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Astringency, a textural defect in dairy products

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Summary — Like bitterness, astringency is a defect liable to affect dairy products, but it has not been studied as extensively. This review article attempts first to clarify the confusing use in the literature of the term 'astringent' to describe some associated textural defects of dairy products and to better define astringency. Although astringency in dairy products might originate from two known causes: compounds resulting from heat treatment and proteolytically induced peptides (probably C-terminal breakdown products of β -casein), the presence of phenolic compounds could also be a plausible cause. Astringent compounds reported to be present in many dairy products are listed, as well as some methods of extraction and isolation.

astringency / dairy products / peptide

Résumé — L'astringence, un défaut de texture dans les produits laitiers. Parmi les défauts susceptibles d'être rencontrés dans les produits laitiers, l'amertume est celui qui a été le plus étudié. Toutefois, l'astringence mérite également que l'on y prête attention. Aussi, cet article tente, en premier lieu, d'éclairer la confusion qui existe sur l'utilisation du mot astringent dans la description de certains défauts de texture rencontrés dans les produits laitiers. Bien que l'astringence des produits laitiers soit attribuable principalement à des composés résultant de l'effet des traitements thermiques et de la protéolyse, notamment peptides dérivés de la caséine β , des composés phénoliques pourraient également être impliqués dans ce défaut. Cette revue de synthèse traite des différents produits lactés dans lesquels l'astringence est rencontrée, ainsi que des méthodes d'extraction et d'isolation de ces composés astringents.

astringence / produit laitier / peptide

INTRODUCTION

In a previous report (Lemieux and Simard, 1991) on defects in dairy products, the factors likely to influence the development of bitterness, mainly in cheeses, were reviewed. Bitter peptides originating from caseins — their formation, isolation and identification, structure, masking and inhibition — were reviewed in an exhaustive second report (Lemieux and Simard, 1992). Although the exact role of different proteolytic enzyme systems in the development of bitterness is not fully understood, α_{s1} -casein has been recognized as always inducing more bitterness than β -casein. So, when extracting peptides, more bitter peptides originated from β -casein than from α_{s1} -casein are detected. However, the resistance of β -casein toward the enzymes involved in the cheese ripening process is higher than that of α_{s1} -casein. So, when extracting peptides, more bitter peptides originated from β -casein than from α_{s1} -casein are detected. This particularity could explain the tendency to associate β -casein with bitterness.

As stated previously (Lemieux and Simard, 1992), there are five primary tastes: sweet, sour, salty, bitter and umami (which means 'agreeable'). Not only the primary but also the secondary tastes, such as astringency, metallicity, and hotness, contribute to the characteristic taste of foods. Mouthfeel properties that are commonly defined in

terms of body texture or consistency are detected by the sense of touch or feel rather than taste. Combined with flavour, they are essential components of organoleptic quality and so influence consumer acceptability. Viscosity, texture and astringency are the principal criteria related to tactile properties. However, there is confusion in the literature around the term 'astringency'. Whereas bitterness is perceived primarily on the back of the tongue, astringency is detectable throughout the oral cavity (Rouseff, 1990). Although astringency has not been studied as extensively as bitterness, it is typically encountered in reconstituted powdered milk and sterilized milk products.

Detectability, intensity, quality and reactions are the four classes of sensory techniques applied to foods and beverages. The last two of these are respectively presented in figure 1 by several specific sensory attributes and preferences (Land, 1983). Moreover, the quality of food consists of safety, nutritional value and acceptability, all of which are interrelated.

The need to develop a rational system and nomenclature for describing and translating textural qualities into precisely defined measurable properties was noted many years ago by Szczesniak (1963). She has pointed out several inherent problems with the nomenclature used to describe textural characteristics in terms of simple words. Thus, a number of terms may be used to

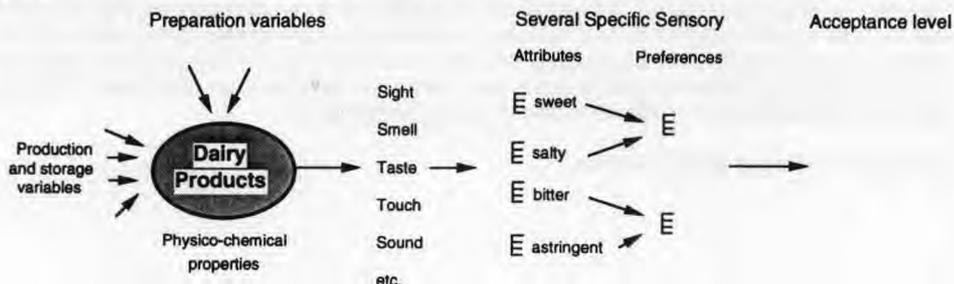


Fig 1. Dairy products. Influence of different variables on their sensory quality.
Produits laitiers. Influence de différentes variables sur leur évaluation sensorielle.

describe the same characteristic or the same term may be used to describe several characteristics. Moreover, the same term may have different meanings for different people. In order to supply the food scientists with a rational tool for a scientific description of food texture, Szczesniak (1963) proposed a classification of textural characteristics. Accordingly, astringency is a mouthfeel sensation, a textural characteristic that cannot be easily resolved on the basis of mechanical (pressure exerted on the teeth, tongue, and palate during eating) and geometrical (appearance of the food product) properties. The same descriptive terms are used to describe different flavours.

With good panel training, and by setting the descriptive terminology of the test form and the scoring scale to detect the finest possible differences, one should improve the sensitivity of the flavour test for food products and beverages (Clapperton and Harwood, 1983). However, dairy quality judging methods differ from the descriptive analysis techniques used for sensory evaluation of many other food products. In fact, descriptive terms in dairy quality judging often refer to root causes of defects rather than simple sensory experiences. Many defect oriented terms are complex concepts, since a single root cause may result in the development of multiple, distinct flavour attributes (Claassen and Lawless, 1992). For example, the general astringency term may include sensory experiences described as metallic, chalky, green flavour, rancid and oxidized (Thurston *et al*, 1935; St-Laurent, 1989).

Besides reporting about the term 'astringency' used to describe different defects in dairy products, this review will cover the work done in this field and also show its importance. There are at least two well documented different sources of astringency, heat treatments (Forss, 1969; Harper and Hall, 1976) and proteolytically induced peptides (Harwalkar *et al*, 1989). A third source,

the presence of phenolic compounds, is also proposed.

