

## Processing characteristics and stability of chemically synthesized carotenoids in food systems

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**SUMMARY.** Product development is driven by consumer demand for variety in food. Increasing health awareness and a corresponding lifestyle are the main factors that influence the development of new food products. The pure nutritional aspect of food is becoming less and less important, leaving enjoyment and health as the major motivators of consumer preference. Research & Development and Technical Service departments for carotenoid formulations have been taking up these challenges for a long time. They have developed carotenoid formulations with processing characteristics and stability to meet the customer's requirements. Carotenoids that are approved under food laws are used as colorants.  $\beta$ -carotene is also important as provitamin A and as a physiologically active substance. Carotenoid formulations are available as dispersions, powders and emulsions. They must meet the requirements of the different food production processes. Ease of handling, and stability to light, air and heat are important technical features of our carotenoid formulations. Some of the main processing parameters and the stability of carotenoid formulations are discussed with reference to the beverage industry, margarine production and the dairy industry.

**Key words:** Synthetic carotenoids, stability, processing characteristics

**RESUMEN.** Características de procesamiento y estabilidad de los carotenoides químicamente sintetizados en sistemas alimenticios. El desarrollo de productos es impelido por la demanda del consumidor por variedad en alimentos. La creciente concientización sobre la salud y el estilo de vida correspondiente son los factores principales que influyen en el desarrollo de nuevos productos alimenticios. El aspecto nutricional puro de los alimentos está siendo cada vez menos importante, dejando el placer y la salud como los mayores motivadores de la preferencia del consumidor. Los Departamentos de Investigación y Desarrollo y Servicios Técnicos para formulaciones con carotenoides han tomado para sí estos desafíos por un largo tiempo. Ellos han desarrollado formulaciones de carotenoides con características de procesamiento y estabilidad que atienden las exigencias del cliente. Carotenoides aprobados por legislación son usados como colorantes.  $\beta$ -Caroteno es también importante como provitamina A y como una sustancia fisiológicamente activa. Formulaciones de los carotenoides se encuentran disponibles como dispersiones, polvos y emulsiones. Ellos deben atender los requisitos de los diferentes procesos de producción de alimentos. Facilidad de manipulación, y estabilidad a la luz, aire y calor son importantes propiedades de nuestras formulaciones de carotenoides. Algunos de los principales parámetros de procesamiento y la estabilidad de formulaciones de carotenoides son discutidos en relación a la industria de bebida, producción de margarina y la industria lechera.  
**Palabras clave:** Carotenoides sintéticos, estabilidad, características de procesamiento

### INTRODUCTION

In recent years, consumer demand has developed more in the direction of products with refreshing properties that are associated with greater enjoyment and quality of life. Increasing health-awareness and a corresponding lifestyle are having a strong influence on the development of new food products. The pure nutritional function of food is receding ever further into the background. Enjoyment and health still remain the primary motives for consumer preference. And enjoyment also means variety. The subject of health is becoming increasingly important in a society with a strongly growing proportion of older persons. Consumers are open to new ideas, which they judge not only in terms of quality but also quite

consciously in terms of the price/performance relationship.

R&D and Technical Service Departments for carotenoid formulations have always taken up these challenges. They have developed carotenoid formulations that give customers the processing characteristics and stability that customers require.

#### Carotenoid formulations as colorants

- Food products can be coloured for the following reasons:
- to make up for colour lost in the production process, storage, packaging and distribution of the product
  - to improve the brilliance of the existing colour of the food product
  - to give food products a more attractive appearance and to

create an association with their flavour.

We tend to associate the colour of a food with its taste and flavour. For the consumer, the colour is also an indicator of the quality of the food product. An attractive colour increases the incentive to buy, leading to higher sales. The recipes and production processes for food products must aim to meet the interests and wishes of the consumer.

