Interaction of Flavor Compounds with Soy Protein

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ABSTRACT

The addition of flavors to soy protein products often results in a loss or change of the flavor. Processing parameters and especially the specific sorption properties of soy protein for many organic compounds strongly influence the flavor performance in such products. A systematic study on the interactions of individual classes of flavor compounds (alcohols, carbonyls, etc.) has been conducted in our laboratory. We will report on the methods used and the results obtained and will discuss the practical consequences for flavoring soy products. The discussion also will include the influence of processing conditions during texturization of soy protein on the flavors.

INTERACTIONS OF FLAVOR COMPOUNDS WITH SOY PROTEIN

When a flavoring compound is added to soy protein in an aqueous medium, a change in the flavor appearance generally is noticed even without any heat treatment involved. This change is due to one or both of the following reasons: (a) The beany flavor of the soy protein itself interferes with the added flavor, either suppressing it or combining with it to give an altered flavor impression. (b) Some of the compounds that make up the flavoring composition interact with the soy protein.

The present study deals with the interaction between flavor compounds and soy protein. The interactions can be reversible or irreversible and can be due to chemical reactions or physical sorption.

Usually the manufacturer of soy protein-containing foods prefers flavoring compounds which are not affected by the protein. In certain cases, however, a reversible interaction may have benefits, e.g. it may protect the flavor compounds during the processing of the food. When the final food product is masticated, the bound flavors may be released again and perform their function on the palate of the consumer.

For a flavorist who is creating a flavor for soy protein foods, it is important to know which of the compounds will react with soy protein. He wants to know whether the interaction is reversible and to what extent added flavors are taken up by the protein.

We have developed an analytical method which allows us to determine whether a flavor compound reacts reversibly or irreversibly with soy protein and what percentage of an added flavor is bound by the protein. The method is sensitive enough to work with dosages down to 0.2 mg flavor compound/g dry soy protein. In an edible product containing 20% soy protein this represents a dosage of 40 ppm particular compound. We feel that the analytical work should be conducted at flavor levels as low as they occur in practical flavor application, which is usually in the ppm region.

METHODS

The flavor compounds were assayed by quantitative gas chromatography on a glass column (3 mm x 3 m) packed with Carbowax 20-M on Chromosorb G.

TABLE I

Retention of Aldehydes by 5% Soy Protein Solution

Compound	Percentage retention	Compound	Percentage retention
Hexanal	37-44	2-Hexenal	68-75
Heptanal	62-70	2-Heptenal	82-88
Octanal	83-85	2,6-Nonadienal	90-98
Nonanal	90-93	2,4-Nonadienal	92-97
Decanal	94-97	2-Decenal	100
Undecanal	96-100	2-Dodecenal	100
Dodecanal	94-100		

TABLE III

Retention of Varying Amounts of Volatile by 5% Soy Protein Solution

Mg heptanal/100 ml protein solution	Percentage retention	Mg volatile bound/g protein
1	70-75	ca. 0.14
2	71-75	ca. 0.28
5	68-74	ca. 0.7
10	62-70	ca. 1.4
50	66-73	ca. 7.0
Mg nonanone/100 ml		
2	58-64	ca. 0.2
5	58-68	ca. 0.6
10	54-61	ca. 1.2
15	57-66	ca. 1.8
20	55-60	ca. 2.4

TABLE II

Retention of Ketones by 5% Soy Protein Solution

Compound	Percentage retention	Compound	Percentage retention
2-Hexanone	5-16	4-Methyl-3-pent*en*-2-one	25-39
2-Heptanone	9-22	6-Methyl-5-hept*en*-2-one	36-47
2-Octanone	29-43	3-Oct*en*-2-one	16-29
2-Nonanone	54-61	6-Non*en*-2-one	42-51
2-Decanone	59-68		
2-Undecanone	28-39		
2-Dodecanone	17-32		
2-*Phenyl*methylketone	9-21	2-*Furyl*methylketone	0
(4-Methyl-2-*phenyl*)-methylketone	45-55	(5-Methyl-2-*furyl*)-methylketone	0
(3,5-Dimethyl-2-*phenyl*)-methylketone	48-60	(2,5-Dimethyl-3-*furyl*)-propylketone	58-71
		2-*Furyl*butylketone	55-64