COMPLEXITY OF ASTRINGENCY DEFINITION

The taste mechanism, with its three distinct parts, gustatory (tongue), tactile (touch), and olfactory (smell), depends primarily upon chemical stimulation in establishing the composite sensory response termed flavour. The tongue, with receptors located primarily on its sides and base, serves as the major organ of taste. Papillae of various types can be noted chiefly at the tip, along the sides, and at the base of the tongue. The taste buds, with which the sapid substance (in liquid form) must make contact before a taste sensation occurs, are located in many of these papillae (Bodyfelt *et al*, 1988; Hughes, 1992). Astringency, a sensation associated with trigeminal ganglion systems, cannot be easily defined, and is considered a tactile flavour defect described as a dry, puckery sensation in the mouth (Joslyn and Goldstein, 1964; Harwalkar, 1972a; Singleton and Noble, 1976). Astringency has been suggested by Bate-Smith (1954) to be a sensation of touch or pressure instead of taste. This sensation has also been characterized by the terms chalky, rough, dry, mouth coating or powdery because it suggests finely divided insoluble particles (Boudreau, 1980; Bassette *et al*, 1986). Many workers have tried to understand the mechanism by which astringent compounds impart a sensation in the oral cavity. Schiffman *et al* (1992b) showed that in rodents, the signals for astringent compounds are transduced by the chorda tympani nerve (a taste nerve) rather than by the trigeminal nerve. They later (Schiffman *et al*, 1992a) found regional differences in sensitivity to astringent compounds in the oral cavity of humans. Indeed, the glossopharyngeal nerve may be more sensitive to astringent stimuli than the nerves inner-

vating the anterior tongue. According to Fischer *et al* (1992), the salivary flow rate would affect the temporal perception of astringency. Subjects having a low saliva flow-rate have thus been found to take a longer time to reach maximum intensity for astringency, and have a longer duration of this taste. These subjects are also able to rate the maximal astringency intensity of wine higher than subjects having a high saliva flow-rate.

A carry-over effect is encountered in the sensory assessment of intensely astringent samples, and it appears to increase the perceived astringency of the next sample. In order to overcome this problem, a reversed-order paired comparison tasting procedure has been devised (Arnold, 1983). The panel was divided into two groups and they tasted their pair of samples in reversed order. To compare a set of 'm' samples, it was thus necessary to have $[m(m-1)/2]$ sessions to give a complete replication of all possible pairs, as within a session the same pair of samples was assessed by all testers, half in each order (Guinard *et al*, 1986). This procedure enabled any carry-over effect to be evaluated and eliminated, thus giving more precise estimates of parameters for comparison.

One physical effect of the presence of astringent substances is the destruction of the natural lubricant property of the saliva *via* precipitation of proteins and mucopolysaccharides in the mucous secretions of the salivary glands. The mucous membranes of the palate and/or tongue tend to shrink (pucker). Since its perception in the mouth is not instantaneous, astringency is thus considered as a delayed effect. Different groups of true astringents have been listed by Kudale (1970): 1) salts of multivalent metallic cations (aluminum, chromium, zinc, lead, calcium, magnesium, etc); 2) vegetable tannins (*eg* gallotannic acid); 3) dehydrating agents (*eg* ethyl alcohol, acetone, glycerine); and 4) mineral acids.

Thus reference solutions of aluminum potassium sulphate (alum, 1.5 mmol/l), and 0.08% w/v and 0.11% w/w alum in water were respectively used to characterize astringency in acid or cottage cheese whey, infant formulas (Mc Gugan *et al*, 1979; Malcolmson and McDaniel, 1980), and plain yogurt (Harper *et al*, 1991). A reference standard solution of alum was also used for the detection of astringency (900 ml spring water + 1.2 g alum) in flavoured milk beverages (Lederer *et al*, 1991).

Since astringency is only detected when and if the sample is placed in the mouth, it is traditionally listed as a flavour defect. Flavour may be a sensory perception, a combination of taste and aroma, which are perceived respectively by the papillae on the tongue and olfactory epithelium in the nose (Schultz *et al*, 1967; Joglekar and Gupta, 1981). Flavour is also defined as being the net effect of several physiological reactions involving various combinations of taste, odour, mouthfeel, pain, sensibility to temperature, and kinesthetic sensations attributed to the muscular effort of chewing (Gardner, 1966). Moreover, the term 'flavour' also includes the astringent sensory property (Tobias, 1990).

More recently, Watson (1992) suggested that flavour is the additive effect of taste and smell while texture is a measurement of the physical characteristics; it usually involves the senses of sight, touch and sound. Table I shows the sense of gustation and its associated sensations (Watson, 1992).

SENSORY DEFECTS INCLUDED UNDER ASTRINGENCY

Shipe *et al* (1978) listed defects associated with astringency in miscellaneous along with chalkiness, while metallic off-flavour was associated with an oxidized defect although it is frequently differentiated from this defect. The metallic defect is characterized by an

Table 1. The sense of gustation and its associated sensations.
Le goût et ses perceptions associées.

| <i>Receptor</i> | <i>Stimulus</i> | <i>Sensation</i> |
|-----------------|----------------------------|---|
| Tongue/mouth | Water soluble Chemicals | - taste (sweet, salt, acid, bitter and metallic) - feeling (astringency) |

astringent, rough, puckery mouthfeel, and a metallic sensation similar to that observed when an iron nail or metal foil is placed in the mouth, and is due to lactates resulting from the solubilization of various metals (iron, copper and copper alloys) in lactic acid solutions. It is also generally associated with the early stages of metal-induced oxidation (Hunziker *et al*, 1929; Whitfield *et al*, 1936). Unhomogenized or cream-line milk is substantially more susceptible to the development of the metallic off-flavour than homogenized milk for reasons that are not clearly understood. However, since stainless steel has replaced monel (white metal) in milk handling and processing equipment, the metallic defect has substantially decreased as a problem. However, the presence of rust or copper in equipment or water supplies has to be avoided.

The metallic off-flavour is quite frequently encountered in dairy products such as buttermilk, sour cream, yogurt, cottage cheese and cream cheese, but may also be found in other dairy products, including butter, certain types of cheese and ice cream (Bodyfelt *et al*, 1988). The metallic off-flavour can be imitated by adding 1-octene-3-one to milk or cream (Shipe *et al*, 1978; Bassette *et al*, 1986).

Chalkiness is a textural (consistency) defect which is usually detected as numerous, extremely fine, undissolved particles within the masticated product. This tactile defect is described by Charalambous (1980) as being similar, if not identical, to astringency. A chalky defect is frequently encoun-

tered in skim milk samples. The composition of skim milk appears to favour occurrence of this defect (off-flavour); it probably stems from the ratio of proteins to milkfat found in skim milk (Bodyfelt *et al*, 1988). Mechanical and thermal treatments of milk cause the formation of aggregates containing protein, fat, and lactose as well as inorganic salts of varying composition. Depending on their size, specific weight and electric charge, these aggregates either sediment or clump together on the surface of UHT or in-bottle sterilized milk, imparting chalkiness or astringency (Blanc *et al*, 1981; Schröder, 1983). According to Burton (1988), increasing homogenization pressure would help to reduce the occurrence or the intensity of the chalky defect in UHT milk.

Calcium fortification of cottage cheese has caused chalkiness (Puspitasari *et al*, 1991). However, as the report in question did not define the chalky defect or report a sandy mouthfeel, it is difficult to know if astringency was involved.

