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Mini Review

Quality of Dietetic Food: Significance for Human Nutrition

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1. Introduction

The recommendations made by food scientists today provide valuable guidance for every healthy human in all questions of healthy nutrition. But there is still a discrepancy between scientific knowledge on the one side, and the general nutrition behaviour of the population on the other. For most people the sensory quality of food obviously is of primary importance. Sensory quality, by the way, is also one component of the total quality which consumers can judge by themselves. Corresponding inquiries have shown that about ⅔ of the population wish to enjoy eating.
People requiring a special diet obviously behave differently. They are much more inclined to adapt themselves to specific nutritional necessities. For them, special dietetic food is available.
In Germany the term dietetic food has been defined by the legislator (1). Accordingly, dietetic foods are products intended for serving a specific nutritional purpose by increasing or lowering the supply of certain nutrients or other physiological substances or by guaranteeing that such substances are supplied in a certain ratio or quality. Dietetic food hence differs from usual food products of the same kind by its composition and its properties. Dietetic food serve a specific nutritional purpose because they help in meeting specific nutritional requirements resulting from sickness, deficiencies, functional anomalies or hypersensitivity against individual foods or certain food ingredients; furthermore they are useful during pregnancy and lactation, and for babies and infants.
Dietetic food hence represents a special group in the spectrum of foods available; an important difference as compared to conventional products is the different value of partial qualities of such foods. The overall quality of a food product usually consists of different partial qualities, about the use and significance of which several ideas exist. Figure 1 shows such quality aspects, their determination and concentration on relevant partial qualities. The most important three partial qualities finally are the nutrition-physiological, the technological and the sensory quality.
Fig. 2 now shows these partial qualities arranged according to the importance they have for conventional and dietetic food. Accordingly, the nutrition-physiological quality, i. e. defined composition and specific properties are of primary importance in dietetic food. Here now a certain quality problem

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OVERALL QUALITY</td><td>HYGIENIC
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Fig. 1 Overall and partial qualities of foods

CONVENTIONAL FOOD	DIETETIC FOOD
1. SENSORY QUALITY	1. NUTRITION-PHYSIOLOGICAL QUALITY
2. TECHNOLOGICAL QUALITY	2. SENSORY QUALITY
3. NUTRITION-PHYSIOLOGICAL QUALITY	3. TECHNOLOGICAL QUALITY

Fig. 2 Importance of partial qualities

may arise, for many food ingredients, whether originally present or added during processing, are not stable. Changes taking place such as, for instance, abiotic changes in preserved and stored food, may influence also specific properties of the product.

2. Composition of products and constituents of special importance for the quality

About every sixth citizen of the Federal Republic of Germany, according to a careful estimation, is dependent on a diet (2). These people suffer from civilizational disease which may also be caused by inadequate nutrition. The share of dietetic food in total food sales in Germany was 1.5% in 1980, corresponding to 2 billion DM (3). Sales of dietetic food comprise three sectors, as is shown in **Fig. 3:** food for sick patients, baby and infant food, and finally nutrient concentrates.
Indications for dietetic measures include diseases caused by malnutrition, constitutional metabolic disorders, and incompatibility with certain food ingredients. At a symposion held in 1978 a catalogue of 19 diseases was established which

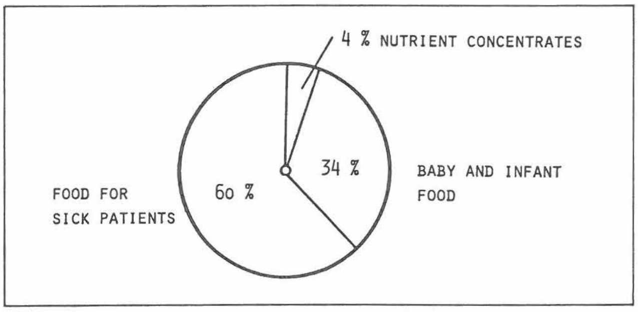

Fig. 3 Relative shares of dietetic foods as to sales

1	FOOD FOR PARTIAL OR COMPLETE NUTRIENT SUPPLY	' FORMULA DIETS ' MIXTURES OF NUTRIENTS AND ACTIVE SUBSTANCES ' BABY AND INFANT FOOD
2	SUBSTITUTES	' SUGAR SUBSTITUTES ' SWEETENERS ' SALT SUBSTITUTES
3	OTHERS	' READY MEALS FOR CHILDREN AND ELDERLY ' SWEETS ' COFFEE ' MINERAL WATER ' ALCOHOLIC DRINKS

