Review Article

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Digestive stimulant action of spices : A myth or reality?

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Spices have long been recognized for their digestive stimulant action. Several spices are also employed in medicinal preparations against digestive disorders in traditional and Indian systems of medicine. Earlier reports on the digestive stimulant action of spices are largely empirical; only in recent years, this beneficial attribute of spices has been authenticated in exhaustive animal studies. Animal studies have shown that many spices induce higher secretion of bile acids which play a vital role in fat digestion and absorption. When consumed through the diet also spices produce significant stimulation of the activities of pancreatic lipase, amylase and proteases. A few of them also have been shown to have beneficial effect on the terminal digestive enzymes of small intestinal mucosa. Concomitant with such a stimulation of either bile secretion or activity of digestive enzymes by these spices, leading to an accelerated digestion, a reduction in the food transit time in the gastrointestinal tract has also been shown. Thus, the digestive stimulant action of spices seems to be mediated through two possible modes: (*i*) by stimulating; the liver to secrete bile rich in bile acids, components that are vital for fat digestion and absorption, and (*ii*) by a stimulation of enzyme activities that are responsible for digestion. This review highlights the available information on the influence of spices on the digestive secretions and enzymes.

Key words Bile secretion - digestion - digestive enzymes - food transit time

The use of spices as food additives has been practiced widely since ancient times. Apart from enhancing the taste and flavour of food, spices have been widely believed to exert digestive stimulant action. A few medicinal properties of spices such as tonic, carminative, stomachic, diuretic, and antispasmodic have long been recognized. These attributes, largely empirical, nevertheless efficacious, have earned them pharmacological applications in the indigenous systems of medicine as digestive stimulants and to relieve digestive disorders[1,2]. Several preparations available to correct digestive disorders contain a few specific spices besides other plant substances. A few preparations make use of digestive enzymes, while many others contain plant substances such as chirata, gentian, calama, quassia, orange peel and many spices. Spices such as mint, garlic, ginger, ajowan, cumin, fennel and coriander are the usual ingredients of digestive stimulants, both commercial as well as home remedies. Medicinal properties of some of the spices pertaining to digestion are listed in Table I.

Influence on salivary and gastric secretions

Spices are well recognized to stimulate gastric function. They are believed to intensify salivary flow and gastric juice secretion, and help in digestion[14]. Salivary and gastric secretions are increased when the nerve centres are stimulated by the sense of smell and by the presence of pungent principles in the foodstuff[15]. Glatzel[14] while studying the effect of spices on the secretion and composition of saliva in humans observed that red pepper, ginger, capsicum, black pepper and

mustard enhanced the secretion of saliva and the activity of salivary amylase. Further the saliva stimulating capacity was greatest for red pepper and mustard among these spices.

Pathak and Pai[16] in their study with Indian foods reported a slightly increased acid secretion after food rich in spices, and a greater increase when spices were given along with pulses. Orally administered capsaicin was found to increase gastric acid secretion and mucosal blood flow in the rat possibly through the release of endogenous gastric secretagogues[17]. Contrary to this, Toh *et al*[18] found no such effect of capsaicin on acid secretion. Among the other spices, paprika, black pepper and cinnamon increased the same in humans, while mustard decreased the acid output. Celery, nutmeg and sage did not have any effect on acid secretion[19]. The mucin content of gastric juice was appreciably increased by *Curcuma longa* intake in rabbits and this mucus stimulatory effect was associated with the therapeutic effects of this spice on gastric disorders[20].

The role of spices in digestion is not limited to a single effect, but is a combination of their influences on salivary, gastric, biliary and pancreatic secretions and the terminal digestive enzymes present on the mucosa of small intestine. There has been a renewed interest on their role in aiding digestion through a stimulatory influence on bile secretion and activities of enzymes responsible for digestion, the two prime factors contributing to the process of digestion.

Stimulation of bile secretion

The digestive stimulant action of spices is probably exerted through stimulation of the liver to produce and secrete bile rich in bile acids, which play a very important role in fat digestion and absorption. Sixteen commonly used spices and spice principles have been examined for their effect on bile secretion in our laboratory using experimental rats[21-25]. In these animal models, bile was systematically collected by cannulating the common biliary-pancreatic duct following the spice treatment. The spices evaluated included ginger, coriander, cumin, fenugreek, mustard, asafoetida, ajowan, fennel, cinnamon, tamarind, onion, garlic, and mint and the spice principles-curcumin, capsaicin and piperine. Three spice mixes containing coriander, red pepper, black pepper, turmeric, cumin, ginger, onion, mustard, fenugreek, cinnamon, clove and bay leaves in varying proportions were also tested[26]. The spices were examined for their influence on bile as a result of both a continued intake through the diet for a period of time and as a one-time exposure orally (Table II).