Another off-flavour, the 'green flavour', due to the formation of relatively high concentrations of acetaldehyde by the culture used in the preparation of cultured milk products (buttermilk, sour cream, kefir, Bulgarian buttermilk) may suggest a somewhat 'astringent' character. This off-flavour can be attributed to the selection of the wrong microbial strain, incubation at incorrect temperatures, and/or overincubation (Bodyfelt *et al*, 1988).

An 'astringent', puckery feeling perceived at the base of the tongue and upper throat

may also describe the 'rancidity' noted in cottage cheese and other dairy products such as cream, milk and butter (Bodyfelt *et al*, 1988). This defect is due to the action of the enzyme lipase on milkfat and can be prevented, provided the raw milk and cream supplies were free of this defect, by proper pasteurization of all milk products used in making cottage cheese.

Various stages may be differentiated in the 'oxidized' off-flavour. A very slight intensity encountered in ice cream or ice milk makes the product flavour seem flat or missing whereas for a moderate intensity or upon a longer holding in the mouth, the sample may be described more accurately as 'astringent' metallic, or puckery. Upon incubation for 3 months at ambient room temperature, non-dairy and cow's milk powdered creamers developed an astringent off-flavour. This defect has been related to an oxidation phenomenon by Jolly and Kosikowski (1974). Heat processing of milk has an effect on its flavour; generally, the more extensive the heat treatment, the more substantial the flavour change (Joglekar and Gupta, 1981). However, the release or activation of sulphhydryl groups during high heat treatment of milk (> 77°C) provides a protection against oxidized flavour (Tobias, 1976; Joglekar and Gupta, 1981; Bassette *et al*, 1986; Morr and Ha, 1991). Market surveys done by Jensen and Poulsen (1992) have shown that one of the flavour defects developed by retail packed cream within the stated period of shelf-life is the oxidized flavour. Resulting from oxidation of the unsaturated fatty acids in milkfat, the oxidized flavour defect may be described by the terms cardboard and metallic. Copper-induced oxidations affect the lipid fraction of milk; in this case the phospholipids of the fat globule membrane are attacked, leading to a cardboard flavour. As skim milk is not free from phospholipids, a copper-induced oxidized flavour development is therefore possible (Schröder, 1983). A scoring guide for astringency and its flavour attributes in dairy products is suggested in table II.

MECHANISM OF THE ASTRINGENT SENSATION

More work is necessary before the mechanism of the astringent sensation can be defined and the significance of the sensation fully understood. Astringency comparison of two or more stimuli presented sequentially is difficult. Moreover, bitterness and astringency are 'twin sensations': oral astringency may indeed be closely linked to bitterness (Singleton and Noble, 1976; Clifford, 1986); untrained taste panellists may thus confuse astringency with bitterness (Lea and Arnold, 1978). In an attempt to determine if the tactile component (dryness) and associated taste (bitterness) component of astringency were perceptually separable, Lyman and Green (1990) found that the perception of mouth dryness increased with repeated exposure to an astringent stimulus, and that increased salivary volume reduced astringency. However, this last observation would not support the suggestion of Joslyn and Goldstein (1964), relating astringency to a reduction in, or inhibition of salivary flow. Scores for astringent and bitter off-flavour in milk are listed in table III (Shipe, 1980).

From their work on English ciders Lea and Arnold (1983) found that both bitterness and astringency were present and were due to phenolic procyanidins. While the sensation of bitterness was predominant in the oligomeric procyanidins (peaking with the tetramer), that of astringency came out top with the polymers.

THEORIES ABOUT ASTRINGENCY IN MILK AND MILK PRODUCTS

Flavour defects in milk may result from many causes. According to Shipe *et al* (1978),

Table II. A suggested scoring guide for flavour of milk, cream, cultured milk products (buttermilk, sour cream, creamed cottage cheese and cultured cream butter) and dry milks.

Guide numérique proposé pour l'évaluation des différents défauts de saveur rencontrés dans le lait, la crème, les produits laitiers de culture (lait de beurre, crème sure, fromage cottage, beurre de culture) et dans les laits séchés.

| Intensity of defect | Flavour defect ^a | | | | | | | | | | | |
|---------------------|-----------------------------|----------|--------|-----------------------|-------|----------|--------|--------|------------|--------|----------|--------|
| | Milk and cream | | | Cultured milk product | | | | | Dry milks | | | |
| | Astringent | Metallic | Rancid | Astringent | Green | Metallic | Chalky | Rancid | Astringent | Chalky | Metallic | Rancid |
| Slight | 8 | 5 | 4 | 7 | 8 | 6 | 8 | 4 | 8 | 8 | 4 | 5 |
| Definite | 7 | 3 | 1 | 5 | 7 | 4 | 5 | 2 | 6 | 6 | 2 | 3 |
| Pronounced | 6 | 1 | 0 | 3 | 6 | 2 | 2 | 0 | 0-4 | 0-4 | 0 | 0-1 |

^a A numerical score of '10' is assigned to a product free of undesirable flavours (no criticism) while an assigned score of zero (0) is indicative of an unsalable product.

Table III. Scoring of astringent and bitter off-flavour in milk.
Evaluation numérique des défauts d'astringence et d'amertume dans le lait.

| Off-flavour intensity ^a | Off-flavour | |
|------------------------------------|-------------|--------|
| | Astringent | Bitter |
| Slight | 8 | 5 |
| Definite | 7 | 3 |
| Pronounced | 5 | 1 |

^a A score of 10 is given to a sample that has a 'typical fresh' taste and is free of undesirable flavours. Samples with off-flavours are scored lower.

seven categories of flavour defects have been defined, and are listed in table IV. Astringency is allotted to miscellaneous, a category which includes the flavour defects that either cannot be attributed to a specific

cause or specifically defined in sensory terms.

During World War II, a reconstituted beverage prepared with whole milk powder was supplied to the US armed forces. However, this product was qualified as astringent and because of this defect, the reconstituted beverage was generally rejected (Patton and Josephson, 1952). This gave rise to research into the intricate chemical mechanisms involved in textural changes, particularly astringency, as this defect had been noted in raw and heated milk products (Josephson, 1954). A chalky sensation was also reported for homogenized milk shortly after its commercial introduction. However, this defect might have been caused by improper pasteurization-homogenization procedures (Shipe *et al*, 1978). It was thus imperative, in order to control and protect the characteristic properties of dairy foods, to know the good practices of milk transformation and maintain them in the factories.

Table IV. Categories of flavour defects in milk.
Classification des défauts de flavour du lait et identification de leur origine.

| Flavour alterations - descriptive or associative terms | Causes |
|---|---|
| Cooked or sulphurous, heated or rich, caramelized, scorched | Heat treatment |
| Oxidized (light-induced), burnt, activated, sunlight | Exposure to various forms of radiant energy |
| Rancid, goaty, soapy, butyric | Milk lipase catalysed hydrolysis of milk fat triglycerides |
| Acid, malty, fruity, unclean, bitter, putrid | Accumulation of the products of bacterial metabolism |
| Oxidized, cardboard, cappy, metallic, tallowy | Reaction between molecular oxygen and lipids (oxidation) |
| Feed, weed, cowy, barny | Transmission (passage of substances from the cow's feed or surroundings to milk while it is in the udder) |
| Absorbed, astringent, bitter, chalky, chemical, flat, foreign, lack freshness, salty. | Miscellaneous |

Heat, astringency and heat treatments

Milk is heat processed to eliminate pathogenic microorganisms which may be present in the raw milk and to increase the shelf-life. While heat processing can preserve the natural flavour by careful inactivation of the enzymes, treatments may also alter flavour in a more or less desirable manner during concentration and preservation stages.