Fig. 5 Other categories of dietetic foods

LOW-ENERGY / ENERGY-REDUCED / ENERGY-FREE	HIGH-ENERGY
LOW-PROTEIN / NITROGEN-FREE	HIGH-PROTEIN
LOW-FAT / LOW-LIPID	HIGH-FAT / HIGH-LIPID
LOW-CARBOHYDRATE	HIGH-CARBOHYDRATE
FIBER-FREE	HIGH-FIBER
LOW-MINERALS	HIGH-MINERALS
-	VITAMIN-RICH
LOW-SODIUM	-
LOW-PURIN	-
GLUTEN-FREE	

Fig. 4 Categories of dietetic foods with reduced, removed or enriched constituents

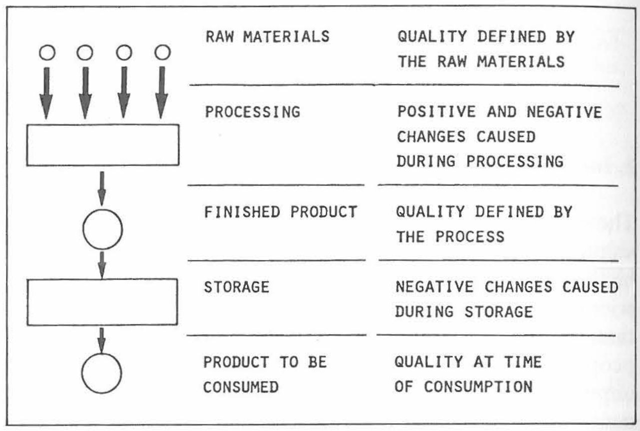

Fig. 6 Food processing and quality

require dietetic measures to accompany medical treatment. In view of the present subject, however, dietetic food composition appears to be a better criterion to discuss quality problems. The total of about 800 dietetic food products presently available in Germany can be classified into 27 categories (4). This classification is of course somewhat arbitrary. The categories comprise food of very different nature, a fact complicating a category-specific approach. Common to 16 categories, however, which shall be discussed below is that a quite specific component is either reduced, removed or enriched **(Fig. 4)**.
The components concerned specify the aim and significance of this type of dietetic food. Its nutrition-physiological quality, particularly the effect of one single substance, is absolutely dominant. It should be noted here already that such products frequently present difficulties in ensuring a sensory quality consumers usually expect. In view of the importance diets have for consumers' health, however, one is more inclined to accept also products of lower sensory quality. The remaining 11 categories may be classified as is shown in **Fig. 5.** They include dietetic food intended for partial or complete nutrient supply, sugar or sodium salt substitutes and some other products for specific purposes. Since the food listed in figure 5 is as well intended primarily for therapeutical use, its nutrition-physiological quality is the dominant parameter.
However, it would be unjustifiable to confine discussion to the nutrition-physiological quality, because in many of the products listed in **Fig. 4** and **5**, a satisfactory or good sensory quality represents a decisive stimulant for regular use. Also dietetic food can fulfil its purpose only as long as it is consumed.

3. Problems related to quality changes

Today dietetic foods are products based on the results of modern nutrition research and requiring high-standard food engineering. This technological aspect shall be discussed in the following. It deserves special attention in the case of products the composition of which is so strictly defined. But is it in fact possible to produce and maintain the qualities dietetic food is expected to show?
To answer this question, it is necessary to discuss the changes food products undergo. In foods, as is well known, several mechanisms of most different nature take place during processing and also during storage as a function of external conditions and the inner matrix of the product. They result in changes of mostly irreversible character. The pertinent principles of food engineering therefore fully apply also to dietetic food. It seems, however, as if this technical aspect is not or only insufficiently known, although, as mentioned before, the actual state of the product is essential in the case of dietetic food.
Fig. 6 shows the most important phases from production to consumption of a food product and possibilities of quality changes. There are 3 subsections relevant for the quality. First, the raw materials which may show different quality levels. The selection of raw materials hence influences the final quality level of the product decisively. During processing, the raw materials usually undergo mechanical and thermal unit operations, intended to produce a food item showing the desired properties. In most cases this product can be stored for a certain time since processing usually includes measures for preservation. However, during processing also undesirable changes may occur which may influence the