Studies from our laboratory[21-23] and elsewhere[27,28] restricted to a few specific spice principles/spices, namely, curcumin, capsaicin, piperine (the active principles of turmeric, red pepper and black pepper respectively), ginger, fenugreek and cardamom evaluated their effect on the cholesterol turnover in terms of bile acid secretion and their possible hypocholesterolemic action. The hypocholesterolemic spices-curcumin, capsaicin, ginger and fenugreek stimulated bile acid production by the liver and its secretion into bile, while piperine had no such stimulatory influence[21-23]. Ramprasad and Sirsi[27] observed the choleretic effect of curcumin (sodium salt) in anaesthetized dogs. Curcumin almost doubled the bile production with associated increase in bile salts, bilirubin and cholesterol, while the essential oil and other fraction of *C. longa* were relatively less effective than the pigment. Though cardamom is not a known hypocholesterolemic spice, the cholagoguic action of the glucosides of a-terpeneol, its active ingredient as indicated by higher bile acid output was observed in experimental rats[28].

In our earlier studies[21-26], the spices were fed to animals at levels corresponding to about five-times the average human intake based on the spice consumption statistics available for Indian population[29]. It was observed that the food intake was essentially similar in various spice-fed groups and the corresponding control group. Similarly, for single oral administration, the dosages of test spices used corresponded to five times the concentrations normally encountered.

Dietary intake of the test spices either individually or in combination for 6-8 wk generally influences bile acid output profoundly (quantity secreted per unit time). Dietary fenugreek had the highest stimulatory influence on bile acid secretion among the various spices with increase of 80 per cent over the control[22].This is followed by cumin (71%), curcumin (62%), coriander (59%), tamarind (58%), mustard (50%), onion (47%), and ajowan

Table I. Medicinal properties of spices pertaining to digestion

Spice	Medicinal property	Ref.
Ajowan *(Trachyspermum ammi)*	corrects digestive disorders	3
Anise seeds *(Pimpinella anisum)*	carminative	1
Asafoetida *(Ferula asafoetida)*	laxative, antispasmodic, carminative and antiflatulent	2,4,5
Black pepper *(Piper nigrum)*	carminative and laxative; remedy for dyspepsia, diarrhoea, flatulence, nausea and vomiting	2,3,4,8 6
Cardamom *(Elettaria cardamomum)*	antiemetic and stomachic	3
Clove *(Eugenia caryophyllus)*	gastric stimulant and carminative; useful in nausea, indigestion and dyspepsia	7
Cinnamon (*Cinnamomum zeylanicum)*	carminative, astringent and stimulant; antiemetic	7
Coriander *(Coriandrum sativum)*	stimulant and carminative; stomachinc, antibilious, digestive stimulant	3
Cumin *(Cuminum cyminum)*	stimulant and carminative; stomachic and astringent; useful in dyspepsia and diarrhoea	1,2
Fennel *(Foeniculum vulgare)*	carminative	1
Fenugreek *(Trigonella foenumgraecum)*	carminative, tonic	2,3,5
Garlic *(Allium sativum)*	gastric stimulant; carminative	1,6
Ginger *(Zingiber officinale)*	remedy for dyspepsia and indigestion; stomachic relieves stomach pain and nausea	2,3,4
Mint *(Mentha spicata)*	carminative, stomachic, tonic, antispasmodic	1,3 9,10
Mustard *(Brassica nigra)*	useful in abdominal colic, vomiting; gastric stimulant	2,5
Red pepper *(Capsicum annuum)*	remedy for dyspepsia, stomachic and carminative	2,4,11
Turmeric *(Curcuma longa)*	antiflatulent, stomachic, tonic, antacid & carminative; reduces pungency of food by increasing mucin content of gastric juice	12, 13

