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AQUANOVA's micellation technology: what can it do for the food industry?

In modern food production food additives are indispensable aids for making tasty, safe, stable, low calorie, good-looking and colourful foods. In times of increasing health awareness, which has led to the advent of the functional food category, micronutrients and health ingredients are enjoying a steep career in the food industry.

Both food additives and health ingredients can often not be used because they have certain drawbacks, which disqualify them from certain products or processes. In order to overcome those problems, in addition to chemical modification, formulation technologies such as micro-encapsulation and micro-emulsification have been developed. These technologies have solved a lot of problems and contributed considerably to the current standard of food production, but there is still plenty of room for improvement as consumers' expectations are ever growing.

AQUANOVA's micellation technology

AQUANOVA has taken micro-emulsification a step further and developed a technology referred to as 'solubilisation' or 'nano-emulsification' or 'micellation'. Micro-ingredients, whether they are technical food additives or

nutritional ingredients are encased in nanosized micelles, where they display amazing new properties.

As shown below, the Product Micelles consist of one or more active ingredients in the core (red in the image) and the shell (blue). The shells are composed of food-approved surfactants and other excipients to achieve certain properties. The shell composition has to be specifically developed for each active or combination of actives since it is one of the objectives to maximise the 'loading' of the micelle, in other words, to fit as much active ingredient in as possible. This depends on the shell composition and the chemical structure of the active. The smaller and more flexible a molecule is, the higher the 'loading' of the micelle. Concentrations of up to 30% w/w are possible.

In summary, the Product Micelles have the following main features:

- Core = active ingredient(s),

the shell is the solubiliser (surfactant) system

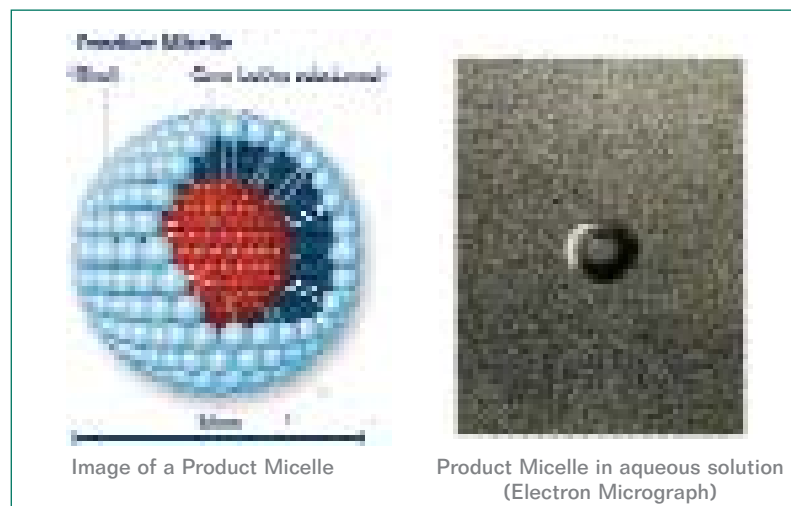
- Several ingredients can be combined in the same ratios in each Product Micelle
- Spherical particles, ca. 30nm in diameter
- Extremely narrow micelle size distributions
- Thermodynamically stable aggregates kept together by van der Waals forces
- Very high thermal, mechanical and pH-stability.

The unique properties the ingredients obtain due to micellation are discussed in the next chapter together with practical application examples.

Although the size of the Product Micelles are below 100nm and thus fall under its commonly used definition, AQUANOVA's micellation technology cannot be understood as nanotechnology in the sense that potentially harmful novel particles are created. In fact, AQUANOVA's technology mimics the principle that nature has been applying throughout evolution for making nutrients soluble and bioavailable, e.g. casein-micelles in milk, cholesterol-micelles in eggs or mixed micelles of fat soluble nutrients in the gastrointestinal tract of humans and animals.

Properties and applications

In the previous chapter we looked into the 'microcosmos' of the Product Micelles. Now we will look at the macroscopic properties of





Amphiphilicity – crystal clear solutions in water and oil

the ingredient formulations resulting from the micellation process. The products AQUANOVA develops and manufactures are liquids consisting of Product Micelles. These liquid formulations are commonly referred to as 'solubilisates'. The solubilisates have the following general properties, which are taken advantage of in various applications:

- They are amphiphilic, meaning they are both hydro- and lipophilic, hence soluble in both water and lipids
- They yield crystal clear solutions
- They increase the absorption (bioavailability), hence the efficacy of nutrients
- They function independently of the pH-value

- They improve the skin penetration of actives, which opens them to a wide field of application in cosmetics.

