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ORIGINAL ARTICLE

Effect of Dietary Turmeric on Breath Hydrogen

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Abstract Turmeric is widely used in Indian cuisine. The main constituents of turmeric are curcumin and its analogues, which are well-known antioxidant compounds. In the present study, we hypothesized that turmeric in curry might increase bowel motility and activate hydrogen-producing bacterial flora in the colon, thereby increasing the concentration of breath hydrogen. Eight healthy subjects fasted for 12 h and ingested curry and rice with or without turmeric (turmeric knockout curry). Breath-hydrogen concentrations were analyzed every 15 min for 6 h by gas chromatography with a semiconductor detector. Curry with turmeric significantly increased the area under the curve of breath hydrogen and shortened small-bowel transit time, compared with curry not containing turmeric. These results suggested that dietary turmeric activated bowel motility and carbohydrate colonic fermentation.

Keywords Curry · Turmeric · Curcumin · Breath hydrogen · Small-bowel transit time

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Introduction

Turmeric, the rhizome derived from the plant *Curcuma longa*, is widely used as an ingredient in common Indian curry spice. Curry spices are spread from India to neighboring Asian countries, Western countries, and throughout the world. The cooking methods often depend upon the ingredients. Japanese-style curry and rice was established and is now very popular in Japan. For curry, turmeric is often used in combination with such spices as red pepper, coriander, and cumin seeds.

On the other hand, turmeric has been used to treat various ailments for centuries in Ayurvedic medicine, a traditional Indian system of healing. Based on Ayurveda, turmeric has been used to reduce various clinical symptoms, such as flatus [1], jaundice, menstrual difficulties, hematuria, hemorrhage, and colic [2]. Furthermore, as reviewed by Aggarwal et al. [3], substantial in vitro data indicate that curcumin, extracted from turmeric, has antithrombotic, antiatherosclerotic, hypolipidemic, anti-inflammatory, and antioxidative effects. Besides the possible beneficial effects on Alzheimer's disease [4], the main clinical targets of curcumin have been digestive organ diseases, such as familial adenomatous polyposis [5], inflammatory bowel disease [6], ulcerative colitis [7], and colon cancer [8]. Thus, curcumin seemed to be beneficial mainly for digestive organs; however, curiously, very few papers have focused on the effects of curcumin or turmeric on intestinal and colonic functions in humans.

It is widely accepted that breath hydrogen reflects carbohydrate fermentation in the colon [9, 10]. When unabsorbed carbohydrate enters the colon it is rapidly fermented to short-chain fatty acids by anaerobic colon bacteria, liberating carbon dioxide, hydrogen and, in some people, methane. Thus, analysis of breath hydrogen has been used to measure the small bowel transit time (SBTT) [11] and colonic fermentation.

In the present study, we first considered whether turmeric in the usual diet has beneficial effects on intestinal motility and colonic fermentation. Next, a very recent study reported that inhaled hydrogen plays an antioxidative role against hydroxyl radicals OH• [12]. In this study, we therefore examined the dietary effects of curry containing four spices and turmeric knockout curry using breath hydrogen analysis, and considered the effects of dietary turmeric and its possible clinical significance.

Materials and Methods

Subjects

Eight adults (two men and six women) volunteered for this study, as listed in Table 1. The subjects were aged 29.6 ± 13.4 (mean ± SD) years old. Their body height, weight, and BMI were 163.5 ± 8.3 cm, 57.8 ± 14.6 kg, and 21.4 ± 3.4 kg/m^2, respectively. One of the women had constipation. The other subjects did not have any diseases.

Curry Preparation

Japanese-style curry generally contains potato, carrot, onion, and either beef, pork, or chicken [13]. Among these ingredients, ingestion of potato increased breath hydrogen, whereas carrots, onions, beef, and other spices did not in our preliminary studies; therefore, Japanese-style curry containing potato was employed to observe the alteration of breath hydrogen. The methods of curry preparation followed the standard recipe for Japanese-style curry and rice.