(30%). Capsaicin and mint showed a small, but significant stimulation of bile acid secretion (17%)[21,24,25]. Among the three combinations of spices tested, spice mix-III exhibited strong stimulatory influence on bile acid secretion, about 106 per cent over the control[26]. The other two cimbinations (spice mix-II and spice mix-I) produced 86 and 38 per cent higher bile acid secretion, respectively (Table II). The only spices that did not have a similar stimulatory influence on bile acid output were piperine, asafoetida, fennel, cinnamon and garlic[23-25]. One time oral administration of curcumin, piperine, coriander, cumin, fenugreek, mustard, asafoetida, ajowan, fennel and onion as a single dose significantly increases bile acid secretion (Table II). Bile solids were generally not influenced by these spices given as one-time exposure, except ajowan, curcumin, cumin, onion and asafoetida, which exhibited a stimulatory effect (17-71%). Among the dietary spices which increased bile acid secretion, this effect was independent of bile flow rate in the case of curcumin, coriander, mint, and onion, while ginger,

cumin, fenugreek, mustard, ajowan and tamarind exhibited increased bile acid secretion concomitant with the increased bile flow rate. The higher bile solid content observed in most of the spice groups could be due to a higher bile acid content and possibly also due to higher amounts of glucuronides which might arise as a result of conjugation of some compounds present in these spices[22].

Thus, many of the test spices, either dietary and/or consumed as a single oral dose, stimulate bile acid secretion significantly. Spices may also have a beneficial stimulatory effect on other digestive secretions (gastric and pancreatic), especially by enhancing titres of digestive enzymes in gastric and pancreatic juice, and intestinal mucosa. Food ingredients, such as proteins of plant and animal origin, and specific carbohydrates and lipids, have been examined for their differential influence on exocrine pancreatic secretion and digestive enzymes of small intestinal mucosa in animal systems[26, 30-40].

Stimulation of pancreatic enzymes

A report on the effect of spices on digestive enzymes mentioned that freshly prepared 1 per cent emulsion of asafoetida in water affected the activity of pepsin, trypsin and rennin in saliva to a small extent[41]. Enhanced pancreatic amylase activity by asafoetida *in vitro* but with no significant effect on intestinal esterases, phosphatases and peptidases was later observed[42]. The influence of dietary intake and single dose administration of 14 commonly used spices or their active principles on the pancreatic digestive enzymes and the terminal digestive enzymes of the small intestinal mucosa has been reported by us[37-40].

The dietary intake of spice principles-curcumin, capsaicin and piperine and the spices fenugreek, ginger, asafoetida, and ajowan significantly increase lipase activity. Curcumin stimulated lipase activity up to 80 per cent of control, while capsaicin and piperine and whole spices increased the activity of this enzyme by 26-43 per cent of the control. Pancreatic lipase activity was also stimulated by the three dietary spice mixes, this effect being highest for spice mix-III (41%), followed by spice mix-II (25%) and spice mix-I (13%). Dietary cumin, mustard, mint and garlic, however, lower the pancreatic lipase activity by 35-43 per cent (Table III). In contrast to the continued intake, single oral dose consumption of the same spices failed to exert a stimulatory effect on pancreatic lipase. Mint, which had no beneficial effect on continued intake, produced a significant increase in pancreatic lipase activity (43% over control) when administered as a single dose.

Pancreatic amylase activity is elevated by dietary ginger, which had the maximun stimulatory effect (184%), followed by the spice principles - curcumin (96%), piperine (87%), and capsaicin (72%). Dietary asafoetida, cumin and onion also significantly enhanced the activity of pancreatic amylase (24-34%). The enzyme activity was however, decreased by dietary fenugreek, while mustard has no influence on this enzyme. Single dose administration of capsaicin, piperine and fennel enhanced the activity of pancreatic amylase (17-26%). Whole spices - ginger, cumin, coriander and ajowan inhibited amylase (Table III).

The spice principles - curcumin, capsaicin and piperine when incorporated in the diet, stimulate trypsin activity by as much as 120-165 per cent. The dietary intake of whole spices - ginger, ajowan, fennel, coriander, garlic, and onion significantly enhanced trypsin activity. The stimulation of this enzyme activity was highest by ginger, being 133 per cent, followed by the other spices. Fenugreek and asafoetida decreased the activity of this enzyme. Chymotrypsin was also significantly higher in animals fed the three spice principles, and the spices-asafoetida, fenugreek, ginger, cumin, onion and coriander (11-73%), the maximum stimulation observed in curcumin group. Dietary mustard had no influence on the activity of either of the proteases. The three spice mixes also had a significant stimulatory influence on the activity of chymotrypsin, the effect being maximum with spice mix-III (77%) when consumed in the diet. However, the three spice mixes significantly lowered the activity of pancreatic trypsin. Similar influence of the spices on the activity of proteases was not evident when administered as a single oral dose (Table III).