Data reported by Hutton and Josephson (1951) suggested that development of astringency in heated whey was associated with heat denaturation and dehydration of the whey proteins. Milk salts were also presumed to be involved in the astringent defect. Raw skim milk and raw whey samples also developed 'roughness' when heated momentarily (10 min) at 95°C (Patton and Josephson, 1952). Following ultracentrifugation in a Sharples' super-centrifuge at 35 000 rpm, the heat coagulable substances from rennet whey were easily removed and found to be responsible for the astringency. However, as these substances were recovered with difficulty from heated skim milk, Patton and Josephson (1952) suggested that casein might exert a protective colloidal action toward the heat-coagulable whey proteins. Their observations have since been supported by Josephson *et al* (1967) with electron microscopy. Among the whey proteins, β -lactoglobulin was presumed to be a significant contributor to the astringent defect (Hutton and Josephson, 1951). As the astringency in dry milk was primarily attributed to the formation of insoluble calcium-protein aggregates as a result of heat treatment and drying, Josephson (1954) proposed to overcome this defect by sequestering of calcium ion activity and removal of calcium ions from the milk and/or low temperature processing of the dry milk. Tessier and Rose (1958) have also reported that heating skim milk (82°C, 30 min) caused precipitation of calcium phosphate and low-

ered [Ca^{2+}]; skim milk was also found to contain from 2.5 to 3.4 mmol Ca^{2+} /l.

Modler and Emmons (1978) have found a way to utilize acid whey obtained from cottage, bakers or cream cheese, which would otherwise be a serious disposal problem. Although neutralization of this product with an aqueous suspension of calcium oxide (CaO) 1 mol/l has helped in reducing the sticking problem on dryer box and cyclone while spray drying, the concentrated whey was chalky and astringent (Modler and Emmons, 1977). Removal of insoluble calcium salts improved flavour and yielded a final product with characteristics close to those of sweet whey.

The increments in astringency obtained by Josephson *et al* (1967) on lengthening the heat treatment of skim milk and rennet whey at 90°C from 10 to 30 min are shown in table V. Josephson *et al* (1967) also observed that, for a given heat treatment, a higher level of astringency was produced in rennet whey than in skim milk. Furthermore, the astringent components in whey exhibited considerably larger particle sizes, as evidenced by their sedimentation at a much lower force (3 000 g for 30 min) than that required for heated skim milk (144 000i for 2 h). In order to relate the size and struc-

Table V. Astringency intensity of heated skim milks.

Intensité de l'astringence chez des laits écrémés ayant subi différents traitements thermiques.

| <i>Sample description</i> | <i>Astringency intensity</i> |
|--|------------------------------|
| 1. Pasteurized skim milk (63°C-30 min) | No astringency |
| 2. Heated skim milk (90°C-10 min) | Slight astringency |
| 3. Heated skim milk (90°C-30 min) | Distinct astringency |

ture of aggregate particles to the level of astringency, Josephson *et al* (1967) conducted electron microscopic studies on heated whey systems: fractions free of astringency exhibited no distinct particulate components, while upon flash heating at 80°C, spherically shaped electron-dense particles within the 30–300 µm range were formed. These particles were similar in appearance to caseinate micelles in skim milk. As the degree of heat treatment was increased (80°C, up to 30 min), aggregates in whey systems appeared larger and more numerous, and the level of astringency was more pronounced. It appears that particle size and composition, rather than shape, accounted for astringency in heated whey systems (Bodyfelt *et al*, 1988).

While Josephson *et al* (1967) concluded that astringency in milk systems is primarily caused by heat-altered whey proteins and to some extent milk salts, both of which are associated by interaction with or adsorption on the caseinate micelles, Kratzer *et al* (1967) reported the presence of astringency in raw milk samples stored for 48 h at 4.4°C. As a matter of fact, astringency had the second highest mean occurrence in raw milk samples (table VI).

The studies of Kratzer *et al* (1967) allowed the identification of many important

Table VI. Frequency of some flavour types detected in raw milk.

Fréquence de détection de quelques types de saveur dans le lait cru.

| Flavour | Mean occurrence (%) ^a |
|------------|----------------------------------|
| Feed | 88.4 |
| Astringent | 12.7 |
| Cow | 11.0 |
| Oxidized | 6.1 |
| Flat | 4.1 |

^a The percentage sum is more than 100 because more than one flavour was detected in many samples.

sources of variation in milk flavour (environmental factors, stage of lactation and age of the cow at calving, genetic effects and panellists for the milk evaluation). Heat alone did not account for the occurrence of astringency in raw or pasteurized milks and dry milk powders. It was therefore imperative to isolate and characterize the astringent components in raw milk and milk products to know their source.

Astringency and casein breakdown products (proteolysis)

Harwalkar (1969) was the first to report on the isolation of astringent compounds from Cheddar cheese. The isolated astringent fraction had the characteristics of a complex of associated peptides with an unusually high content of hydrophobic amino acid residues (leucine, tyrosine, valine, phenylalanine, etc) and an isoelectric point at pH 6.5. Some other physical and chemical properties of the astringent fraction are listed in table VII. Absorption in the 200 to 300 nm range had a maximum in the region of 276 nm. The low mineral values obtained for this fraction led Harwalkar (1972a) to conclude that minerals were not involved in Cheddar cheese astringency. Strong astringency was detectable at acid or neutral pH but not at highly alkaline pH (>pH 10). This loss of astringency at pH 10.5 coincided with the ionization of the phenolic groups. The changes resulting in loss of astringency were found to be reversible, since astringency was restored by lowering the pH. The state of ionization of phenolic groups was thus found to be important for the astringent taste (Harwalkar, 1972a).

Methods for reducing heat-induced astringency in skim milk were tested by Kudale (1970). His results showed that although treatment with ultrasonic vibrations was effective in reducing this defect, an objectionable 'burnt protein' flavour was produced.

Table VII. Some physical and chemical properties of the astringent fraction.
Quelques propriétés physiques et chimiques de la fraction astringente.

| Property | Values |
|---|-------------------|
| Absorption spectra in the 200 to 300 nm range | 276 nm |
| Sedimentation velocity, $S_{20,w}$ | 1.25 |
| Estimated molecular mass ^a | 9 000 - 12 000 Da |
| Mineral content: calcium | 0.04% |
| magnesium | < 0.02% |
| phosphorus | ≈ 0.05% |
| Carbohydrate | Undetectable |

^a Obtained by gel filtration chromatography on Sephadex (Harwalkar and Elliott, 1971; Harwalkar, 1972 a) and by size exclusion HPLC (Lemieux *et al*, 1989).