TABLE IV

Retention of Aldehydes by 5% Soy Protein Solution in Two Systems

Compound	Percentage retention head space system	Percentage retention vacuum transfer system
Hexanal	37-44	<5
Heptanal	62-70	<5
Octanal	83-85	6-11
Nonanal	90-93	10-19
Decanal	94-97	13-22
Undecanal	96-100	24-36
Dodecanal	95-100	29-38
2-Hexenal	68-75	28-34
2-Heptenal	82-88	36-45
2,6-Nonadienal	90-98	24-30
2,4-Nonadienal	92-97	29-37
2-Decenal	100	38-48
2-Dodecenal	100	43-51

TABLE V

Retention of Volatiles by Soy Protein during Drying

Compound	Percentage retention	Compound	Percentage retention
Hexanal	72-78	2-Hexenal	93-95
Heptanal	76-84	2-Heptenal	97-100
Octanal	79-87	2,6-Nonadienal	100
Nonanal	88-93	2,4-Nonadienal	100
Decanal	100	2-Decenal	100
Undecanal	100	2-Dodecenal	100
Dodecanal	100		
Isopentanol	36-46	2-Hexanone	51-55
Hexanol	55-62	2-Heptanone	65-68
2-Octanol	78-87	2-Nonanone	83-86
1-Octen-3-ol	70-75	2-Undecanone	95-98
2-Phenylethanol	85-88	2-Dodecanone	100
1-Phenylethanol	78-86	2-Tridecanone	100
Benzylalcohol	80-84		

Head Space Method

The flavor compounds were reacted with 100 ml 5% solution of soy protein isolate (Promine-D, Central Soya) at pH 6.9 in a thermostated 1 liter flask (22 C) equipped with a stopper especially modified for head space analysis. The contents of the flask were stirred gently; and, at regular intervals, samples (5 ml) were withdrawn from the gas phase and injected into the gas chromatography column. The individual compounds in the samples were quantitated and expressed as percentages of the corresponding results from control runs in phosphate buffer at pH 6.9. Subtraction of this percentage from 100 gave the decrease in free volatiles which we expressed as percentage retention. In the results the retentions are given as ranges of variation among three parallel sample and control runs.

High Vacuum Transfer Method

Promine-D solution (100 ml 5%) at pH 6.9 containing the flavor compounds to be tested were stirred at 22 C in a 1 liter flask A for 1 hr and then shell frozen at -70 C. The flask subsequently was connected with a joint to a second flask B and the system was evacuated immediately to 0.05 mm Hg and sealed. The contents in flask A were thawed gently; and flask B was immersed in a chilled bath (-20 C), whereupon the water and the free volatiles distilled into flask B. The transfer of the liquid phase proceeded at ca. 10 C and was complete after 6-8 hr. The volatiles in the distillate were extracted with methylene chloride and assayed by standardized quantitative gas chromatography the same way as described above. Again the retention was calculated by comparing the results with those from control runs devoid of soy protein.

RESULTS

Compounds assayed with our method so far include: saturated and unsaturated aldehydes; saturated, unsaturated, phenolic, and heterocyclic ketones; and saturated, unsaturated, and phenolic alcohols.

Head Space System

In this system, equilibria of the volatiles between the gas and the liquid phase were formed within 30 min. They remained undisturbed throughout the experiment; the 5 ml gas samples occasionally withdrawn from the 1 liter gas phase had no influence on the stability of the equilibrium. A retention observed could, therefore, be due either to a reversible or an irreversible interaction with the protein.

Of the alcohols none reacted with the protein. Aldehydes and ketones, however, showed a significant interaction with the protein (Tables I and II).

