparable to freshly produced material in appearance and analytical data. There was no difference between samples kept in the light and in the dark. Under normal storage conditions, no problems are anticipated in keeping Acesulfame K for a reasonable period of time.

Acesulfame K does not have a definite melting point. Instead of melting, Acesulfame K starts to decompose at about 225 °C under the conditions of melting point determination. A higher decomposition point might be observed with a fast temperature rise, and prolonged exposure to slightly lower temperatures might also result in decomposition. The ability of Acesulfame K to withstand higher temperatures, therefore, seems to be sufficient for all heating processes commonly used in food processing (Table 1).

Acesulfame K is readily soluble in water. Solubility rises sharply with increased temperature. At 20 °C, approximately 270 g dissolve in 1 litre water, at 100 °C far more than 1000 g. Stock solutions of higher concentration can therefore be produced even at room temperature. In most organic solvents, e.g. alcohols, the solubility is low. In anhydrous ethanol only about 1 g litre^{-1} can be dissolved (Fig. 2). However, with increased water content, the solubility increases. Hence no solubility problems exist in alcohol–water mixtures used for cosmetic preparations (Clauss, Lück & von Rymon Lipinski, 1976).

So far, in food applications of Acesulfame K, no precipitation or turbidity has been reported either by interested companies and institutes or from our laboratory studies. No other indication of undesired reactions of Acesulfame K with food ingredients has been found. In model investigations with selected food ingredients, no reactions have been detected.

TABLE 1
Solubilities of Acesulfame K at 20 °C (Clauss, Lück & von Rymon Lipinski, 1976)

Solvent	*g per 100 ml solvent*
Water	27
Ethanol	0·1
Glacial acetic acid	13
DMSO	> 30

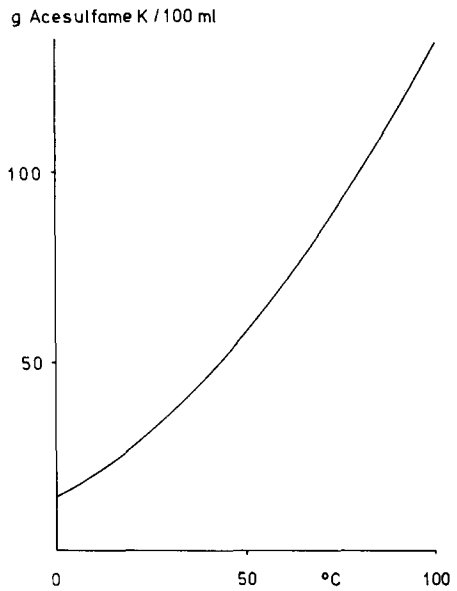

Fig. 2. Solubility of Acesulfame K.

APPLICATIONS (Table 2)

Acesulfame K can be used as the single sweetener in foods and beverages as long as no bulking or humectant properties are required, since these cannot be supplied by the minute quantities needed for appropriate sweetness.

Soft drinks is a potentially large field of application for Acesulfame K. For soft drinks, Acesulfame K can be used as dry material which dissolves

TABLE 2
Potential Applications of Acesulfame K

Bakery products
Chewing gum
Confections
Desserts
Drugs
Dry beverages
Jams and marmalades
Oral hygiene products
Soft drinks
Table-top sweeteners

quickly in the stirred liquid. Preparation of stock solutions is also possible, if dosage in liquid form is preferred. Many different flavours of soft drinks have been prepared. Examples are cola, tonic, orange, lemon, grapefruit, blackcurrant and apple. With most flavours, Acesulfame K could be used as the single sweetener up to moderate sweetness without any taste problems, although differences in compatibility with different flavours used for soft drinks might exist.

The commonly used nutritive sweeteners, sucrose, glucose, fructose or glucose/fructose syrups, impart more body to the drink than minute quantities of non-nutritive sweeteners. Therefore, several mixtures of Acesulfame K and nutritive sweeteners have also been tested. Sweetness levels corresponding to 10 % sucrose and higher can be very acceptable in those mixtures.

Due to good solubility and ability to withstand pasteurisation, Acesulfame K can be added to concentrates and syrups for beverages. Dry beverage mixes are similar to soft drinks with respect to the combination of Acesulfame K and flavours. Its good solubility is advantageous in dissolving the dry mix; the addition as a powder to the dried flavourings is possible, and even spray-drying together with the other ingredients.

