II Application of Research Findings to the Development of Commercial Flavourings

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1 Introduction

It is estimated that each year between fifty and one hundred million US dollars are invested in flavour research and the combined efforts in industrial and institutional laboratories must certainly be ranked among the major research efforts in the food field. Since flavour is inseparably linked with food, it is only logical that the research efforts in both fields have very much in common. Some topics of modern flavour research could just as well be filed under food research.

Flavour research involves the chemist, the physicist, the biochemist, the microbiologist, the food technologist, the toxicologist, the nutritionalist, and the flavourist, and in order to apply research findings to the development of commercial flavourings, quite often physiological, psychological, and even sociological and ethnological aspects have to be considered. The development of food flavours has many facets. Three problematic areas have been chosen which occupy much of our time. These may help to explain that the development of new and better food flavours is not only a function of analytical capacity.

2 Research and Food Safety

In the early days of flavour research new or known chemicals which exhibited more or less pleasant flavour properties were incorporated into commercial flavours without any of today's considerations. Fortunately, the knowledge and the procedures in those early days were rather limited, so that only simple chemicals, mainly esters, were used commercially. Today the situation is different. The large number of known flavour substances already permits an indefinite number of combinations, leading to all sorts of nuances of flavour, yet we still need more insight into the natural pathway of flavour generation, and we need more flavour chemicals in order to develop those flavours which cannot yet be made in reasonable qualities, *e.g.* meat, vegetables, bread, and roasted products.

The analytical part of flavour research today is exclusively geared to detect those food components which are responsible for or which contribute to the specific flavour of a food. Flavour research must however be limited by our concern about the safety of our products. Food safety cannot be achieved without flavour safety!

The analytical tools which are at our disposal will certainly discover hundreds of new constituents of natural flavours, but our knowledge of possible hazards requires that none of these substances should enter our flavours if there is even the slightest doubt about their safety.

There are only two countries which permit *expressis verbis* in their food law the utilization of those flavouring substances which are known under the term 'nature-identical'. Only one country has published a list of permitted synthetic flavouring substances. In all other countries practically no reference can be found as to what is and what is not permitted. As much as the flavour industry welcomes the liberty of using research results without public disclosure, it also realizes the burden and the responsibility of its trade. Responsibility in this context does not mean bearing the burden and the consequences afterwards, but endeavouring to the best of its knowledge and conscience that no adverse effect will be encountered. It is obvious that it neither wants to take risks nor can it afford to do so. But only very few official publications or statements indicate how new flavouring substances can be tested and how undue risks can be excluded.

The flavour industry finds itself in the situation of having to decide on its own how to handle this problem. The decision as to whether a newly isolated, unique flavouring substance, the result of many hours work of a flavour chemist, should be used by the flavourist, who again invests much time to evaluate the potential of this material before he starts using it in his flavour creations, requires the utmost care and attention. Those who have to take these decisions can receive scientific help from toxicologists and pharmacologists. They can base their considerations on two systems which have been published and which so far have not been proven to be erroneous, the FEMA approach,[34] and a paper published by the Food Protection Committee of the National Research Council.[35]

The following criteria offer a reasonable system for the evaluation of the relative safety of flavouring substances: (*a*), chemical structure; (*b*), purity; (*c*), functional properties; (*d*), dosage in food; (*e*), total consumption anticipated; (*f*), structural relationship with chemicals of known toxicity and/or known metabolism; (*g*), toxicity data; (*h*), occurrence in traditional food; (*i*), toxicological significance.

A. Chemical Structure.—The FPC publication differentiates between 'simple' chemical structures and complex molecules. In this context 'simple' means 'straight chain or branched chain aliphatic alcohols, acids, and esters, mononuclear aromatic compounds containing only carbon, hydrogen, and oxygen and equipped with one or more functional groups that include hydroxyl, aldehyde, and keto'. These substances are recognized as being practically non-toxic.

Pyrazines, thiazoles, pyridins, and other more complex chemicals are not regarded as 'simple' and they should be evaluated more carefully and with more reservations.

[34] R. L. Hall and B. L. Oser, *Food Technol.*, 1965, **19**, 151.

[35] Guidelines for estimating toxicologically insignificant levels of chemicals in food. Food Protection Committee, National Research Council, National Academy of Sciences, Washington DC, 1969.

B. Purity.—This criterion is of little importance in so far as flavouring substances represent only p.p.m. in food and any impurities in the order of a few percent would be present in food in extremely tiny quantities far below any significant concentration. Unless the impurities consist of heavy metals, compounds of heavy metals, or other substances known to be highly toxic, impurities can be neglected for practical purposes, though their chemical character must be known.