Proteins, starch and triglycerides, the major macromolecules in food are hydrolyzed by the major pancreatic enzymes - proteases (trypsin and chymotrypsin), amylase and lipase respectively. Since fat digestion is vital to the digestion of other food macromolecules, the role of pancreatic lipase assumes greater significance.

Cereals are the staple food of Indian diets. Stimulation of amylase could be significant in the Indian context,

Table II. Influence of spices on bile flow rate and bile acid secretion (µmol/h) in experimental rats

Spices/ principles	Continued intake				One-time exposure				Ref.
	Dietary (g%)	Bile flow	Biliary solids	Bile acids	Oral dose (mg/kg)	Bile flow	Biliary solids	Bile acids	
		% Stimulation				% Stimulation			
Ajowan	0.2	26	41	30	80	41	71	66	25
Asafoetida	0.25	9	20	10	250	9	17	35	24
Capsaicin	0.015	0	(-)4	17	7.5	40	11	13	21
Cinnamon	0.05	2	8	3	-				24
Coriander	2.0	15	32	59	400	6	15	54	25
Cumin	1.25	25	35	71	600	3	30	58	26
Curcumin	0.5	(-)16	(-)16	62	250	37	33	76	21
Fennel	0.5	11	19	8	200	5	14	48	25
Fenugreek	2.0	44	12	80	500	35	(-)4	35	22
Garlic	0.5	21	15	11	2500	3	(-)3	6	25
Ginger	0.05	20	4	25	10	3	(-)6	2	22
Mint	1.0	(-)3	20	17	400	2	5	3	25
Mustard	0.25	30	41	50	250	(-)4	0	28	24
Onion	3.0	0	24	47	2500	9	21	33	24
Piperine	0.02	9	(-)7	(-)15	25	0	15	30	23
Spice mix-I	2.0	23	17	38	-				26
Spice mix-II	2.0	41	27	86	-				26
Spice mix-III	2.0	74	80	106	-				26
Tamarind	2.5	26	40	58	-				24

* Fresh spice used; (-), negative effect

Table III. Influence of spices on pancreatic digestive enzymes in experimental rats

Spices/ principles	Continued intake					One-time exposure					
	Dietary (g%)	Lipase	Amylase	Trypsin	Chymo-trypsin	Oral (mg/kg)	Lipase	Amylase	Trypsin	Chymo-trypsin	Ref.
		% Stimulation					% Stimulation				
Ajowan	0.2	26	9	48	5	100	(-)7	(-)50	18	10	40
Asafoetida	0.25	37	24	(-)43	45	250	(-)40	14	(-)26	(-)13	39
Capsaicin	0.015	36	72	120	25	15	12	17	0	2	39
Coriander	2.0	3	8	34	11	500	17	(-)40	(-)42	15	40
Cumin	1.25	(-)35	26	19	24	500	(-)47	(-)39	(-)28	(-)49	39
Curcumin	0.5	80	96	154	73	500	(-)16	8	(-)8	(-)10	39
Fenugreek	2.0	43	(-)25	(-)60	43	200	(-)36	2	13	(-)28	39
Fennel	0.5	(-)16	14	98	3	250	7	26	17	(-)15	40
Garlic	0.5	(-)43	(-)5	18	(-)5	2500*	19	8	(-)20	(-)24	40,37
Ginger	0.05	29	184	133	30	500*	(-)42	(-)24	(-)17	(-)21	39
Mint	1.0	(-)42	(-)12	(-)9	(-)9	500*	43	0	15	(-)8	40,37
Mustard	0.25	(-)43	8	(-)2	(-)23	250	(-)45	15	(-)12	(-)27	39
Onion	2.0	(-)6	34	14	15	2500*	(-)7	0	(-)30	4	40
Piperine	0.02	37	87	165	30	50	(-)13	24	(-)7	(-)11	39
Spice mix-I	2.0	13	16	(-)36	25	-					26
Spice mix-II	2.0	25	0	(-)54	23	-					26
Spice mix-III	2.0	41	16	(-)43	77	-					26

* Fresh spice used; (-), negative effect

where starch, the major ingredient of cereals, contributes over 75 per cent of dietary energy intake. This is also true for other developing countries where non-cereal starch is the major contributor of dietary energy. Most of the spices have shown significant stimulation of pancreatic amylase activity when consumed through the diet.