Proteolytic enzymes (commercial bovine pancreatic enzyme preparations, crystalline trypsin and pancreatin), when used at proper concentrations, were found to be very effective in reducing heat-induced astringency of skim milk. These findings thus supported the hypothesis that astringency in heated skim milk can be reduced by dissociation of aggregates and/or complexes of milk constituents formed as a result of heat treatment.

As reported by Demott (1971), astringency may also be produced when milk is fortified with iron salts, especially ferrous salts (ferrous sulphate, ferrous gluconate, or ferrous lactate). Shipe *et al* (1972) have reported that incubation of glass bead immobilized trypsin (2.5 g in each of four paddle compartments) in bulk milk samples with copper added helped to reduce the oxidized flavour. Moreover, astringency was detected if the level of immobilized trypsin exceeded 2.5 g per chamber. An excess of enzyme would thus increase proteolysis and cause astringency.

Later on, while investigating the influence of pH on astringent compounds and their

extractability from cheese with a mixture of chloroform and methanol (C/M; 2/1, v/v), Harwalkar and Elliott (1971) and Harwalkar (1972a, b, c) found that only the fractions extracted from an acid Cheddar cheese or skim milk culture were astringent, while those from neutral or slightly alkaline samples were bland. The requirement for acid pH (pH 4 or 3) for the extraction of astringent components would thus indicate that they are involved in a salt-type linkage. Thus at neutral or alkaline pH, astringent components would be anionic and accordingly form salts with various cations, especially calcium, similar to the situation in milk proteins. Presumably, these salts are slightly soluble in the C/M solvent. Solubility of astringent peptides may possibly be influenced by the ionization state; these components seemed to be less tightly bound to the curd as the ionic strength was reduced, and washing the curd with pH-adjusted distilled water appeared to release astringent components from the curd. As the pH is lowered the bound calcium salt dissociates, giving rise to ionic calcium and peptides free from salt linkage. Furthermore, a low pH hinders ioni-

zation of free carboxyl groups, resulting in an increase in apparent hydrophobicity, and may thereby facilitate extraction of polypeptides by moderately polar (polarity $\phi = 5.0$) solvents such as chloroform-methanol mixtures ($\phi_{\text{CHCl}_3} = 4.3$; $\phi_{\text{MeOH}} = 6.6$; $\phi_{\text{CHCl}_3} : \text{MeOH}; 2:1 = 5.0$).

Amino acids found in the methanolic phase (astringent fraction) of the six dried fractions (untreated original milk: whole milk or 10% non-fat dry milk; acidified milk; whey; unwashed curd; washed curd and washings) extracted with the C/M solvent were predominantly hydrophobic residues (Harwalkar, 1972c); this is a typical characteristic of γ -casein. Moreover, polyacrylamide gel electrophoretic (PAGE) patterns for the extracts of unwashed curd, which were astringent, showed at least three faint bands in the region of whole γ -casein. It is therefore tempting to speculate that residual proteolytic activity or its reactivation is involved in the formation of astringent components in stored non-fat dry milk or pasteurized milk. This possibility seems plausible from the fact that β -caseins result from proteolytic breakdown of β -casein (Gordon *et al*, 1972; Gordon and Groves, 1975; Reimerdes, 1978). Since then, Harwalkar *et al* (1993) have confirmed this relationship between astringency in pasteurized skim milk treated with psychrotroph proteinase and plasmin and the production of breakdown products of β -casein. Indeed, they were able to show, using FPLC (fast protein liquid chromatography) and urea-PAGE (polyacrylamide gel electrophoresis) techniques, that astringent compounds from treatment of purified β -casein with plasmin were γ -casein components (fragments of β -casein consisting of residues 29-209 (γ_1 -), 106-209 (γ_2 -) and 108-209 (γ_3 -)). They have thus been able to link astringency with γ -caseins. Moreover, these product levels were higher in extracts from astringent samples.

According to taste-panel results for cheese grading, aseptically manufactured

Gouda cheeses have been found by Visser (1977b, c) to contain astringent compounds. However, they were completely lacking in cheese flavour (Visser, 1977a). This may explain why Visser (1977c) was cautious about the possible contribution, as suggested by Harwalkar and Elliott (1971), of astringency to cheese flavour.

Studies on heat-treated milk samples have been done by Jaddou *et al* (1978). They observed that astringent off-flavour in milks heat-treated for 3 s (UHT) decreasing with storage time (slight astringency after 7 d to no astringency after 84 d), while it increased linearly during storage of milks heat-treated for 90 s (sterilized) at 140°C (astringent after 1 month to very astringent after 112 d storage). These observations have allowed Jaddou *et al* (1978) to explain the latter astringency by a physical reason. Although this milk was free of astringency during the first several weeks of storage, it did show signs of gelation after 2 months, implying changes in its colloidal structure. Harwalkar (1991) has also reported about defects in UHT-sterilized milk particularly when stored at higher than ambient temperatures. From studies conducted on UHT milks (homogenized whole UHT milks (3.5% fat)) stored in the dark for 4 months, partly at 20°C and partly at 1°C, Mottar (1981) has observed, even after very intensive UHT treatments, residual proteolytic and lipolytic activities. When compared to indirectly heated UHT milk, directly heated UHT milk presented a more important loss in taste (drop in rating). Moreover, directly heated UHT milk stored at 20°C showed a higher degree of proteolysis and lipolysis than when stored at 1°C. It follows that the taste pattern of UHT milk stored at 20°C is highly dependent on the quality of the raw milk, more particularly on the concentration of thermoresistant proteases and lipases. Proteolysis appears to affect the taste of UHT milk stored uncooled more negatively than lipolysis. Although ultra-high temperature

treatment strongly restrains the enzymatic activities, it does not stop them completely. These observations would thus suggest a greater involvement for proteolysis than for lipolysis in astringency.

Some peptides isolated from casein treated by *Pseudomonas fluorescens* and *Alcaligenes* enzyme preparations have been found to be astringent and astringent-sour. From these findings Kostyra (1983) has suggested the following: 1) the sensation of astringency may depend on the hydroxyl and amide groups present in the peptides. The hydroxyl groups would be responsible for the formation of hydrogen bonds and electrostatic interactions with relevant oral cavity proteins, while the amide groups would react with nerve endings; 2) depending on the proportion of sour amino acids to their amides, the peptides may show predominance of sour over astringent taste or *vice versa*. *Alcaligenes* enzyme preparations also liberated bitter peptides, marked by the astringent effect of other peptides. As already mentioned, oral astringency may be closely linked to bitterness which is itself related to the average hydrophobicity of the peptides (Clifford, 1986).

As suggested by Charalambous (1980) there may be more than one combination of components that elicit an astringent response. Although, as previously mentioned, astringency has been associated with milk products that have been processed at high temperature and with proteolysis (Harwalkar *et al*, 1989), the presence of phenolic compounds should also be taken into consideration.