There are situations in which it is difficult to use colorants in foods:

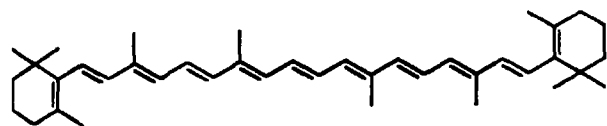
- legal restrictions
- technical properties and stability of the colorant
- the unavailability of a suitable shade
- economic reasons; the colorant costs are too high compared with the overall costs.

Where do carotenoid formulations stand in these situations?

Four synthetic carotenoids are currently used in food products:

- $\beta$ -carotene
- $\beta$ -apo-8-carotenal
- $\beta$ -carotenoic acid ethyl ester
- canthaxanthine

The main characteristics of  $\beta$ -carotene are:



Solubility:	chloroform	very good
	vegetable oils	moderate
	water	insoluble

$$\lambda_{\max} = 445 \text{ nm} \quad A_{1\%}^{1\text{cm}} = 2500 \quad Fp = 176 - 182 \text{ C}$$

all-*trans*- $\beta$ -carotene  $C_{40}H_{56}$

The use of canthaxanthine and apo-carotenal formulations is subject to different food laws in different countries.  $\beta$ -Apo-8-carotenoic acid ethyl ester is used to colour (mark) butter fats.

There are practically no restrictions on the use of  $\beta$ -carotene formulations. According to the EC Additives Directive,  $\beta$ -carotene can be added to food products according to the *quantum satis* principle, i.e. the colorants can be used, according to GMP principles, in quantities that are no greater than are required to achieve an intended effect, though this must not deceive the consumer.

$\beta$ -Carotene formulations can be divided into

- $\beta$ -carotene dispersions
- $\beta$ -carotene powder formulations
- $\beta$ -carotene emulsions
- $\beta$ -carotene solubilizates (described in patents)

The  $\beta$ -carotene dispersions consist of finely ground  $\beta$ -carotene in vegetable oils. They are used to colour food products with a high oil content.

**Margarine:** In many countries, margarine is given its attractive colour with  $\beta$ -carotene dispersions. The  $\beta$ -carotene is present in dissolved form in the oil droplets and fat crystals of the margarine. The antioxidative components in the margarine make  $\beta$ -carotene highly stable.

If the  $\beta$ -carotene is not completely dissolved, the colour obtained is a paler red. The process conditions must be adjusted to ensure that the  $\beta$ -carotene is always completely dissolved in the margarine.

Perhaps the reader has noticed, when shaving off a layer of margarine with a knife, that the margarine exposed has a much lighter shade. What has happened here is not that the  $\beta$ -carotene in the margarine has decomposed, but that its concentration at the surface has increased.

This is because water evaporates from the margarine emulsion at the surface. If the difference is too conspicuous, and undesired, the processing conditions where the margarine is produced are probably not to blame; instead, the water vapour permeability of the packaging should be checked.

The replacement of vitamin A in margarine by provitamin A has been considered. However,  $\beta$ -carotene has such a high coloration power that replacing vitamin A in margarine with provitamin A would give it too strong a colour. The solution here would be a non-colouring  $\beta$ -carotene formulation. Unfortunately, there is as yet no such formulation for use in margarine.

It is also possible to use natural carotene and annatto to colour margarine. Annatto does not give the margarine the desired brilliance of colour and is not as stable as  $\beta$ -carotene.

Economic reasons and variations in colour have prevented the success of natural carotene.

#### **$\beta$ -Carotene formulations in milk products, e.g. yoghurt**

Yoghurt preparations are given the shade that meets customers' wishes by adding  $\beta$ -carotene powder formulations and  $\beta$ -carotene emulsions. It is possible to improve the stability of  $\beta$ -carotene in yoghurt by adding riboflavin.

One reason for the improvement in stability is that riboflavin absorbs light at 450 nm, which is practically the same as the corresponding wavelength for  $\beta$ -carotene, 445 nm.