Influence on digestive enzymes of small intestinal mucosa

Spice principles - curcumin, capsaicin and piperine and the spice - ginger prominently enhanced the activity of intestinal lipase. The stimulation of this enzyme activity was more than 100 per cent of the control in spice principle-treated groups. While dietary ginger has a positive influence on this enzyme (74%), other spices or spice mixes showed no such beneficial influence. Similarly, neither the spice principles nor the spices exerted any influence on intestinal amylase, except onion and mustard that increased and decreased amylase, respectively. Among the three spice mixes, spice mix-I and -II significantly enhanced (40 and 19% respectively) while spice mix-III decreased the activity of amylase (Table IV).

An appreciable increase in intestinal lipase activity was observed in animals given single oral doses of mint, garlic, onion, ajowan, ginger, fennel, piperine, fenugreek and curcumin (461, 361, 144, 113, 82, 70, 64, 58 and 20%, respectively). All the test spice principles significantly increased (21- 47%) the activity of intestinal amylase. Activity of this enzyme was also significantly enhanced by single dose administration of onion, fennel, ajowan, ginger, mint, coriander, asafoetida and cumin (124, 76, 74, 47, 42, 37, 36 and 33 %, respectively) (Table IV).

Dietary coriander and onion prominently stimulated the activities of the disaccharidases sucrase, lactase and maltase of intestinal mucosa. Lactase activity was nearly 3-fold in coriander fed animals. The stimulation of lactase and sucrase by dietary onion was about 90 per cent, while that of maltase was 50 per cent. The spices - ginger, ajowan, fennel, cumin and asafoetida, and the spice principles - curcumin, capsaicin and piperine moderately stimulated the activities of one or more of the disaccharidases. Dietary spices - cumin, fenugreek, mustard, asafoetida and mint and also spice mixes brought significant decreases in the activity of one or more of the intestinal disaccharidases. When administered as single oral dose, curcumin and onion stimulated the activity of all the three disaccharidases (Table V). On the other hand, piperine, ginger, ajowan, mint and asafoetida stimulated sucrase alone, while cumin and fenugreek stimulated only lactase. These spices did not influence maltase activity.

Dietary onion enhanced the activity of intestinal alkaline phosphatase by 73 per cent and coriander by 54 per cent (Table IV). Dietary mint, cumin, fenugreek, mustard and asafoetida and spice mix-I and -III had a decreasing effect on alkaline phosphatase. The activity of acid phosphatase was significantly enhanced by dietary curcumin, capsaicin and ginger but was significantly decreased by cumin, fenugreek, mustard, asafoetida, ajowan, fennel and spice mix-III. Single dose administration of curcumin, mint and onion stimulated both the intestinal phosphatases, while ajowan, mint and mustard stimulated the activity of only alkaline phosphatase, and garlic and fennel stimulated the activity of acid phosphatase alone. Onion has been observed to exert a beneficial stimulatory effect on the activities of all intestinal enzymes when given as a single oral dose.

The digestive enzymes of the small intestinal mucosa play an important role in the overall digestion process. Prominent among these are the disaccharidases, aminopeptidases, phosphatases, amylase and lipase. Intestinal lipase, which is distinct from pancreatic lipase, has been claimed to significantly supplement the pancreatic enzyme in the hydrolysis of dietary fat, especially monoglycerides[43]. Intestinal lipase probably assumes a greater role in the digestion of fat when the titres of pancreatic lipase are limiting. The magnitude of stimulation of intestinal lipase, *viz.*, 74 per cent to as high as 160 per cent by these spices was in fact greater than the stimulation of pancreatic lipase.

The intake of onion either dietary or as a casual single dose brought about a beneficial stimulation of all the disaccharidases, the effect being more pronounced with a continued intake of this spice. Coriander has a similar enhancing effect on all the disaccharidases only when consumed continuously through the diet, while curcumin produced the same effect when consumed as a single oral dose. Cumin, curcumin, fenugreek and onion, spices, which cause a significant stimulation of maltase activity,

Table IV. Influence of spices on intestinal lipase, amylase and phosphatase activities in experimental rats