Astringency and phenolic compounds

Chemicals causing astringency are collectively known as tannins, the larger natural polyphenols (Hughes, 1992). The proanthocyanidins or condensed tannins, which characteristically bind and precipitate pro-

teins, are phenolic polymers synthesized by many plants (Bate-Smith, 1954). The cow eats a lot of these plants to produce milk. Astringency results from the interaction of phenols with proteins of the mouth and saliva (Singleton and Noble, 1976). Proteins and polypeptides with a high proline content have a high affinity for tannin while glycoproteins in general seem to have low affinity for astringent phenols (Hagerman and Butler, 1981). However, casein, which is a glycoprotein found in milk, is relatively rich in proline residues when compared to the whey proteins. Thus the proline content of milk proteins varies from ≈ 1.6 to $\approx 16.8\%$ (caseins: β -: 35 Pro/209 residues, 16.75%; α_{s2} -: 10 Pro/207 residues, 4.83%; α_{s1} -: 17 Pro/199 residues, 8.54%; κ -: 20 Pro/169 residues, 11.83%; whey proteins: β -lact: 8 Pro/162 residues, 4.94%; α -lact: 2 Pro/123 residues, 1.62%; BSA: 28 Pro/582 residues, 4.81%). However, proteins are precipitated by proanthocyanidins most efficiently at pH values near their isoelectric points, where protein-protein electrostatic repulsion is minimized. Thus proteins with acidic isoelectric points like BSA (pI 4.9) have greater affinities for tannin at pH 4.9 than at pH 7.8, and basic proteins like lysozyme have higher affinities at the higher pH (table VIII).

Although the specificity of the interaction is a function of the size, conformation and charge of the protein molecule, β -casein should have a high affinity for the tannins at acidic pH due to its proline content. Harwalkar (1972a) has been able to detect astringency at acid or neutral pH but not at highly alkaline pH ($> \text{pH } 10$). The changes in flavour at alkaline pH were reversible when the pH was lowered. Proanthocyanidin-protein interactions could thus be affected by the pH (Barbeau and Kinsella, 1983). Harwalkar (1972a) has observed absorption spectral changes, a shift in the maxima from 280 to 290 nm, for the astringent fraction from acid pH to alkaline pH. According to Ribéreau-Gayon (1968), the UV absorption wave-

Table VIII. Milk proteins, their isoelectric point and their relative affinity for tannins. *Protéines du lait, leur point isoélectrique et leur affinité relative pour les tannins.*

| | Whey proteins | | | Caseins | | | |
|--------------------------------|---------------|--------------------------|---------------|-------------------|-------------|------------|-----------------|
| | BSA | α -lact | β -lact | α_{s1} - | β - | κ - | α_{s2} - |
| Isoelectric point ^a | 4.9 | 5.14 | 5.13 | 4.24–4.76 | 4.6–5.1 | 5.3–5.8 | – |
| Relative affinity for tannins | BSA > | α -lact \approx | β -lact | α_{s1} - > | β - > | κ - | – |

^a Eigel *et al*, 1984.

length of the simple phenols is around 270 nm. Upon neutralization at alkaline pH, phenolic compounds become 'phenolates' and thus have different spectral characteristics. Preliminary studies conducted by Guinard *et al* (1986) on acidity-astringency interactions in model solutions and wines have indicated that acidity significantly increased the astringency of the solutions tested. Moreover, since the ability of condensed tannins to precipitate proteins decreased sharply at pH 8.0, Guinard *et al* (1986) suggested that it was due to a modification of the phenol ionization of the tannins, making them therefore unavailable for hydrogen bonding. Thus an acidic pH, by raising the percentage of tannins in the phenol form, can thereby increase the likelihood of hydrogen bonding between dihydroxyphenol groups of milk tannins and ketoimide groups of mouth proteins. Besides, Harwalkar (1972b) has concluded that astringent components should be extracted at acid pH.

It has been observed, for English ciders, that oxidation during juice extraction was accompanied by a marked lowering in the level of the polymeric procyanidins, with consequent reduction in astringency (Lea and Timberlake, 1974). During oxidation of milk, the flavour defect changes from flat to oily (table IX).

According to Bruhn *et al* (1976), a good quality of green feeds is needed to reduce liability to oxidation as they have a high content of the antioxidant tocopherol. Phenolic compounds in green feeds possess many OH groups which, in aqueous solution, induce many hydrogen bonds to form between the tannin molecules, resulting in aggregates of various sizes.

The phenolic compounds present in milk could, upon oxidation, change the flavour of the product to an oxidized flavour and thus cause a decrease in astringency. Indeed, astringency has been shown to

Table IX. Changes in milk flavour upon oxidation. *Variations dans la saveur du lait au cours de l'oxydation.*

| | | | | | | |
|------|------|------------|------|------------|------|---------|
| Flat | ---> | Metallic | ---> | Oxidized | ---> | Oily |
| | | Astringent | | Papery | | Tallowy |
| | | Puckery | | Cardboardy | | Painty |
| | | | | | | Fishy |

decrease with time in wine and cider (Lea and Timberlake, 1974; Charalambous, 1980). In Cheddar cheese the astringent fraction also decreased upon proteolysis during the maturation period (Lemieux *et al*, 1989). Gamma-caseins are proteolytic fragments of β -casein. Moreover, flavour development and stability to oxidation are influenced by proteolysis of the β -casein, which is dependent on the storage conditions (Reimerdes, 1978).

All these observations should thus suggest that phenolic compounds could also be responsible for astringency in dairy products.

THE DEFECT OF ASTRINGENCY IN MILK AND MILK PRODUCTS

Following the preceding where research has been done to try to understand and explain astringency in milk and milk products, some other works are listed in literature where the authors report about this defect. This section will be concerned about these observations and ways to reduce astringency.

Fresh, concentrated, dried and UHT milks

Identification of compounds responsible for the stale flavour defect in sterilized concentrated milk was performed by Arnold *et al* (1966). They found that astringency was absent from fresh whole milk, slightly present in the control sterile concentrate and more marked in stale sterile concentrate.

The flavour stability of evaporated milk produced by three different methods of processing: 1) the conventional method; 2) the high-temperature short-time (HTST) method; and 3) the aseptic method, was determined on subsequent storage at 10 and 27°C (Sundararajan *et al*, 1966). A sig-

nificant effect of processing on the initial flavour score was observed: aseptic process > HTST > conventional process. However, regardless of the method of manufacture, the flavour of the products deteriorated more rapidly at 27 than at 10°C and showed defects such as astringency and puckery.

In a study of the effect of preheat treatment and storage of whole milk powder manufactured from New Zealand milk, astringency, which was defined as the degree to which the reconstituted milk left a drying, chalky feel in the mouth after swallowing, was evaluated. This textural characteristic (astringency) slowly increased up to 15 months, and then decreased after 18 months' storage; moreover, it was not significantly affected by the preheating conditions (Baldwin *et al*, 1991).