Amphiphilicity – crystal clear solutions in water and oil

This amazing property opens up new areas of application for ingredients where they could not be applied before, i.e.

- Fat soluble nutrients such as vitamin E, CoQ10, isoflavones, carotenoids and others in clear beverages
- Water soluble natural antioxidants such as ascorbic acid, polyphenols and others in oils and fats, where they can replace unpopular additives such as BHA and BHT.

Enhanced bioavailability = enhanced efficacy

Bioavailability is the measure of the absorption of a nutrient or a drug. It expresses the rate by which a nutrient or drug is absorbed into the blood and/or cell. The best nutrient doesn't work if it doesn't arrive where it is needed. This is a critical point not only for pharmaceutical developers but also for manufacturers of dietary supplements and functional foods.

A nutrient needs to be water-soluble to get absorbed. If it is not water-soluble by nature, like the

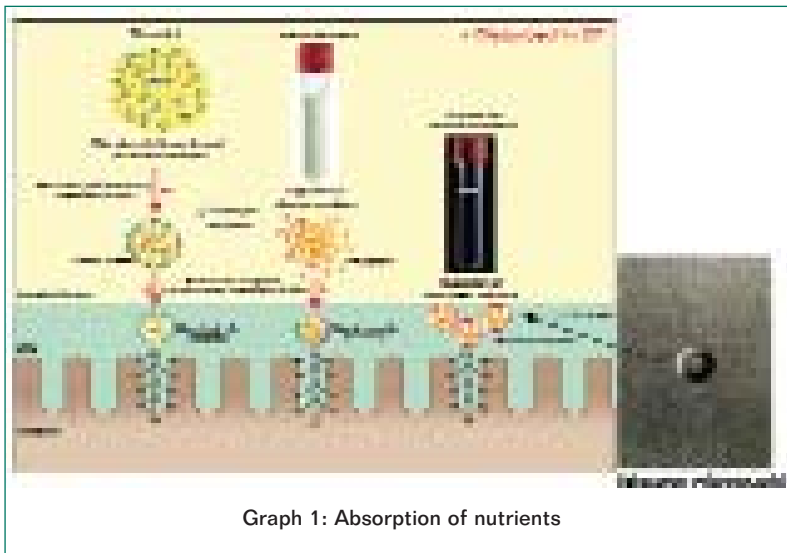
vitamins A, D, E and K, CoQ10, Omega-3-fatty acids and many others, it has to be pre-processed in the human gastrointestinal tract. This is schematically depicted in Graph 1.

pH-independence – the key for innovative food preservation

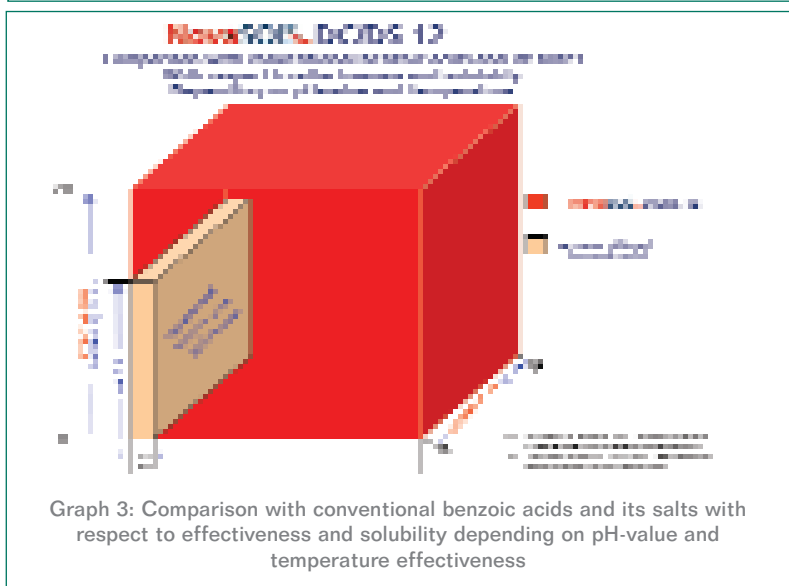
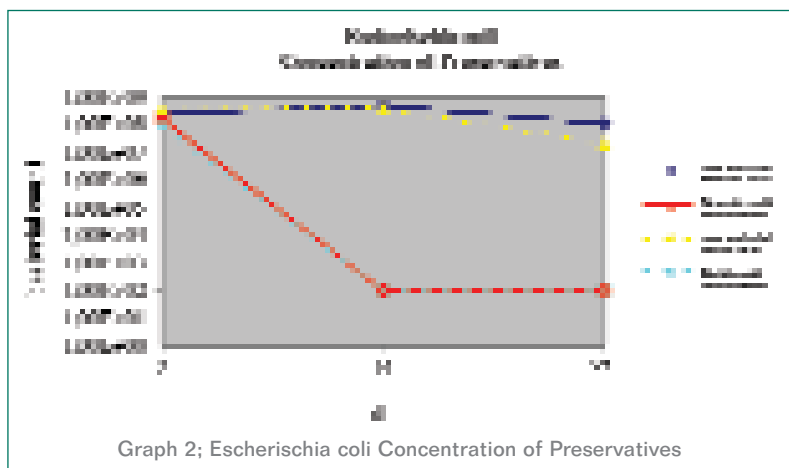
A substance transported in the tiny 'submarine' Product Micelle doesn't 'feel' the pH-value of its surrounding space. It is resistant to it. This has led to the groundbreaking development of micellized sorbic and benzoic acid, which solve the well known problems associated with the conventional forms of these well established preservatives.