Spices/ principles	Continued intake					One-time exposure					Ref.
	Dietary (g%)	Lipase	Amylase	Alk-phosphatase	Acid phosphatase	Oral (mg/kg)	Lipase	Amylase	Alk. phosphatase	Acid phosphatase	
		% Stimulation					% Stimulation				
Ajowan	0.2	(-)16	(-)9	0	(-)27	100	113	74	104	18	40
Asafoetida	0.25	(-)7	0	(-)23	26	250	11	36	0	(-)22	38,39
Capsaicin	0.015	161	(-)17	16	43	15	9	26	14	15	38,39
Coriander	2.0	0	13	54	11	500	5	37	(-)9	(-)20	40
Cumin	1.25	21	(-)8	(-)33	(-)26	500	0	33	11	(-)29	38,39
Curcumin	0.5	137	(-)13	0	26	500	20	21	70	40	38,39
Fennel	0.5	(-)28	(-)9	(-)10	(-)33	250	70	76	24	17	40
Fenugreek	2.0	(-)12	(-)12	(-)33	(-)42	200	58	17	0	10	38,39
Garlic	0.5	(-)10	3	11	8	2500*	361	13	0	35	37
Ginger	0.05	74	4	8	22	500*	82	47	12	(-)23	38,39
Mint	1.0	(-)21	10	(-)34	(-)16	500*	461	42	57	31	37
Mustard	0.25	(-)35	(-)33	(-)33	(-)30	250	(-)6	(-)20	25	(-)20	38,39
Onion	2.0	(-)6	24	73	(-)2	2500*	144	124	29	17	40
Piperine	0.02	144	0	(-)7	0	50	64	47	18	(-)8	38,39
Spice mix-I	2.0	(-)50	40	(-)26	(-)20	-					26
Spice mix-II	2.0	19	19	(-)8	(-)13	-					26
Spice mix-III	2.0	21	(-)42	(-)30	(-)37	-					26

* Fresh spice used; (-), negative effect

may find pharmacological application for lactose intolerant individuals. Interestingly, single dose administration of spices other than curcumin and onion did not increase intestinal maltase unlike their dietary intake. Phosphatases of intestinal mucosa are non-specific enzymes, which hydrolyze all dietary organic phosphates. A few spices produced a stimulation of either of the phosphatases, although this was not a general trend.

Apart from a positive influence on the digestive enzymes of pancreas and small intestine, a few spices, either dietary or as a single oral dose, are found to reduce the activities of specific enzymes[38-40]. However, the positive influences of these spices on digestive enzymes in general may out-weigh their negative influence. Mustard either dietary or given as a single oral dose, seems to be exceptional in this regard as it did not stimulate any of the pancreatic digestive enzymes; it lowered the activities of lipase and chymotrypsin, as well as those of the digestive enzymes of intestinal mucosa.

Garlic oil and mint, which are ingredients of pharmacological preparations against digestive disorders, seem to exert their stimulatory influence by increasing the lipase activity of both pancreas and intestinal mucosa when given as a single dose. The negative influence on the same enzyme by dietary mint, however, remains incomprehensible. Ginger and cumin are extensively used to correct digestive disorders in Indian households. Both ginger and cumin lowered the activities of most of the pancreatic enzymes when given as a single oral dose. Since stimulation of digestion is not restricted to activation of pancreatic digestive enzymes alone, other factors such as salivary, gastric, intestinal and biliary secretions must be contributing to their digestive stimulant action. The positive influence of ginger[22] and cumin[25], given as dietary or single oral dose on bile volume and bile acid secretion may probably account for the digestive stimulatory potential of these spices.

Among all the spices, onion had a favourable influence on most of digestive enzymes of both the pancreas and small intestine. This beneficial influence of onion on pancreatic digestive enzymes was more evident by a continued intake of this spice, while intestinal enzymes were stimulated even with one-time exposure. This observation suggests that onion has a great potential as a digestive stimulant by virtue of its action on digestive enzymes. Garlic, which also belongs to the *Allium* species, did not seem to stimulate digestive enzymes as much as onion.

While the pancreatic enzymes were not influenced by the test spices given as a single oral dose, their one-time exposure had a significant enhancing effect on intestinal enzymes, particularly lipase and amylase. The transient presence of the spice at the site of action may have been responsible for such a differential effect. Many of these spices showed a positive effect on the activities of pancreatic lipase and amylase when incubated with pancreatic tissue *in vitro*[44] although they did not influence intestinal disaccharidases similarly. This indicates that the presence of relevant spice/spice principle in proximity to these specific pancreatic digestive enzymes in the gastrointestinal tract has a desirable effect on their activity.

Influence of dietary spices on food transit time

The evidence that the beneficial digestive stimulant action of spices is mediated through an appropriate stimulation of the activities of pancreatic digestive enzymes and digestive enzymes of small intestinal mucosa, and a stimulation of the liver to produce and secrete bile enriched in bile acids, has led to a study on the influence of spices on food transit time. The food transit time in the gastrointestinal tract was examined in experimental rats by feeding test spices at levels similar to those proven to produce digestive stimulant action[45]. Generally, all spices except fenugreek and mustard shortened the food transit time. This reduction was more prominent for ginger, ajowan, cumin, piperine, coriander and asafoetida, which produced a decrease in food transit time by 24-31 per cent. Capsaicin, mint, onion, curcumin and fennel also decreased the food transit time, albeit to a lesser extent (12-19%) (Table VI).