The proximity of the wavelength of maximum absorption (450nm) for  $\beta$ -carotene and riboflavin can lead to problems in the quantitative analysis of multivitamin products.

Yoghurt often contains a fruit preparation.  $\beta$ -Carotene powder can be added to this fruit preparation. Incorporating 10% powder formulations into fruit preparations can present a technological challenge.

10% powders contain amorphous  $\beta$ -carotene, which is one reason why they give a much redder shade than the 1% powder

containing  $\beta$ -carotene dissolved in oil.  $\beta$ -Carotene can be extracted from the 10% powder. The dissolved  $\beta$ -carotene shifts the shade in the direction of orange-yellow. By carefully controlling the production conditions, it is possible to adjust the shade in this way.

### Pasta in Asia

In some countries, it is permitted to colour pasta products with  $\beta$ -carotene. Instant noodles are given their attractive colour by adding approximately 4 ppm of  $\beta$ -carotene.

### Carotenoids for colouring beverages

Some segments of the food market are showing symptoms of saturation and increased competition - the driving force for the development of new products. Particularly in the beverage market there has been a large number of new products in recent years.

Yesterday's niches are becoming today's market sectors.

The number of different beverages is becoming ever larger. Their appearance and colour are the first and most important impression that affects the purchasing behaviour of the consumer. The beverage can be clear or turbid; it can have a wide range of different shades of colour between yellow and red-orange.

Carotenoid formulations are very important as colorants for beverages.

To meet the wide range of different processing conditions as well as the demands of the food industry, carotenoid formulations must be developed to meet the following challenges:

- color strength of the formulation
- consistency of shade from batch to batch
- good flow properties
- low dust formation
- good wettability
- good dispersibility in water
- narrowest possible particle-size distribution
- good chemical stability of the  $\beta$ -carotene in the dry powder
- good chemical and physical stability in foods
  - light stability
  - opalescence, if required
  - lowest possible sensitivity to Ca
  - no changes in the pH range of the isoelectric point
  - no tendency to creaming
- kosher quality

The following processing parameters must be observed when handling  $\beta$ -carotene powder formulations and emulsions:

- proper preparation of the stock dispersion
- proper preparation of a stock emulsion
- homogenization parameters
- oxidation protection, enhancement of light stability

The following processing conditions should be maintained to obtain squashes and non-carbonated beverages with a shelf life of 6-12 months:

1. Use the recommended colorant concentration
2. Keep the copper concentration below 0.5 ppm
3. Keep the iron concentration below 0.3 ppm
4. Add ascorbic acid and the colorant as late as possible in the process
5. Use a relatively low ullage and a relatively high filling temperature

Natural colorants like anthocyanins are often heat-sensitive, react to changes in pH value, lack colour strength, can affect the flavour of beverages, and their shade can vary.

$\beta$ -Carotene formulations have a particularly high colour strength, consistency of shade, are free flowing and dispersible in cold water, as well as being chemically and physically stable in the beverage.

The  $\beta$ -carotene powder and emulsion formulations have no tendency to cream. However, aroma oils or other components in the beverage can separate out and form a ring on top of the beverage at the beverage/glass/air boundary.

$\beta$ -Carotene is soluble in oil and colours the otherwise colourless ring. Consumers who spot this frequently believe the beverage is of inferior quality.

The separation phenomenon can be minimized by careful attention to the processing parameters, i.e. the recipe for the beverage, the point at which the  $\beta$ -carotene is added and the homogenization parameters.

Vitamin C or d,l-alpha-tocopherol are added to stabilize the  $\beta$ -carotene in the beverage.

$\beta$ -Carotene powder formulations demonstrate good stability even in alcoholic beverages (4% by volume).

There are on the market carotene formulations of different colour intensity in the yellow-orange and orange-red to red ranges. Depending on the beverage manufacturer's processing parameters, it is therefore possible to select the most suitable  $\beta$ -carotene formulation with the greatest colour yield in the desired colour range.