Harwalkar *et al* (1989) have come to the conclusion that the astringent compounds in UHT-sterilized milk, analysed by PAGE, are γ -casein-like breakdown products of casein. Although heating UHT-milk by direct-steam injection would also produce astringency, it is still not known which of the γ -caseins are astringent and if there is an optimum ratio required to elicit the astringency response (Harwalkar *et al*, 1993). For this purpose the amino acid composition and sequence of the astringent compounds are required.

Ice cream and ice milk

Ice cream and ice milk prepared by adding a 12% corn sweetener solution showed an astringent off-flavour. Sulphur dioxide (as bisulfite ion), 5-hydroxymethylfurfural (a sweetener impurity), ethanal (acetaldehyde), methylpropanal (isobutyraldehyde) and 3-methylbutanal (isovaleraldehyde), the flavour components of the corn sweeteners, have been found responsible for this flavour defect (Olson, 1970).

Cheese

In the early seventies cheese makers found that *kasal*, a blend of phosphate salts (primarily sodium aluminum phosphate, basic) could be used as an emulsifying salt up to a level of 3%. Besides improving melt, appearance, texture and other characteristics of processed cheese, cheese spreads and cheese foods, *kasal* added no astringent off-flavours of its own (Anonymous, 1971).

In order to evaluate the role of microbially derived Strecker-type volatile compounds in commercial Cheddar cheeses, Dunn and Lindsay (1985) added phenylacetaldehyde (500 ppb), an authentic Strecker-type volatile aldehyde, to clean-flavoured mild Cheddar cheese. They observed that phenylacetaldehyde contributed astringent and bitter sensations to the cheese flavours.

Yogurt

Out of 12 sensory descriptors used to describe plain yogurt flavour-by-mouth evaluation, astringency has been found by Harper *et al* (1991) to be significantly different among samples ($P \leq 0.001$). People are more conscious nowadays about their health and want low-calorie products. Mistry and Hassan (1990, 1992) have developed a delactosed, high milk protein powder (HMPP) which serves as a stabilizer in non-fat yogurts to improve body and to reduce whey separation. They have thus been able to produce low-fat/non-fat yogurts from skim milk fortified with HMPP. However, when the protein content exceeds 5.6% (Hassan and Mistry, 1991) yogurts are too firm and have an astringent off-flavour.

Traditional cow milk yogurts sold in Brazil have a protein content of 3.6%. However, the protein content of a yogurt analogue prepared with dry soymilk, whey solids and skim milk powder could not exceed 3.1% due to a very marked astringent off-flavour. Paoliello

et al (1987) have observed that by adding calcium sulphate in small quantities (0.104%, w/v), they could improve overall acceptability and attain the normal protein level of 3.6% without adversely affecting consumer acceptability. Chien and Snyder (1983) have already shown that the addition (10–50% v/v) of skimmed cow's milk was effective in decreasing the astringency of soymilk. The opposite has also been done. Soybean is known as an inexpensive protein and excellent energy source. For that reason soybean milk has been used to replace milk in some fermented products. Cheng *et al* (1990) have thus prepared *sogurt*, a yogurt-like soybean product. However, *sogurt*, a 100% soymilk product, had an astringent taste intensity higher than that of yogurt.

Whey protein concentrate

Although whey protein concentrate (WPC) is generally described as bland, flavour attributes have been associated with it. Thus, personnel tasting solutions at 5% protein of 50 WPC samples with greater than 80% protein attributed milky, sweet, soapy, bitter and astringent off-flavours to all products whereas the chalky defect was uncommon (Huffman and Marks, 1990).

Hydrolysis of raw defatted soy flour by Denapsin (an acid proteolytic enzyme) gave a product which had an excellent nutritional value without an astringent off-flavour (Moretti, 1978). Later on, this hydrolysate was used together with recovered cheese whey protein in a proportion of 3:7 (whey protein: hydrolysed soy protein) for the preparation of a soluble protein mixture neutral in flavour.

Flavoured milks and formulas

High carbonation level (1.42 CO₂ volumes) increased the sourness and astringency of

strawberry, raspberry, peach and root beer flavoured milks (Lederer *et al*, 1991). Since the taste perception of sourness often stimulates the feeling of astringency (Moncrieff, 1971) and since some acids are perceived as more astringent than sour, it is suggested that the panellists could have been confused in the astringency evaluation and could have then responded to increased acidity in the flavoured milks. Thus, raising acidity has previously been suggested to increase the intensity of astringency in wine (Guinard *et al*, 1986). Moreover, the rate of saliva production would have thus been affected (it would have increased) by the chemical composition of the beverage, affecting the sensory magnitude of the viscosity (Szczesniak, 1979).

In a study which evaluated the sensory properties of formulas commonly replacing human milk (commercially prepared formulas based on cow's milk, home-made formulas prepared using whole and evaporated milk), Malcolmson and McDaniel (1980) found them to be all astringent, but in varying intensities. Only the whole milk formulas were found to be significantly less astringent than a reference sample made of a 0.08% alum solution and considered extremely astringent.

EXTRACTION AND ISOLATION OF ASTRINGENT COMPONENTS

This section is a summary of the different methods dealing with the extraction and isolation of astringent components from dairy products. Aqueous suspensions or solutions have been tasted for astringency by a trained panel or experienced judges. It can be observed that technologies used for the study of astringent components become more and more sophisticated with years. This way, from aggregate particles through astringent peptides, the information obtained

is getting close to the identification of the astringent components.

According to Josephson *et al* (1967) selected milk systems, skim milk, whey and ultrafiltrate systems, have been heated at varying levels (skim milk: 82°C, 1 h or 80°C, 30 min; whey: 80°C, flash to 30 min; ultrafiltrate systems: boiling bath: 10–30 min or 80°C, 30 min) to produce astringency. The astringent components were then sedimented by ultracentrifugation at different forces. Gel filtration (G-100 and G-200) on Sephadex, polyacrylamide gel electrophoresis (PAGE), electron microscopy and chemical analyses were carried out to study changes in the size, shape and composition of protein-salt aggregate particles present (Josephson *et al*, 1967).

The astringent components can be extracted from raw or pasteurized milk, UHT-milk and non-fat dry milk by means of the method proposed for isolating bitter and astringent compounds from Cheddar cheese (Harwalkar and Elliott, 1971). The major modification is the adjustment of the milk to pH 5.2 and freeze-drying before extraction by C/M (Harwalkar, 1972b, c). The astringent components in these extracts have been partly purified by isoelectric precipitation at pH 7.0 and by size-exclusion chromatography on Sephadex G-50 columns using water as a mobile phase. They have been further analysed by fast-protein liquid chromatography (FPLC) using a Mono-Q anion-exchange column and PAGE.

All the studied samples of aseptically (normal, starter-free, rennet-free and rennet- and starter-free) manufactured Gouda cheeses contained astringent compounds which have been isolated by Visser (1977b, c). The elution profile of the astringent fraction obtained, according to the method of Harwalkar and Elliott (1971), from a normal aseptic cheese after molecular sieving on Sephadex G-50 with 0.01 N acetic acid, showed two fractions with a molecular mass of approximately 7 000 and 3 000 Da, respectively.