C. Functional Properties.—This reference is again found in the FPC report and it has obviously been taken over from another source[36] where a compilation of all published toxicity tests has shown that only heavy metal compounds and chemicals manufactured for the purpose of the destruction of biological life, exhibit toxic properties in tests with experimental animals at dietary levels below 40 p.p.m.

It is very unlikely that any of the known toxic substances which have been developed and which are used by virtue of their toxicity, will ever be incorporated into food flavours.

D. Dosage in Food.—It is interesting to observe that practically all of the newly discovered constituents of natural food flavours are active at extremely low concentrations (flavouring substances occurring naturally in larger quantities were found long ago and are publically known in literature).

E. Total Consumption Anticipated.—This figure becomes important when approximate *per capita* consumptions need to be calculated. Whenever this figure surpasses a certain amount, responsible flavour companies will have to reconsider their original decision: they will have to support it by further studies.

F. Structural Relationships with Chemicals of Known Toxicity and/or Known Metabolism.—To incorporate these considerations into the evaluation of a new chemical certainly requires experience, and pharmacologists and toxicologists should be consulted. In spite of insufficient knowledge about the relationship between structure and pharmacological properties, quite a number of critical structures are known, which permit the prediction of the possibility of hazards.

G. Toxicity Data.—Whenever doubt is cast on the safety of a new substance toxicity studies become necessary. The Ames Test[37] may be helpful in verifying the absence of carcinogenic properties. Also, 90 day feeding studies and metabolic investigations are carried out. More stringent studies are economically justified only when the chemical under question is to be used in very large quantities. This, however, applies only to very important and widely used substances. Whenever the economics do not permit such studies, the chemical has to be dropped.

[36] J. P. Frawley, *Food Cosmet. Toxicol.*, 1967, **5**, 293.
[37] J. McCann, E. Choi, E. Yamasaki, and B. N. Ames, *Proc. Nat. Acad. Sci U.S.A.*, 1975, **72**, 5135.

H. Occurrence in Traditional Food.—This criterion is a very important one for the flavour industry. The well-known argument that whatever is contained in traditional food, the safety of which is beyond any doubt, must be regarded as safe as long as the daily intake of the synthetic material lies in the same order of magnitude as that of the natural constituent, is still the main basis for the safety evaluation of flavouring substances.

I. Toxicological Insignificance.—The FPC report covers this aspect widely. A careful extrapolation of its conclusions—the report has not been compiled for flavouring substances—leads to levels of toxicological insignificance of the order of between 1 and 10 p.p.m. in food, depending on the evaluations of the various criteria.

To apply the listed criteria in a responsible manner for the evaluation of newly discovered flavour constituents of traditional food is today the most important basis for the decision whether and how research results can be applied in commercial flavours. Self-discipline and a highly ethical conscience are necessary. The flavour industry wants to defend its present relative freedom in some countries and it wants to be regarded as honest, safety conscious, and a reliable partner of both the consumer and the food industry.

3 Food Science

The objectives of modern flavour research have become more complex.

While the discovery of new substances in food was the primary objective some years ago, flavour research today contributes to make the work of the flavourist more scientific by supplying him with data about the physico-chemical fate of flavouring substances in food.

Modern food technology, the various processes, the very large number of food items, and certainly also the increasing quality consciousness of the consumer require more and more that flavours be tailor made. If the parameters of food technology, heat stress, time, and pH are disregarded, flavours may perform unsatisfactorily. Mostly, it is said that flavour is unstable. If we were able to stabilize our flavours, or if we could predict in which application instability can be expected, we would largely facilitate the development of flavours for specific food and specific applications. Looking closer at the phenomenon of instability, or better incompatibility, we can distinguish between the following possibilities: physical instability; chemical instability (*i*), innate; (*ii*), in food; interactions of flavour components with food ingredients.

Physical instability is in most cases due to the volatility of flavour components at elevated temperatures. The poor flavour retention during the baking procedure is a well known difficulty. While it is technologically possible to protect volatiles in such a manner that evaporation losses become negligible, these protective measures normally do not yield products which release the flavour at the time and at the conditions of consumption. A compromise has to be found between the reduction of evaporation losses and ready release properties under consumption conditions.

Research becomes necessary to overcome chemical instability problems. Oxidation of sensitive flavour components is well known to every flavourist. Polymerizations, hydrolyses, and condensations occur as well, but they are only of minor importance. We also know some cases where the natural flavour components themselves are unstable, *e.g.* those responsible for the flavour of freshly baked bread.