Both sorbic and benzoic acid exert their antimicrobial effect only in their undissociated state. At low pH-values that works well. However, the higher the pH-value of a food is, the more the acids dissociate, and as a result of that lose their preserving potency. Sorbic and benzoic acid and their salts show a very weak effect at pH-values above 5 and no effect at pH 6 and above. This disqualifies them for a wide array of foods.

If the preservative is micellized, however, in other words 'sheltered' from the pH, it does not dissociate and thus keeps its full preserving power. When a micelle with the preservative inside meets a micro-organism, it attaches to its membrane and releases the preservative into the organism, as described above for the human gastrointestinal tract. Because it is undissociated, no matter what the pH of the food is, it can migrate into the micro-organism and kill it. This was, for instance, impressively shown in an experiment with a malt broth inoculated with yeasts at pH 6.2, where regular benzoic acid had no effect on the yeast growth at all but micellized benzoic acid inhibited the growth resulting in a germ count of zero after 2 weeks.



Graph 1: Absorption of nutrients



Another convincing result was obtained from an experiment with E-coli in malt broth at pH 6.0 (see Graph 2).

The initial germ count was $>10^9$. Neither conventional benzoic acid (dark blue line) nor conventional sorbic acid (yellow line) could reduce it to any degree worth mentioning within 21 days. The two micellized acids, however (solubilisates, red and light blue lines), reduced the germ count to 10^2 . And this was achieved within 14 days.

Smallness of the micelles – key for effective surface preservation

Conventional sorbic and benzoic acid or their salts are not effective in protecting microbiologically sensitive surfaces of foods such as cheese and raw sausages, or salami, from moulds. The solubility

of both acids in water is very low and not sufficient for a surface treatment. Their salts are sufficiently soluble to be dissolved in the dipping baths but after the food has been dipped and its surface has dried, the sorbate or benzoate crystals remain – and crystallised preservatives do not work, they have to be in solution.

This is different with micellized acids. A 5% solution of either a sorbic or benzoic acid solubilisate, or a combination of both, is an ideal dipping bath. Once dipped, the water film on the food, e.g. salami, evaporates and a nanosized film of micelles remains, which covers the entire surface without a gap. No mould or bacteria can penetrate this 'wall' of micelles filled with preservatives.

Instead of being used as a dipping

bath, diluted solubilisates can also be sprayed on all foods that need microbiological surface protection such as nuts, cereals and citrus fruits.

Graph 3 schematically shows, for the example of benzoic acid, the superiority of the micellized form (solubilisate) over the conventional form.

Summary and conclusion

Using its proprietary micellation/solubilisation technology, AQUANOVA has developed novel formulations of food and cosmetic ingredients, nutrients, nutraceuticals and pharmaceutical actives with superior properties providing new opportunities of application.

The technology renders fat soluble substances water soluble and vice versa. This offers new opportunities for products and applications such as:

- Dietary supplements with enhanced bio-availability/absorption, hence efficacy
- Addition of fat soluble ingredients to clear beverages
- Functional cosmetics with improved skin penetration, hence efficacy
- Application of water soluble food/cosmetic antioxidants in oils and fats/creams
- More effective, pH-independent food preservatives
- Micellized preservatives for microbiological surface protection.

The new delivery forms (solubilisates) consist of Product Micelles, versatile carrier systems at the nano level, which are responsible for the unique properties of AQUANOVA products. ■

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