Seasonal Variation in Amount of Unabsorbed Dietary Carbohydrate from the Intestine after Breakfast in Young Female Thai Subjects: Comparison with that of Japanese Subjects

Yuki Tsumura¹⁾, Luksana Makonakwkeyoon²⁾, Porn-ngarm Limtrakul²⁾,
Naoko Hirota³⁾ and Yoshiaki Sone⁴⁾

1) *Department of Food and Nutrition Studies, Junshin Junior College*

2) *Department of Biochemistry, Faculty of Medicine, Chiang Mai University, Thailand*

3) *Faculty of Human Health Science, Matsumoto University*

4) *Graduate School of Human Life Science, Osaka City University*

Abstract Previously, using the breath hydrogen test, we investigated seasonal variations in the amount of unabsorbed dietary carbohydrate from the intestine after breakfast in female Japanese university students and young Polish subjects. In the study we found that there were significant seasonal variations in both countries with the smallest unabsorbed dietary carbohydrate in autumn and the biggest in winter. Considering the theory of human adaptation to living environments, we suggested a hypothesis that this seasonal variation in the efficiency of carbohydrate absorption in the intestine may reflect human adaptation and/or a response to seasonal change in the living environment. In order to prove this hypothesis, we carried out the same examination in Chiang Mai, Thailand, where there is different seasonal change in the living environment from that of Japan and of Poland. In this examination, we measured the amount of unabsorbed dietary carbohydrate (UDC) from the intestine after breakfast and the oro-cecal transit time (OCTT) of the breakfast in female Thai university students using the same method and experimental protocol as previously carried out with Japanese subjects. We conducted the examination in April (the hot season), in August–September (the rainy season), and in November–December (the dry season) of 2008, at the Medical School of Chiang Mai University, Chiang Mai. The results are summarized as follows: (1) there were no significant seasonal variations in the amounts of unabsorbed dietary carbohydrate from breakfast in Thai subjects; (2) there were no significant seasonal variations in the oro-cecal transit times of breakfast or a soluble indigestible trisaccharide (lactosucrose) solution in Thai subjects; (3) there were no significant differences in the oro-cecal transit times of breakfast between the two countries in any season; (4) the UDC of Thai subjects was significantly less than that of the Japanese subjects in the three seasons. These results suggest that differences in seasonal change in a

living environment have different effects on seasonal variations in the efficiency of carbohydrate absorption in the intestine after breakfast. *J Physiol Anthropol* 29(4): 141–147, 2010
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Introduction

In the field of Physiological Anthropology, one important area of study is to reveal human physiological adaptability and response to living environments. Among environment conditions, regional climate is an important factor for human adaptation: “Climate is a pervasive and consistent aspect of the physical environment. Changing slowly on a geological time scale, it acts as an agent of natural selection and results in well-adapted populations” (Beall and Steegmann, 2000). During the course of our investigation on the effects of the environment on the human digestive system, we measured seasonal variations in the amount of unabsorbed dietary carbohydrate from the intestine after breakfast in young female Japanese university students (in 2003–2004) and Polish subjects (in 2004–2005), and found that the amount of unabsorbed dietary carbohydrate from breakfast was largest in winter and smallest in autumn (Tsumura et al., 2005ab). These results indicate that carbohydrate absorption is better in autumn than in winter, which is consistent with the seasonality of insulin secretion reported by Haus et al. (1988) where the insulin response to the three meals was in the order: autumn>summer>spring>winter. The seasonality of human biological function (digestive

activity in our research) could be one of the physiological adaptations to annual environmental change and be related to the behavioral rhythm of animals that hibernate (Sargent, 1968). Regarding annual environmental change, Japan and Poland belong to regions with four distinct seasons where the difference in the hottest and the coldest monthly mean temperature of an average year in Osaka and Poznan, for example, are about 23°C and 20°C, respectively. In contrast to these two cities, the average annual temperature is around 26°C in Chiang Mai, Thailand, and the monthly mean temperature is almost constant (varying by less than 8°C) when compared to those of Japan and Poland. In order to prove the hypothesis that seasonal variation in the efficiency of carbohydrate absorption found in young Japanese and Polish subjects may reflect human adaptation and/or response to seasonal change in a living environment, we examined seasonal variations in the amount of unabsorbed dietary carbohydrate from the intestine after breakfast in young female Thai subjects living in Chiang Mai using the same method and experimental protocol as done with Japanese and Polish subjects.

In this paper, we first analyzed seasonal variations in the amounts of unabsorbed dietary carbohydrate from the intestine after breakfast and oro-cecal transit times of two test meals in three seasons: the “hot season,” the “rainy season,” and the “dry season” in Chiang Mai. Then we compared the mean values of the unabsorbed dietary carbohydrate (UDC) from the breakfasts and oro-cecal transit times (OCTT) of the test meals between Thai and Japanese subjects only because the subjects’ gender, age, and anthropometric values were similar in the Thai and Japanese groups. We compared the UDC and OCTT values obtained in the following three seasons of around the same calendar months: the Thai “hot” season (April–May)—Japanese “spring” (April–May); the Thai “rainy” season (August–September)—Japanese “summer” (July–August); and the Thai “dry” season (November–December)—Japanese “autumn” (October–November).

In this study, we estimated the amount of unabsorbed carbohydrate (and OCTT) by means of the breath hydrogen test. This method has become the “gold standard”, or method of choice, for diagnosing non-digestion of lactose. When lactose or any other dietary sugar is not completely absorbed, colonic bacteria ferment the unabsorbed portion, forming hydrogen, some of which is absorbed into the portal circulation and exhaled in the breath (Savaiano and Levitt, 2000). Details of the breath hydrogen test were described in our previous paper (Tsumura et al., 2005a).