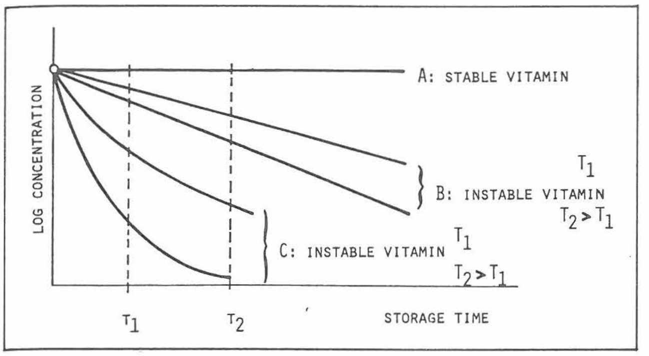

Fig. 7 Change in the vitamin content of a dietetic food during storage

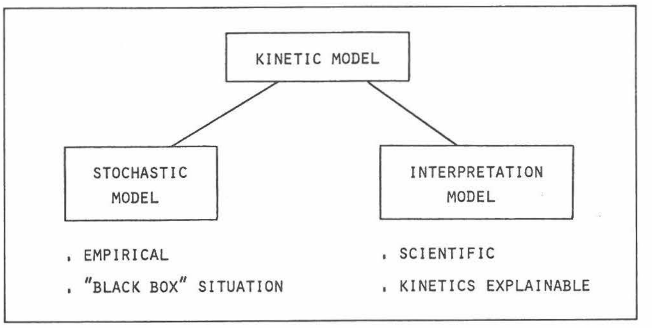

Fig. 8 Kinetic models for the description of changes in properties and quality of foods

product quality. In case of known mechanisms, the quality of the endproduct is predictable; if the influencing parameters are unknown, it is necessary to determine the quality of the endproduct. Subsequently the product is stored until consumption; due to abiotic processes, changes may take place also during storage. To know the kind of changes and their kinetics is essential for an optimization of the production process. This applies particularly to food the composition of which is precisely defined and which is intended for therapeutical use in certain diseases or deficiencies.

3.1 Changes caused by processing

The "art" of food processing is changing more and more into the "science" of food processing. Today processes are systematically analyzed and described, and corresponding models are established. In the past, quantitative data specifying the influence of processing conditions on food constituents were obtained predominantly from end-point determinations which did allow any conclusions to the kind of changes taking place during a certain process or treatment.

In the case of dietetic food listed in **Fig. 4,** it is essentially one component which is either fortified, reduced or which is completely eliminated. Whereas the process of fortification represents no problems in general, the reasons for this kind of treatment may be quite different (5).

Restoration is the addition of nutrients to a food to compensate for losses of nutrients during processing, whereas fortification is the addition of nutrients at levels higher than those found in the original or comparable food. Enrichment is the addition of nutrients to levels specified in standards of identity, and supplementation is a general term encompassing all of the above, i. e., the addition of a nutrient at any level.

These definitions already suggest that there are various reasons for nutrient deficits in food. A reduction in one component is accomplished primarily by selection of raw material, or by a corresponding composition of the daily diet. Gluten-free products, for instance, must not contain wheat, rye, barley, oats nor the protein-containing constituents of these. In case of low-sodium products, the permissible sodium content is limited to a defined level; this represents no difficulties for producers, since raw materials for foods usually are relatively deficient in sodium. Problematical rather are those products in which changes during processing are unavoidable. This applies to vitamin-rich products in particular because the majority of vitamins is sensitive to heat.

To dietetic food listed under 1 (food intended for partial or complete supply) and 3 (other food) of **Fig. 5,** the principles governing the manufacture of normal food apply. Substitutes are relatively unproblematical. But there are a few exceptions such as aspartame which changes under high processing temperatures. The use of this sweetener in food is therefore limited, particularly in baking and frying processes and in longterm sterilization. Aspartame can be used in UHT and HTST treatments where the product is rapidly cooled afterwards, particularly if the products show pH values between 3 and 5.

These few examples demonstrate that it is necessary to know what changes those components which are responsible for the specific effect or properties of a dietetic food undergo during processing, and that also defined processing conditions are required to predict the influence on the food concerned.

3.2 Changes during storage

Preserved food in particular is expected to show adequate storage stability. Macronutrients generally change little; but there are still several mechanisms which influence also the nutrition-physiological quality of such food. The changes in question are nearly always undesirable ones.

Products of precisely defined composition are expected to be stable as well; but they behave the same way as the group of food mentioned before, as is exemplified by formula diets.