Bulking ingredients are needed, in addition to sweeteners, for several types of foodstuffs, unless nutritive sweeteners impart sweetness as well as bulk. Sugar-free jams and marmalades, bakery products, sugar-free sweets and chewing gum are examples of such products.

Sugar-free jams and marmalades are suitable for diabetics, if mixtures of Acesulfame K and sorbitol are used. Sorbitol supplies the required bulk and the basic sweetness and Acesulfame K is used to adjust the sweetness to the normally desired higher level and to round the flavour. The taste of these mixtures is pleasant and full. Alternatively, isomalt and maltitol can be used to supply the required bulk. For calorie-reduced products not intended for diabetics, a reduced sucrose content in combination with Acesulfame K is possible. A distinct reduction in calories may be achieved if bulking ingredients are used in lower concentrations than sucrose in normal recipes. Although there is an increased risk of microbial spoilage, it can be prevented easily by using, for example, potassium sorbate.

Sugar-free sweets and chewing gum also need bulking ingredients. These products need fillers or extenders for supplying basic sweetness and diluting the high-intensity sweeteners to appropriate levels. The flat taste

of the commonly used sugar alcohols can be rounded with Acesulfame K which, in addition, contributes to the initial build-up of flavours. Suitable bulking ingredients for Acesulfame K-containing products are sorbitol, xylitol, maltitol, isomalt and polydextrose.

Various sweets have been produced without using any sucrose or glucose. The appropriate means of application is to use dry Acesulfame K or, if water will not cause a problem in the production, a concentrated stock solution.

Baked goods also need suitable fillers. The same bulking ingredients as for sweets can be used. Cakes and biscuits often require a special texture to supply the mouthfeel normally associated with these products. Combinations of, for example, Acesulfame K and sorbitol bring about a good approximation to the texture imparted by sucrose and an acceptable flavour for people accustomed to the consumption of sucrose-containing products.

Acesulfame K has been marketed successfully in table-top preparations, especially in tablets and table-top powders. Effervescent tablets, granules, and solutions can be produced without difficulty and kept on the shelf at room temperature for months or even years. The good solubility of Acesulfame K aids quick dissolution in hot drinks.

Outside the food sector, some applications are found in oral cosmetics, for example toothpastes, mouthwashes and similar products. Some of the commonly used ingredients can impart a bitter taste, if suitable flavours and sweeteners are not used. The sweetness of Acesulfame K is perceived quickly, and it therefore is particularly suited for use in oral hygiene products. The unpleasant taste of some ingredients can be masked by using relatively small amounts of Acesulfame K. The compatibility with most flavours used in oral hygiene products is good. Solubility in alcohol–water mixtures is high enough to reach the sweetness levels desired for mouthwashes (von Rymon Lipinski & Lück, 1981).

Bitter tasting ingredients often make the ingestion of pharmaceuticals unpleasant. The fast onset of the sweetness of Acesulfame K is an advantage in masking the bitter taste, especially when drugs have to be produced for diabetics.

STABILITY

Pure solid Acesulfame K seems to be stable at room temperature for several years. Most foodstuffs, however, are aqueous, and stability

against hydrolytic decomposition is much more important for sweeteners than stability in the solid state. Demands on non-nutritive sweeteners for long-term stability are high because the pH value of foods may vary between less than pH 3, in acidic soft drinks, and about pH 7 in a few other products.

Stability tests on Acesulfame K were carried out on Acesulfame K in buffered aqueous solutions and in soft drinks prepared according to commercial recipes. At pH values of 3 and higher, no apparent shelf life problems exist. We did not find any detectable decrease in the concentration of Acesulfame K after storage at about 20 °C in winter and about 25 °C in summer, even after several months' storage. There is no real risk of decreasing sweetness in beverages of pH 3 and higher at room temperature, as the analytical deviation in the determination of Acesulfame K is about 2 % and differences in sweetness can only be tasted after much higher losses of Acesulfame K.