A fairly new type of 'instability' is caused by interactions of flavour components with food ingredients. It is not simply a case, for example, that a rancid, peroxide-containing fat, which might accidentally find its way into food, rapidly destroys most of the commonly used flavour components. Interactions occur between flavouring substances and such common food constituents as carbohydrates, proteins, and fats. The first investigations in this field were concerned with the poor flavour retention in extrusion procedures, especially during the extrusion of soy protein.[38] It became evident that soy protein and the extrusion operation were a very complex field for exercises, and valid conclusions could not really be drawn. It could only be established that reversible and irreversible bindings of flavour components to some part of the soy protein occurred.

Consequently the behaviour of easily detectable single flavouring substances in model food systems has been studied.[39] The concentrations of the flavouring substance under question were determined by different analytical procedures, extraction, steam distillation, high vacuum transfer, head space techniques and by sensory analysis with the help of a trained panel. Table 7 demonstrates one typical result of these studies.

Table 7

System	*Citral content measured by extraction in % of added amount*		
	Added amount (p.p.m.):		
	100	1000	10 000
5% Maltodextrin in H_2O	78	—	85
10% Lactose in H_2O	81	82	77
10% Casein in H_2O	76	65	48
10% Soy isolate in H_2O	42	22	7

The significance of such results to the practical work of the flavourist is obvious. We can deduce from this table for instance that carbohydrates can, and soy protein cannot, easily be flavoured with citral. We can also deduce that the increase of the citral concentration in a vegetable protein will markedly affect its sensory level.

The stability of flavour chemicals in food depends of course also on time, temperature, and for example, the pH of food. These parameters make the

[38] H. A. Gremli, *J. Amer. Oil Chem. Soc.*, 1974, **51**, 95A.

[39] B. A. Gubler, H. Gremli, J. Wild, and C. Verde, Proceedings International Union of Food Science and Technology, Madrid, 1974; B. A. Gubler and H. Friedrich, Lecture at the 4th Meeting of the Austrian Society for Nutrition Research, 1977.

investigations quite voluminous, for instance the results of the citral stability as a function of time (Figure 2).

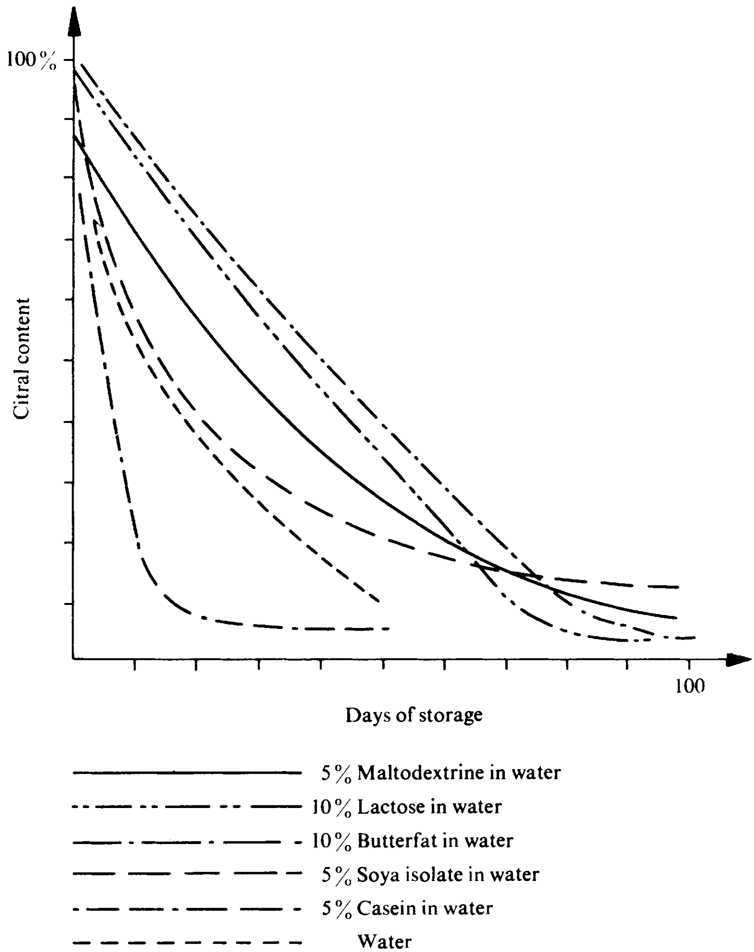

Figure 2 *Citral stability in various food models. Storage temperature:* 4 °*C*

Quite severe losses of flavour activity can be observed in all tested systems. The drastic and immediate drop of the citral concentration in the casein suspension is the most pronounced.