Table 1 Characteristics of the subjects

Subjects	Sex	Age	Height (cm)	Weight (kg)	BMI	Diseases
A	F	20	162.4	45.9	17.4	None
B	M	51	180.7	91.2	27.9	None
C	M	28	163.0	50.4	19.0	None
D	F	22	155.2	47.9	19.9	None
E	F	22	159.1	53.0	20.9	None
F	F	51	157.5	61.7	24.9	Constipation
G	F	20	170.3	60.5	20.9	None
H	F	23	160.0	51.5	20.1	None
Mean	F6/M2	30	163.5	57.8	21.4	
SD		13	8.3	14.6	3.4	

Food ingredients: The spices used for the curry for each subject were 0.5 g turmeric, 0.5 g cayenne pepper, 3 g coriander seeds, 0.5 g cumin seeds (GABAN Co., Ltd., Tokyo, Japan). The ingredients were 100 g beef, 67 g onion, 77 g potato, 46 g carrot, 7.5 ml rape-seed oil, 300 ml water, and 2.5 g salt for each subject. All food was prepared for four persons before the experimental days and divided equally. After the cooking procedures and re-boiling on the experimental days, the curry weighed 343 g for each person. The turmeric powder contained 10.96 mg/g curcumin, 3.23 mg/g demethoxycurcumin, and 2.3 mg/g bismethoxycurcumin (HPLC, Technical services at the House Food Analytical Corporation, Tokyo); therefore, the subjects had 5.48 mg curcumin, 1.62 mg demethoxycurcumin, and 1.15 mg bismethoxycurcumin for each meal.

Ingestion of Curry and Rice

The subjects were asked to refrain from eating turmeric-containing foods for at least 1 week before the experiments. They were also asked not to have any food, supplements, or drugs, except water, for at least 12 h before the experiments. The same subjects consumed turmeric-containing curry as well as turmeric knockout curry on different days in a randomized crossover design. Each experiment for the same subject was performed separately after at least a 1-week interval.

On the experimental day, the subjects rested for 15 min and then ate the curry and rice within 15 min. For the rice, 200 g of commercially available instant rice (Sato Food Industries Corp., Ltd., Niigata, Japan) was used. Finally, the subjects drank 100 ml of water to rinse their oral cavity. Turmeric knockout curry was made without adding turmeric, but using exactly the same procedure. Both curry and rice with or without turmeric provided 28.0 g protein, 18.7 g fat, 98.7 g carbohydrate, 3.8 g dietary fiber, and 695 kcal total energy.

Breath Sampling and Analysis

End-alveolar breath was obtained in a breath sampling bag (200 ml volume, Otsuka Pharm. Co. Ltd, Tokyo, Japan) every 15 min immediately after eating (0 min) to 360 min. All subjects underwent training to obtain the end-alveolar breath before the experiments. The breath was immediately transferred to a gas-tight glass syringe and 1 ml was injected into the gas chromatograph with a semiconductor detector (TRIlyzer mBA-3000, Taiyo Ltd, Osaka, Japan) to measure breath hydrogen, methane, and carbon monoxide. Breath concentrations of each gas were calculated by subtracting ambient air collected into the same sampling bag.

Statistical Analysis

Statistical values are expressed as the mean ± standard deviations of the means. Statistical analysis was preformed by a paired *t*-test or two-way analysis of variance. Statistical significance was accepted if $P < 0.05$.

This study was performed with permission from the ethics committees of Kobe College and the National Cardiovascular Center, and all subjects gave informed consent.

Results

Changes in the concentrations of breath hydrogen are shown in Fig. 1. The initial rise of breath hydrogen occurred between 30 and 90 min, with a later rise at approximately 300 min. Turmeric knockout curry slightly increased the initial and later breath hydrogen; however, the curry with turmeric markedly increased the initial and later breath hydrogen compared with turmeric knockout curry ($P = 0.024$).