Formula diets are based on certain isolated food components which are selected to fulfil specific dietetic requirements (6). These products which are highly perishable are preserved mainly by sterilization or drying. Either product form, however, undergoes changes during storage which may affect the vitamin contents, for instance. Vitamin levels indicated on the package therefore are minimum quantities which differ from the actual vitamin content which can be expected to be higher.

A qualitative example is shown in **Fig. 7.** Stable vitamins represent no problems insofar. Depending, however, at what time of the process the substance is added, losses due to processing must be restored. Examples B and C refer to unstable vitamins with different kinetics of changes. Various vitamins were found to follow a mechanism corresponding to B, i. e. losses per time are higher at the beginning of storage and decrease with increasing storage time. The mechanism corresponds to a first-order reaction. In case C, the mechanism is even more pronounced and reflects a second-order reaction rather. The problem now is that producers indicate precisely those vitamin contents on the package which products show at the last date of use which must be indicated as well. If the product is consumed earlier, however, several components can be expected to be present at higher concentrations than indicated on the package. A computation of the actual levels is possible only to someone who knows the initial concentration, the kinetics of changes and the storage time.

In the case of dietetic food it is in general not so difficult to determine or indicate the initial contents, and it seems

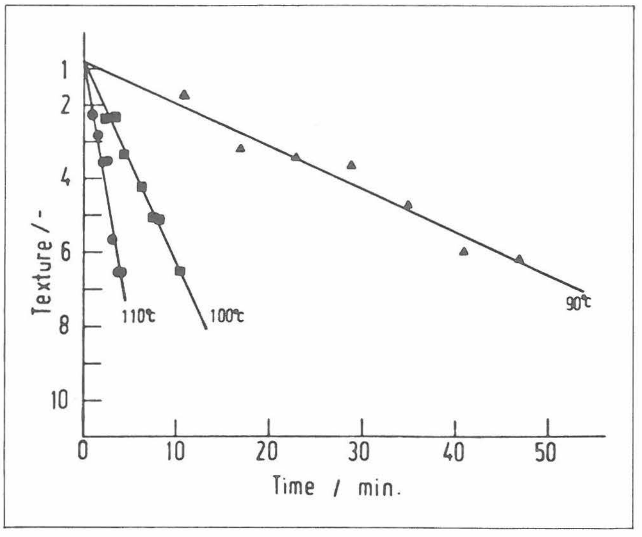

Fig. 9 Development of the texture of potatoes during cooking

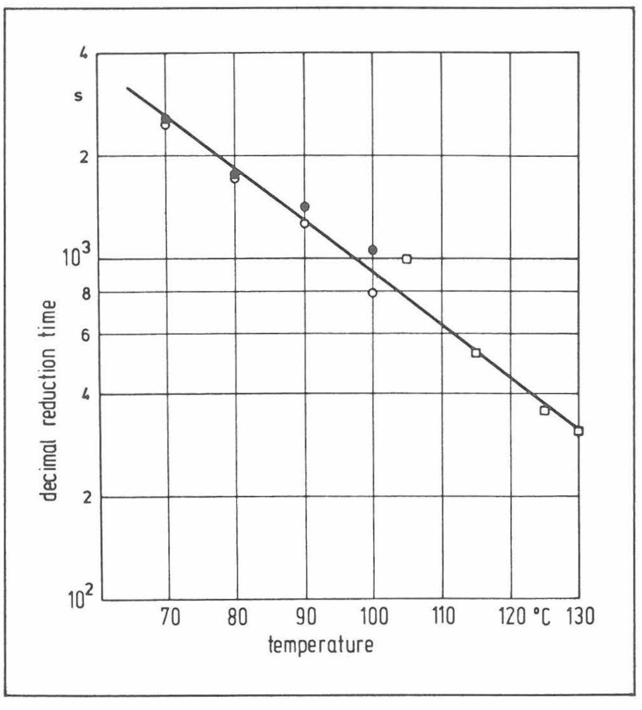

Fig. 11 Vitamin C losses in spinach during thermal treatments in water

Equ. [1] $$-\frac{DA}{DT} = K \cdot A^N$$

A = NUTRIENT CONCENTRATION
T = TIME
N = ORDER OF THE REACTION
K = RATE CONSTANT

Equ. [2] $$K = K_0 \cdot E^{-\frac{E_A}{R \cdot T}}$$

K_0 = PRE-EXPONENTIAL FACTOR
E_A = ACTIVATION ENERGY OF THE REACTION
R = GAS CONSTANT
T = TEMPERATURE IN °K

Fig. 10 Mathematical expressions for the description of nutrient losses

recommendable anyway to inform consumers also of the storage times. The actual problem hence are the kinetics of change.