The results indicate an increase in retention with the mol wt of the aldehydes; ketones follow a different pattern with the retention rate increasing up to 2-decanone and decreasing with compounds larger than that. Unsaturated aldehydes are retained more strongly than the corresponding saturated ones. The comparison between unsaturated and saturated ketones is difficult for lack of a homologous series. Phenolic ketones also interact with the protein, whereas, of the ketones containing a furan ring, the smaller compounds do not react with the protein.

The experiments were conducted with additions of 10 mg each individual aldehyde and ketone to 100 ml 5% soy protein solution. The retention rate was the same whether each volatile was tested individually or in the presence of others. In an attempt to determine the amount of volatile that could be bound by a given amount of protein, we varied the dosage of heptanal and 2-nonanone (Table III).

An equilibrium seems to exist between bound and free volatile which is independent of the amount of volatile added. Apparently even the higher dosages of volatiles were insufficient to saturate the protein. At the dosage levels common in flavor application, we may, therefore, be faced with losses of ca. 70% added heptanal and 60% 2-nonanone. Consequently, the loss of the other aldehydes and ketones in flavoring a soy protein food may be of the order of magnitude indicated in Tables I and II.

High Vacuum Transfer System

In this system, any equilibrium between bound and free volatiles is constantly disturbed; a retention can be due only to an irreversible interaction. By comparing the retention rates measured with the two different methods, we could determine whether a given volatile reacted reversibly or irreversibly with the soy protein.

None of the ketones were retained during the high vacuum transfer; hence, the retention observed in the head space system must be caused by a reversible interaction. The aldehydes, however, were retained partially even under high vacuum (Table IV). The interaction of aldehydes with soy protein appears to have reversible and irreversible features.

PRACTICAL CONSEQUENCES

Alcohols do not interact with soy protein and are, therefore, not affected in their flavor performance.

Aldehydes strongly react with the soy protein, especially the unsaturated compounds. Of the latter a certain percentage is permanently bound, due to an irreversible reaction with the protein. A greater portion binds reversibly to the protein; this suppresses their primary flavoring impact and makes them unsuitable for beverages containing soy protein. When they are used in foods that require mastication,

e.g. meat substitutes, they may be released gradually during consumption. Still to obtain an instant flavor perception, an excess of the particular compounds has to be added. The excessive amount can be estimated from the percentage that was shown to react with the protein.

The above discussion correspondingly applies to those ketones which were demonstrated to interact with the soy protein.

What happens to the flavor compounds in a soy protein food during drying? We have studied this question with the high vacuum transfer system representing a model for a mild drying process. The 5% soy protein solution was replaced with a 50% soy dough containing the added volatiles (Table V).

All compounds tested were retained remarkably during drying. The retention seems to be quite unspecific and is related probably only partially to particular interactions of the protein with the volatiles. It is rather a general feature of natural substances of high mol wt (proteins, polysaccharides) during drying processes and is due mainly to inclusion phenomena.

When we reslurried the dried residues to give a 5% solution in water and repeated the high vacuum transfer, the alcohols and ketones were quantitatively distilled off. The aldehydes were retained in a pattern corresponding to that of the original transfer in 5% soy protein solution (Table IV).

We can expect a considerable retention of flavor volatiles incorporated into a soy protein food during a slow and relatively mild drying process. Higher drying temperatures result in a denaturation of the protein which might lock in a portion of the added flavor to such an extent that it is lost for the consumer.

The results obtained in the present study can be applied to foods and beverages containing a portion of unprocessed soy protein. In texturization processes, however, such as extrusion-cooking, the situation is different. With the sudden flash-off of moisture at the extruder die, a sizable portion of free and reversibly bound volatiles can escape. On the other hand, the rearrangement of the protein molecules to fibrous structures may capsule the volatiles and protect them from loss. Here again the encapsulation should not prevent the flavors from being liberated during mastication of the food product.