The reduction in food transit time produced by the dietary spices appears to be associated with their beneficial influence either on digestive enzymes or on bile secretion. Thus, the dietary spices, which either enhanced the activity of digestive enzymes or caused a higher secretion of bile acids, also reduced the food transit time at the same level of consumption. This reduction in food transit time could probably be attributed to acceleration in the overall digestive process as a result of increased availability of digestive enzymes and of bile acids that facilitate fat digestion. Dietary mustard, with an unfavourable influence on

Table V. Influence of spices on intestinal disachharidases in experimental rats

Spices/ principles	Continued intake					One-time exposure				
	Dietary (g%)	% Stimulation			Ref.	Oral (mg/kg)	% Stimulation			Ref.
		Sucrase	Lactase	Maltase			Sucrase	Lactase	Maltase	
Ajowan	0.2	12	(-)20	0	40	100	22	0	0	40
Asafoetida	0.25	(-)29	0	27	38	250	35	7	9	32
Capsaicin	0.015	38	3	21	38	15	(-)16	7	9	39
Coriander	2.0	47	194	22	40	500	(-)39	(-)44	(-)16	39
Cumin	1.25	(-)18	(-)7	25	38	500	15	57	0	39
Curcumin	0.5	21	7	11	38	500	18	33	17	39
Fennel	0.5	24	(-)17	5	40	250	8	7	6	40
Fenugreek	2.0	(-)30	(-)11	4	38	200	15	27	7	39
Ginger	0.05	6	(-)10	12	38	500*	17	6	(-)4	39
Garlic	0.5	13	3	(-)5	40	2500*	5	(-)27	(-)12	37
Mint	1.0	(-)37	(-)75	(-)17	40	500*	21	(-)34	12	37
Mustard	0.25	(-)35	(-)7	(-)9	38	250	(-)7	0	5	39
Onion	2.0	90	87	50	40	2500*	36	25	25	40
Piperine	0.02	36	8	30	38	50	12	(-)3	7	39
Spice mix-I	2.0	(-)41	(-)32	(-)27	40	-				
Spice mix-II	2.0	(-)47	(-)81	(-)5	26	-				
Spice mix-III	2.0	(-)50	(-)45	(-)28	21	-				

* Fresh spice used; (-), negative effect

digestive enzymes[38,39] showed no change in food transit time. Fenugreek which had a favourable influence on pancreatic digestive enzymes[39] and on bile acid secretion[22], did not show any effect on the food transit time. Yamahara *et al*[46] examined the influence of extracts of ginger roots on gastrointestinal motility in mice and observed an enhanced charcoal meal transport following oral administrations of acetonic extract containing volatile oils and bitter substances or gingerol (active flavour ingredient).

Nutrient absorption is believed to be associated with time the food stays in the small intestine, although the degree to which transit time or contact time normally limits absorption is not established[47]. Absorption of food generally depends on the length of time nutrients are in contact with the absorptive epithelium and the acceleration of intestinal food transit time in humans by the use of laxative agents has been observed to increase the escape of otherwise absorbable nutrients[47].

The accelerated food transit time caused by dietary spices, is essentially whole gut transit time (mouth to anus), and the reduced food transit time does not amount to a compromise on nutrient absorption for the following reasons: (*i*) unlike the laxative agents, spices do not induce diarrhoea nor increase the bulk of faeces; (*ii*) animals fed spice diets gained body weight comparable to control animals. Thus, the reduction in the whole gut transit time

Table VI. Influence of dietary spices on gastrointestinal food transit time in rats[45]

Spice	Dietary level (g%)	Reduction in food transit time (%)
Ajowan	0.20	28
Asafoetida	0.25	24
Capsaicin	0.015	19
Coriander	2.0	25
Cumin	1.25	26
Curcumin	0.5	11
Fenugreek	2.0	6
Fennel	0.50	12
Garlic	0.50	22
Ginger	0.05	31
Mint	1.0	17
Mustard	0.25	11
Onion	2.0	16
Piperine	0.02	25