In order to analyse the chemical composition of Swiss cheese and to relate it to its characteristic taste, Swiss cheese samples have been fractionated into oil-soluble, water-soluble-volatile and water-soluble-non-volatile components. This last fraction was found to contain astringent components which were further separated according to a modification of the procedure of Kirimura *et al* (1969). This process consisted of passing the water-soluble-non-volatile fraction through 5 successive Dowex 50 columns (20 x 200 mm) with decreasing degree of cross-linkage (x16, x12, x8, x4 and x2, respectively) to allow the separation of amino acids and peptides of different sizes. The average chain length of the astringent peptides (APL) was found to increase from 1.66 to 6.06 with the reduced degree of resin cross-linkage (Biede and Hammond, 1979) and it was calculated according to the formula (Takeuchi *et al*, 1967):

$$\text{average peptide chain length (APL) or average} = \frac{\text{Total nitrogen}}{\text{number of amino acids amino-nitrogen in the peptides}}$$

Astringent fractions have been isolated according to the method of Harwalkar and Elliott (1971) from Cheddar cheese made with added *Lactobacillus* strains to accelerate ripening. Size-exclusion high-performance liquid chromatography (HPSEC) on a TSK-G2000 SW column of these astringent fractions has allowed the estimation of their molecular masses at approximately 84 000–18 000 Da (Lemieux *et al*, 1989). Dinakar *et al* (1989) have also used the method of Harwalkar and Elliot (1971) to extract astringent components from Cheddar cheese prepared from cow or buffalo milk with either calf rennet or a soluble partially purified enzyme from *Withania coagulans*. Upon tasting, the extract from control cheese was found to be more astringent than bitter.

Knowing that the appearance of off-flavours in UHT milk is partly due to the proteolysis, López-Fandiño *et al* (1993) have used reversed-phase HPLC (RP-HPLC) to investigate the degree of protein breakdown during storage of UHT milk. As measured by SDS-PAGE, comparison of indirectly heated UHT milk samples with directly heated UHT milk samples showed a high level of casein degradation and gave rise to peptides which eluted below or at a concentration of 35% solvent B (0.1% trifluoroacetic acid in acetonitrile). The peptides so obtained were derived from the action of *Pseudomonas fluorescens* strain B52 proteinase on casein and eluted before the proteose-peptone, α -lactalbumin and β -lactoglobulin. According to López-Fandiño *et al* (1993), this RP-HPLC method could help to predict the risk of deterioration on storage of freshly prepared milks and would throw out a hint that the origin of astringency in UHT milk might not be due to whey proteins.

ASTRINGENT PEPTIDES

Kirimura *et al* (1969), in their study on the contribution of peptides and amino acids to the taste of foodstuffs, found that dipeptides involving the γ -COOH group of glutamic acid (Glu) in the peptide linkage are astringent. The assumption is supported by Nishimura and Kato (1988) who established that the peptides listed in table X are astringent.

Astringency has been found to be one of the eight flavour characteristics of acid or cottage cheese whey. In order to increase the utilization of whey in foods, McGugan *et al* (1979) have mixed it with skim milk in various proportions. Since astringency was found to be present at different levels, they have thus reported that change in astringency could result from changes in the ionized forms of astringent peptides.

Table X. Dipeptides tasted in 0.2% aqueous solution and evaluated by a trained panel as being astringent

Dipeptides ayant été évalués à une concentration de 0,2% en solution aqueuse et identifiés comme étant astringents par des panellistes entraînés.

| | | |
|------------------------------------|-----------------------|------------------------------------|
| γ -L-Glu-Gly ^a | γ -L-Glu-L-Val | γ -L-Glu-L-Tyr ^b |
| γ -L-Glu-L-Ala ^a | γ -L-Glu-L-Leu | γ -L-Glu-L-Phe ^b |
| γ -L-Glu-L-Ser | γ -L-Glu-L-Ile | γ -L-Glu-L-Asp ^a |
| γ -L-Glu-L-Thr | γ -L-Glu-L-Trp | γ -L-Glu-L-Glu ^a |
| γ -L-Glu-L-Pro | | |

^a Accompanied by sourness

^b Accompanied by sourness and bitterness.

CONCLUSION

Being handled extensively between production and consumption, milk comes into contact with many plant surface equipments and it is thus prone to many potential sensory changes. These are the main causes of potential sensory changes in milk: i) accidental contamination with chemicals; ii) milk treatments, in particular thermal processing; iii) and reactions during storage due to: a) microbial growth; b) enzymatic or oxidative activity.

Knowing that a successful sensory analysis depends more on people than on methods, experimental designs and computers, a good panel training and a well defined descriptive terminology of the test form and of the scoring scale are thus necessary.

To describe some associated textural defects of dairy products, there is no stated consensus among the sensory evaluators of dairy products in their understanding and use of the attributes or terms for ratings. Thus regarding the confusion around the use of the term 'astringent' a consensus in dairy judging becomes imperative.

From the results mentioned above it appears that astringency arises in treated

milk from at least three different sources: 1) from heat-induced association of whey proteins and calcium phosphate with the caseinate system (Josephson *et al*, 1967); 2) they may be proteolytically induced peptides. In non-fat dry milk samples the astringent components have been shown to be polypeptides associated with the casein fraction, particularly γ -casein (Harwalkar, 1972c). Moreover, mineral content (calcium, magnesium and phosphorus) has not been shown to be involved, and heat alone cannot account for this defect. Astringent components can be extracted only from acidified milk; and 3) they may involve phenolic compounds which are always present in the feeds given to cows.

Ultrasonic vibrations and treatment with proteolytic enzymes (trypsin and pancreatin) have been found to reduce astringency in heated skim milk by the dissociation of aggregates and/or complexes of milk constituents formed as a result of heat treatment (Kudale, 1970). One could establish points of similarity between Kudale's observations and cheese proteolysis, where the astringency is reduced through the degradation of proteins (caseins) to free amino acids. Indeed, proteolytic breakdown during the cheese ripening process (rennet, starter strain, bacteria, etc) implies the degradation of high molecular mass polypeptides (astringent fraction, with M_r of \approx 84000 to 18000 Da) to peptides and free amino acids (Lemieux *et al*, 1989) with a loss of astringency.

Although the role of peptides contributing to the bitter taste in cheese has been studied in detail, further research is necessary to explain the contribution of peptides to food taste. The consumer is the final and decisive judge of eating quality. Acceptance of a food is influenced to a great extent by the tactile properties exhibited by it. Producers should thus supply food products with no assigned defect. They thus should try to minimize the effects of processing. More

interest should also be directed towards the equilibrated sensation to make a dairy product appetizing and satisfying so that the consumer will appreciate and become fond of it. For example, for a frozen dairy dessert to retain its refreshing and pleasing characteristics, the mouthfeel should not be excessively cold, dry or astringent (Bodyfelt *et al*, 1988).

Astringency should stimulate more interest among workers involved in the field of dairy products. More effort should thus be involved in the astringent defect in dairy products to try to understand it and find the exact causes.

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