The stability of other important flavouring substances in different systems as well as the influence of various stabilizing materials, food additives or substances naturally present in food have also been studied. The results are still not easy to interpret; however, only the surface of this field has been touched and we are confident that ultimately these studies will lead to a better understanding of the complexity of food and also to better flavours by enabling our flavourists to use our raw materials in a more effective and a more economical way.

4 Flavour Creation

The development of a new flavour requires teamwork between the researchers, the flavourists, the technologists, and a panel representing the target consumer. The subjectivity of flavour perception requires that the communication between the participants is shaped in such a manner as to overcome this handicap. The flavourist will for instance smell the effluents of the gas–chromatograph in order to pinpoint those notes, that is to say substances, which he requests.

Whenever a new substance has been isolated from a natural source, the flavourist has to use all his skill and his experience in order to find out how this material fits into his flavour. Missing the right concentration, or putting the new chemical into a test mixture of flavour chemicals of unsuitable composition might lead to the rejection of a potentially important new raw material. There are only a few flavour chemicals—known as impact chemicals—which can easily and immediately be associated with specific food. The majority of flavouring substances fit into a number of food flavours. To remember at the right time the right association, requires an extensive, abstract, and creative imagination. Semi-mathematical models have been developed to facilitate this task, but a substitute for experience and talent has not yet been found. The communication between the flavourist and the chemist is therefore not only a matter of a common vocabulary, it is a matter of mutual understanding.

The creation of a new flavour is of course largely facilitated by available analytical information and literature studies, and seen through the optic of a pure chemist it should be easy to reconstitute a flavour using all this background knowledge. Yet, experience has shown that the task is really much more complicated in as far as the reconstituted mixture of analytically detectable substances of a food usually fails to perform as it should. A very critical interpretation of the analytical results is necessary to know which of the single substances are essential and how they have to be dosed in order to achieve the desired result. It is not only the well known threshold value which counts, it is the much more complicated system of flavour strength as a function of concentration and solvent. This relationship is different for each of the known—and also for the so far unknown—flavouring substances. A tremendous memory, experience, and patience are necessary to formulate a flavour to full satisfaction. These talents of the flavourist are quite often referred to as 'artistic'.

But the application of analytical results is only one part of a flavour creation. Market research results as well as legislative and economical aspects have to be taken into account. The following flow sheet of flavour creation lists the most important conditions which have to be considered (Figure 3).

As much as the flavourist and the chemist have to guide each other carefully, just as important is the connection between the flavourist and the food technologist who has to learn how to use a flavour in food for best results. Today, our

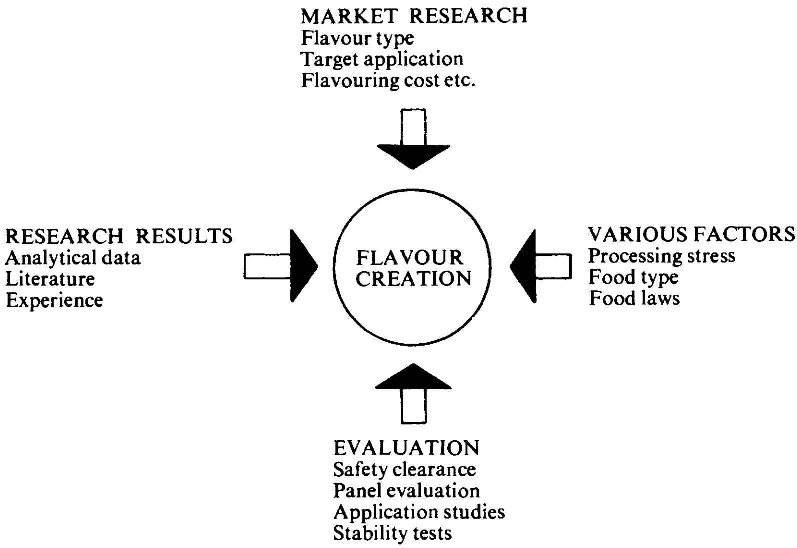

Figure 3

application laboratories are far from being only 'home made sweet manufacturers'. More and more in this field we encounter the limits of traditional craftsmen's knowledge, which calls for real food research. The utilization of sugar substitutes, the development of cocoa free chocolate and other food novelties are examples of this type of work which in turn usually calls for other specific and suitable flavours.

At the finish of the development of a new flavour or a new food stand the last communication barriers, the company panel, and finally the large panel, the consumer. And he, still being 'the King', decides whether the research has been worthwhile.