To assess hydrogen production, areas under the curve (AUC) of breath hydrogen for 6 h were calculated as shown in Fig. 2. Except for one case with chronic constipation, breath hydrogen increased in the other seven cases. The turmeric knockout curry produced breath hydrogen at AUC levels of 57.3 ± 36.5 ppm h, whereas the curry with turmeric significantly increased AUC levels to 85.1 ± 52.6 ppm h ($P = 0.023$).

Small-bowel transit time (SBTT) is shown in Table 2. The SBTT was basically assessed by a breath hydrogen rise of 3 ppm [14]. In two cases, the later rises of breath hydrogen could not reach 3 ppm, but only 2 ppm or less. This rise was conveniently adopted for SBTT determinations. The SBTT for turmeric knockout curry was 300 ± 51 min, whereas the SBTT for curry with turmeric was 251 ± 41 min. The SBTT was significantly shortened by turmeric ($P = 0.009$). As mentioned above, breath hydrogen curves in both curry with turmeric and turmeric knockout curry indicated two peaks. The initial peak time, late peak time, and peak-to-peak time tended to be shortened by turmeric, but this was not statistically significant.

Breath methane in the fasting state was detected in none of the subjects. Breath carbon monoxide levels in subjects did not significantly change throughout the studies (data not shown).

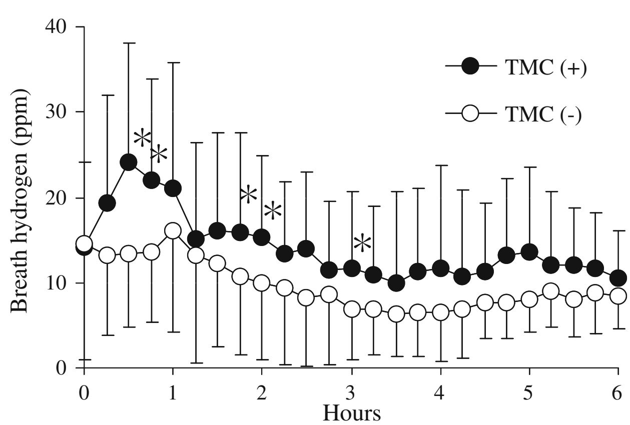

Fig. 1 Changes in breath hydrogen after meal. The difference between the two groups with or without turmeric is significant ($P = 0.024$, two-way analysis of variance). *$P < 0.05$, curry with vs. without turmeric (TMC) by the paired-*t* test

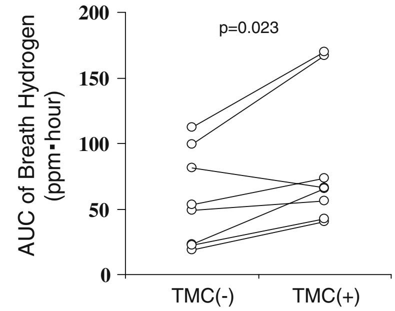

Fig. 2 Area under the curve (AUC) with or without turmeric (TMC)

Table 2 Profile of breath hydrogen concentration

Parameters	TMC (−) Mean ± SD	TMC (+) Mean ± SD	*P* values
1st peak (min)	41 ± 21	38 ± 16	0.626
2nd peak (min)	326 ± 34	300 ± 43	0.165
Peak-to-peak (min)	285 ± 38	263 ± 51	0.156
SBTT (min)	300 ± 51	251 ± 41	0.009

Discussion

In this study, we indicated that turmeric in standard Japanese-style curry and rice increased the concentration of breath hydrogen and shortened the small-bowel transit time compared with turmeric knockout curry.