3.3 Kinetics of quality changes

The kinetics of quality changes, i.. the mathematical description of changes in a food quality or property, is a discipline relatively new also to food engineers. There are two possibilities of approach for establishing kinetic models as shown in **Fig. 8** (7): stochastic models are required where changes are so complex that the change itself is determinable only by its effect. The majority of sensory changes, for instance, is caused by a combination of very different components, and the changes are only infrequently attributable to a simple defined reaction. Interpretation models, on the other hand, are based on the actually present reaction mechanism, to which the mathematical description, in a general form, is applicable and in which only the corresponding coefficients and constants change from case to case.

One example shall be presented for each of the model situations to illustrate the problems involved. A stochastic model shall be explained by texture changes, i.e. a parameter of sensory quality, during thermal treatment of potatoes, whereas the degradation of thermolabile vitamins may exemplify interpretation models.

The changes in the texture of food products during preparation or other thermal processes have been frequently investigated, but have so far not been completely elucidated. They result from complex reactions which are lastly responsible for the final food texture. This situation is reflected by a so-called black-box model, i.e. the target parameter texture is determined and correlated to the relevant test parameters in defined process conditions, here temperature and time of the treatment, with remaining parameters being the same.

Fig. 9 shows the changes in potato slices of one variety which were treated in water (8). The score of 1 for the sensorily determined texture corresponds to the raw product, 6 means optimally cooked, and a value of greater than 6 means an overcooked product. It becomes obvious from the graph that the change in texture is a linear function of time, provided that the temperature is constant; and that, furthermore, the effect is the stronger the higher the temperature. This temperature dependence is expressed by the so-called z-value which is 18°C in the present case and also in several other potato varieties.

The dependencies can be described mathematically so that, once the kinetics are known, the cooking effect can be determined for any temperature-time relation.

In the case of dietetic foods, possible changes in the vitamin content are of special significance. These changes are most pronounced during the usual preparation and preservation processes at temperatures between about 70 and 130°C. For several vitamins in several products, mathematical expressions corresponding to zero-, first- or second- order were developed (9).

The first equation shown in **Fig. 10** describes the change in concentration of a substance at constant temperature, the second describes the rate constant as a function of temperature. It is the so-called Arrhenius equation with the activation energy E_a indicating how strongly a reaction depends on the temperature.

Vitamin C is predominantly governed by the laws shown in **Fig. 10. Fig. 11** shows the relation between decimal reduction time and temperature for vitamin C in spinach (10). It becomes obvious that there is a logarithmic connection between temperature and time. The straight line comprises all those combinations of temperature and time leading to a decrease in the vitamin content by factor 10^{-1}. The change hence can be described and explained by means of this interpretation model.

Tab. 1 Storage times in days after which vitamin concentration in processed foods is decreased by 10%

Product	Vitamin		
	C	B_1	B_2
Chilled	1.5	2.6	4
Pasteurized/Chilled	9	16	23
Deep frozen	52	93	140
Sterilized	52	93	140

Such losses result not only from thermal treatments, but also from the storage of food under usual storage conditions. The mechanism of change during storage is different, however; for important vitamins such as vitamin C, B_1 and B_2 changes as a function of time can be described by a O-order equation, i. e. losses per time unit are constant. **Tab. 1** shows the results obtained from a great many studies on different treated food (11). It should be taken into account that these mean values include very different products and that individual values therefore may fluctuate considerably. However, the data still reflect a certain tendency and illustrate that changes of partly considerable extent must be expected to take place during storage.

4. Consequences

The effects of treatment and processing on the quality of food apply also to dietetic food products. For several categories listed under 2.0 they are as important as for usual food products. These facts are of particular significance, however, in those dietetic food categories in which the composition is precisely defined.

Information concerning labile ingredients is to be interpreted as minimum contents. For a precise information in the individual case, initial content, kinetics of changes of components under the given conditions and the time elapsed between production and consumption must be known.

The usual laws governing changes in food during treatment and processing apply also to dietetic food. Depending on the kind of dietetic product, however, changes in properties and quality parameters must be evaluated in a different way as in the case of usual food which even complicates the problem. In dietetic food, the significance of quality and of the mechanisms of quality changes must therefore always be kept in mind.

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