Although, according to our shelf life tests, the stability of Acesulfame K decreases below pH 3, at pH 2·5 decomposition of Acesulfame K should be limited to a few per cent in the course of half a year. Therefore, even at this low pH value, the risk of detectable changes in sweetness is unimportant compared to potential flavour changes, due to the limited stability of some flavourings.

Hydrolytic decomposition is generally faster at elevated temperatures. Again, at pH 3 there is only a limited risk of decomposition for Acesulfame K. Some loss may be noted after prolonged storage at 40 °C. Changes in sweetness, however, were only noticed after storage at this elevated temperature for some months. At pH 2·5 decomposition seems to be faster than at pH 3. Even at this pH the stability of Acesulfame K can still be regarded as acceptable. Food storage temperatures do not normally reach 40 °C and, even if they do, this high level is usually maintained for short periods only. No real stability problems should therefore be encountered in practice with Acesulfame K (Clauss, Lück & von Rymon Lipinski, 1976).

No decomposition of Acesulfame K was noted in laboratory trials simulating pasteurisation. Our studies were made at the low temperature of 72–74 °C for a few minutes as well as for high temperature pasteurisation at about 90 °C for several seconds.

We did not detect any decomposition of Acesulfame K in baking trials, including baking biscuits at oven temperatures of more than 220 °C. Although the oven temperatures may be close to the decomposition limit

of Acesulfame K, the temperature in the baked product is normally far below the oven temperature. In any case, decomposition of sucrose starts at lower temperatures than the decomposition of Acesulfame K.

PHYSIOLOGY AND TOXICOLOGY

Safety is a prerequisite for practical use and approval of food additives. The extensive safety studies on Acesulfame K (Fig. 3) were subject to rigid examination by international agencies as well as the authorities of several countries. It may be concluded that independent examination did not reveal any safety problems. A favourable assessment was given in the *Report on Sweeteners in Food* by the Food Additives and Contaminants Committee (Anon., 1982). The British authorities, meanwhile, have granted approvals for the application of Acesulfame K in foods, beverages and table-top preparations. The German authorities approved the use in table-top sweeteners. Other countries have announced the completion of their reviews of the safety data and are now moving into legislation. A summary of the safety studies on Acesulfame K was published by the World Health Organization (Anon., 1981) and details need not be given here.

An important reason for consuming high-intensity sweeteners is calorie control. As sugars like sucrose, glucose and fructose are metabolised by the human body, they make a considerable contribution to the calorific value of the normal diet. Nutritive sweeteners like sorbitol and xylitol are also metabolised. Their calorific values are equivalent to those of sugars. Acesulfame K is not metabolised at all and it, therefore, has no calorific value. It is absorbed quickly from the intestine and detectable levels in blood and serum rise quickly. Excretion is similarly fast. No accumulation seems possible, even after repeated ingestion. Pharmacokinetic investigations in several animal species and humans showed fast and complete excretion of Acesulfame K.

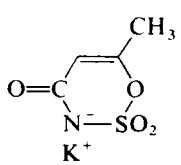

Fig. 3. Acesulfame K.

Several animal species and human volunteers were included in metabolic studies using ^{14}C-labelled Acesulfame K. Urine and faeces were tested for active compounds. No activity attributable to metabolites was detected, and all ^{14}C ingested was completely recovered as Acesulfame K.

As bacteria of the human intestine are known to metabolise cyclamates, the effect of Acesulfame K on bacteria was also studied. Acesulfame K seems to be inert according to present knowledge. Neither antibacterial effects nor promotion of bacterial growth were observed. After prolonged exposure of Acesulfame K to different strains of bacteria, no induced metabolic degradation was observed. No induced metabolism was detected in rats after long exposure to Acesulfame K and then feeding them with a single dose of ^{14}C-marked Acesulfame K.

Acesulfame K did not show any pharmacological activity except for effects caused by potassium. It is suitable for diabetics. No adverse reactions attributable to Acesulfame K have been reported so far.

CONCLUSION

Taste characteristics and technological properties of Acesulfame K meet the requirements of most beverages and foods. Acesulfame K is gaining increasingly greater acceptance, as demonstrated by approvals in some countries. Limited quantities have been available for preparation of several products which have been on the British market for some months. The supply situation will improve in the future, when more products containing Acesulfame K will probably be on the market.

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