As reported for British [14] and Japanese [15] meals, an initial rise in breath hydrogen immediately after eating was observed in this study. Curry with turmeric showed a marked initial rise of breath hydrogen, whereas curry without turmeric also appeared to indicate an initial rise, slightly, but not significantly. For the initial rise of breath hydrogen in the postprandial state, the so-called gastro-ileal reflex [16, 17] causes the entry of non-absorbable substrates into the colon. The following candidates have been considered to produce the initial rise of breath hydrogen:

(1) non-absorbable carbohydrate in the previous meal present in the ileum, (2) a certain proportion of starch that escaped absorption, and/or (3) endogenous mucopolysaccharides [18], as supported by Read et al. [14] and Kagaya et al. [15]; however, the detailed mechanism of the initial rise of breath hydrogen has not been established. Because we wanted to observe the behavior of breath hydrogen under the usual daily living conditions of each subject, our subjects were not restricted from ingesting food containing non-absorbable carbohydrates before the experimental days. The subjects were only asked to fast, except water, for 12 h before the experiments; therefore, the baseline levels in our experiments were slightly higher than in Read et al. [14]. Although our experimental conditions were different from previous reports [14, 15], the baseline levels of breath hydrogen were the same in both curry groups with and without turmeric; therefore, we considered that turmeric played a role in increasing the initial rise of breath hydrogen.

After the initial rise of breath hydrogen, curry with turmeric continuously maintained higher levels of breath hydrogen compared with turmeric knockout curry; therefore, the AUC of breath hydrogen indicated significantly higher levels when turmeric was ingested. In addition to the AUC increase, the SBTT was shortened, which suggested increased motility of the small intestine. This result was compatible with the previous report that food transit time was reduced by dietary curcumin in rats [19]. This activated motility by turmeric might be closely associated with the favorable digestive functions of turmeric based upon the following evidence: (1) enhanced intestinal lipase activity and also the disaccharidases sucrase and maltase by dietary curcumin in rats [20], (2) stimulatory influences of curcumin or curcumin-containing spices on digestive enzymes (lipase, amylase, chymotrypsin and amylase) from the pancreas [21] and small intestine, and on bile secretion and composition (bile acids) in rats [22], caused by (3) contraction of the gall bladder induced by curcumin at least 30 min postprandial in humans [23, 24]. This evidence also supports our experimental results indicating insignificant increases in the later rise of breath hydrogen in the groups with or without turmeric because the ingested meal could be sufficiently digested before colonic fermentation.

In this experiment, the subjects ingested 0.5 g turmeric containing 5.48 mg curcumin, 1.62 mg demethoxycurcumin, and 1.15 mg bismethoxycurcumin. Besides the above curcuminods, turmeric is reported to contain many bioactive chemical compounds, such as zingiberene, curcumenole, curcmol, eugenol, tetrahydroxycurcumin, triethylcurcumin, turmerin, turmerones, and turmeronols [25]; therefore, it remains to be identified in future studies which chemicals potentiated the hydrogen-producing ability.

Breath hydrogen reflects the fermentation of non-absorbable carbohydrates in the colon and has been recognized as "a negative breath marker," which has been utilized for the clinical diagnosis of galactose and lactose intolerance, abnormal fermentation and sometimes irritable bowel syndrome [10]; however, very recently, Ohsawa et al. [12] reported that hydrogen plays an important role in inactivating oxidative stresses such as hydroxyl radicals. This report seemed to give new insight into the roles of hydrogen produced in the body, mostly by colonic fermentation. In accordance with this report, Kagaya et al. [15] reported that younger women had higher concentrations of breath hydrogen at baseline levels and in response to the meal, both the initial and secondary rise, than older women. Therefore, we speculate that turmeric, which increased breath hydrogen, also acts as an antioxidant, in addition to the role of curcumin as a hydrogen atom donor to oxidative stresses, which is reportedly more powerful than vitamin E [26]. The hydrogen-producing abilities of foods and colonic conditions may be a marker of antioxidative stresses.

Conclusion

Turmeric contained in curry increased breath hydrogen and shortened the small-bowel transit time.

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