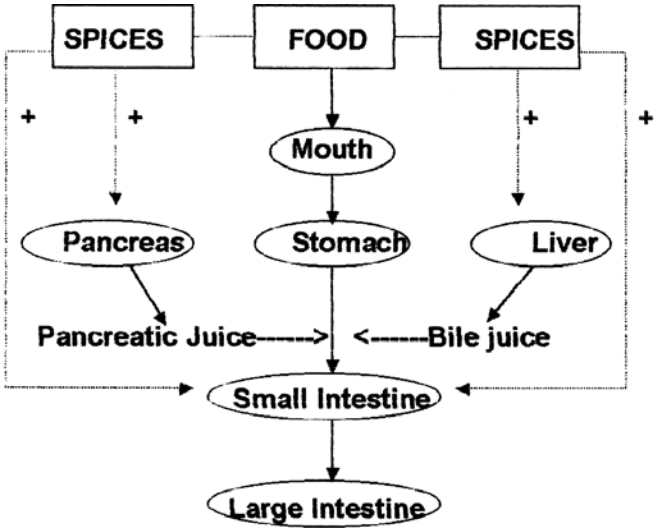

Fig. Mechanism of digestive stimulant action of spices.

caused by dietary spices probably reflects a shorter, post-absorptive colonic phase, which is the longest phase of food transit, rather than that of mouth to caecum transit phase. Reduction in colonic transit time has been implicated in a reduced risk and the incidence of colon cancer, as evidenced in populations consuming diets rich in fibre[47]. Thus, by reducing food transit time, spices may play a role in the prevention of colon cancer besides combating constipation. The intestinal food transit time of Indians has been observed to be shorter compared to Europeans on a comparable fibre intake; and the presence of several spices in the Indian diet has been speculated to be a factor responsible for this phenomenon[48].

Digestive stimulant action of spice mixes vis-a-vis individual spices

Since spices are usually consumed as spice mixes in our diet, the influence of combinations of selective spices has been tested for a digestive stimulant action. The three spice mixes were derived from a few commonly consumed spices of known stimulant action on digestive enzymes of pancreas and small intestine, and on bile secretion and composition in experimental rats[26]. The common ingredients of these mixes were coriander, turmeric, red pepper, black pepper and cumin, while the spice mix-II additionally had ginger, and spice mix-II contained onion. Spice mix-I and -II are based on recipes commonly used in Indian households. Spice mix-III is formulated using those spices, which have been found

to exert maximum beneficial influence on digestive enzymes and bile secretion individually, *viz.*, tumeric, red pepper, black pepper, cumin, coriander, ginger, and onion.

All the three spice mixes when consumed through the diet favorably enhanced the pancreatic lipase, chymotrypsin and amylase activities. The spice mixes also stimulated bile flow and bile acid secretion. Spice mix-III had the greatest stimulatory influence particularly on bile volume, bile acid secretion (which was almost doubled) and the activities of pancreatic enzymes. This study[26] indicated that the stimulatory influence of the component spices of the spice mixes on digestive enzymes of pancreas and small intestine was not additive. The activity of trypsin in particular, which was enormously enhanced by all individual spices, was surprisingly reduced by all the three spice mixes. It was interesting to note that all the three spice mixes brought about an enormous stimulation of bile flow rate and bile acid secretion compared to any of the individual spice components reported earlier[21,22,24,25]. This suggested a tendency towards an additive effect of the individual spices as far as their stimulatory influence on bile was concerned.

Conclusions

Based on the evidences from animal studies, the well-recognized digestive stimulant action of spices may be considered to be mediated through two possible modes (Figure) (*i*) stimulation of the liver to secrete more bile enriched in bile acids, and (*ii*) stimulation of enzyme activities that participate in digestion, both of pancreatic and intestinal origin. Such stimulation of bile secretion and of the activities of digestive enzymes leads to an accelerated overall digestive process, resulting in a significant reduction in the duration of passage of food through the gastrointestinal tract.

The animal studies on the influence of spices on bile secretion and digestive enzymes have employed spice concentrations roughly 5-times the average levels found normally in Indian diets. Such levels of spices can be comfortably consumed in the regular diet, except when their consumption is limited by the pungency (red pepper) or strong odour (garlic). Spice intakes at levels much higher than the average, by different sections of our population, may actually be in practice depending on culinary preferences. The effectiveness of lower doses of these spices cannot be ruled out, though it is not experimentally documented. Among those populations, where spice intake may not be very high, consumption of doses of the food additives comparable to the ones employed in these studies could still be practical in order to exploit their beneficial effect. Thus, the age-old empirical dictum that 'Spices are digestive stimulants' stands today verified by experimental evidences at least in laboratory animals, and is exerted by stimulating bile secretion and activities of digestive enzymes.

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