One question that is frequently asked about processing is: Is it possible to use more of the 1% formulation to achieve the same shade of colour as the 10% formulation?

It would be logical to expect this, but it is not so. The reason is that the products use different carrier materials and the  $\beta$ -carotene is present in different physical forms. A higher concentration of the 1% formulation gives a deeper yellow-orange shade.

The colour of a beverage strongly influences the purchasing behaviour of the consumer. It is not possible to colour all beverages. Thus, for instance, it is not permitted to colour fruit juices. The riboflavine contained in multivitamin fruit juices, and particularly the  $\beta$ -carotene formulation have a major effect on the colour and appearance of the multivitamin fruit

juice. With the same concentration of provitamin A in a fruit juice, the differences in shade can be seen clearly.

Thus carotenoids, as provitamins or physiologically active ingredients, can significantly affect the shade of colour of a fruit juice. Suitable carotenoid formulations can therefore be used to better fulfil the wishes of the consumer.

#### **Health food products with $\beta$ -carotene**

Health food products are continuing to enjoy increasing popularity. Many soft gelatin capsule products and effervescent tablets comply with the food laws in Germany.

Differences in the particle-size distribution of the  $\beta$ -carotene in the dispersions used in non-coloured soft gelatin capsules can give different colour impressions. The finer the  $\beta$ -carotene is ground, the lighter it appears in the capsule. The conditions under which  $\beta$ -carotene crystals are milled can play a decisive role here.

The demand for  $\beta$ -carotene-containing tablets of food quality is growing. Carotene formulations must withstand pressures of several tonnes during tablet compression. The matrix must not disintegrate and no carotene must be expressed, as it would be oxidized by the air with a measurable loss.

$\beta$ -Carotene formulations were developed with tableting conditions in mind.

Effervescent tablets are particularly popular in Germany. The compression conditions for effervescent tablets are much the same as those for any other tablet. However, it must not only withstand the high compression forces, it must also be dispersed readily in cold water. Effervescent tablets containing 10%  $\beta$ -carotene formulations lead to a reddish or orange colour in the beverage.

Liquid multivitamin products are also available on the market as syrups; a  $\beta$ -carotene emulsion can be used to fortify these syrups. It is possible to produce turbid and clear liquid formulations. This is possible only to a limited extent with the powder formulations.

#### **Innovative carotene formulations**

$\beta$ -Carotene formulations with a soya protein matrix are completely new to the market. There is an increasing demand for food products that are free of animal proteins, e.g. for vegetarians. According to our practical experience to date, the production parameters of food products made with  $\beta$ -carotene formulations with soya do not differ significantly from those made with gelatin-based formulations. There are also no obvious differences in the stability of the  $\beta$ -carotene.

#### **To summarize:**

Some of the factors that must be taken into account in processing chemically synthesized carotenoids in food products have been mentioned:

#### **Margarine production**

- proper dissolution of carotenoids
- correct emulsifying properties
- suitable packaging

#### **Milk products**

- auxiliaries such as riboflavine to enhance the light stability of the carotenoids
- correct processing parameters for yoghurts to avoid colour shifts

#### **Properties of carotene formulations for production of**

- plain tablets
- effervescent tablets
- beverages

Processing of carotene in food is straightforward and stability is no problem when the right carotene formulations are used.

### **CONCLUSIONS**

In conclusion, it can be said that, of all the carotenoids approved for use in food products,  $\beta$ -carotene can be used in most foods in almost all countries. A number of examples was given to show that the processing properties of the carotene formulations must meet a wide range of different requirements. The stability of the carotenoid is also affected by the composition of the dispersion, powder or emulsion formulation. The final colour of the food product is affected both by the type of carotenoid formulation and by the processing parameters for the food product. Because of their color strength and versatility, carotenoid formulations are economical. We can look forward to new carotenoid formulations and their processing technology challenges.