Methods

Subjects

Sixteen healthy female Thai university students belonging to the Medical School of Chiang Mai University, aged from 19 to 25 years (23.9 ± 1.6 years), volunteered for the 3-season study (over the course of one full year) as paid participants. They

Table 1 Comparison of subjects’ height, weight, and BMI between Thai and Japanese

	n	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m ²)
Thai subjects	16	23.9 ± 1.6	157.5 ± 5.6	49.5 ± 6.0	20.0 ± 2.4
Japanese subjects	26	20.2 ± 1.5	158.0 ± 4.9	49.9 ± 3.7	20.0 ± 1.4

Average $\pm$ SD (height and weight were recollected at the first examination of the breath hydrogen test)

were in the 2nd or 3rd year of an undergraduate course and living in Chiang Mai University dormitory or in the house in the town of Chiang Mai during the period of examination. Their average height, weight (recollected values) and Body Mass Index (BMI) were 157.5 ± 5.6 cm, 49.3 ± 6.0 kg, and 20.0 ± 2.4 kg/m², respectively. In the examination of 2004 in Japan (Tsumura et al., 2005a), twenty-six healthy Japanese females, aged from 19 to 23 years, volunteered for examination over the course of a year. Table 1 shows the comparison of height, weight, and BMI values between Thai and Japanese subjects. All participants were non-smokers and were required to report any antibiotic therapy received during the year (Gilat et al., 1978). Subjects underwent the breath hydrogen test in the follicular phase of their menstrual cycles, because the menstrual cycle can affect gastrointestinal activity (Wald et al., 1981).

We explained the purpose of the study and the procedures involved to all the subjects before they gave their written consent to participate according to the protocol approved by the Research Ethics Committee 3 of the Faculty of Medicine, Chiang Mai University (approval No. 256/2007).

Selection of calendar months for the Thai survey

As described in the Introduction, we examined UDC and OCTT values in Chiang Mai in the following three seasons, the “hot” season (April–May), the “rainy” season (August–September) and the “dry” season (November–December) of 2008. Table 2 shows monthly mean temperature, precipitation and sunshine duration of an average year (based on meteorological data from 1971 to 2000 in World Meteorology 2005, Maruzen Co. Ltd.,) in Chiang Mai, Thailand and Osaka, Japan. This table shows that in Chiang Mai, there are three “seasons” according to monthly mean temperature and precipitation that are inversely related to sunshine duration: the “hot” season (April–June, the hottest with mild precipitation), the “rainy” season (July–October, hot temperature with more precipitation) and the “dry” season (November–March, a little cooler temperature with less precipitation). The aim of this study was to find out the seasonal variation of the efficiency of carbohydrate digestion and absorption in the intestine. We therefore selected and conducted the breath hydrogen test in Chiang Mai in the three “seasons” of “hot,” “rainy,” and “dry.” In detail, the periods of time of each season when we carried out the breath hydrogen test were; April 1st to April 25th (the

Table 2 Comparison of monthly mean temperature, precipitation, and sunshine duration of an average year between Chiang Mai, Thailand and Osaka, Japan

	Chiang Mai, Thailand			Osaka, Japan		
	Temperature (°C)	Precipitation (mm)	Sunshine duration (hours)	Temperature (°C)	Precipitation (mm)	Sunshine duration (hours)
January	21.5	8	284	5.8	44	141
February	23.5	9	277	5.9	59	131
March	26.7	12	279	9.0	100	158
April	29.1	55	271	14.8	121	183
May	28.8	153	284	19.4	140	199
June	28.1	130	180	23.2	200	149
July	27.7	152	154	27.2	156	187
August	27.4	219	143	28.4	99	211
September	27.3	203	174	24.4	175	149
October	26.4	118	223	18.7	109	162
November	24.4	56	234	13.2	66	147
December	21.6	0	260	8.3	38	149

Based on meteorological data (World Metrological Data, 2005)

hot season), August 19th to September 5th (the rainy season), and November 25th to December 16th (the dry season).

As for the examination in Japan, we carried out the examination with two groups of subjects (twelve subjects in Osaka, fourteen subjects in Nagano), in the winter (January, February), spring (April, May), summer (July, August) and autumn (October, November) of 2004. The two factor (season and sub-group) independent measures analysis of variance shows that there was no significant difference in the amount of UDC and OCTT between the two sub-groups in any season. Accordingly, we pooled the data and used them for comparison with the values of Thai subjects in this paper.

Breath hydrogen test

The examinations were carried out following the same protocol as previously described (Fig. 1) (Tsumura et al., 2005a). Subjects were required to choose an easily digestible, low-fat evening meal at 20:00 on the day before (Day 0) and the first day (Day 1) of their participation. Fasting periods of at least twelve hours prior to the first breath sample were required on Days 1 and 2. Subjects were also required to retire earlier than 23:30 on the nights of Days 0 and 1. Subjects (usually in pairs) entered an air-conditioned room at 08:30 in the morning of Day 1 and Day 2 and remained sedentary in the room under normal fluorescent lamps until the end of the breath hydrogen test. Approximate mean room temperatures where the examination was carried out in Chiang Mai were 25°C in the three seasons (approximate average room temperatures in Osaka and Nagano were 24°C, 25°C, 27°C and 24°C in the winter, spring, summer and autumn, respectively). Subjects were instructed on how to collect their end-alveolar breath sample before the first breath sampling at 08:40, and ate a normal breakfast at 09:10 on Day 1. This meal was prepared from commercially available canned minestrone and macaroni (their nutrient compositions are shown in Table 3). On Day 2,

Fig. 1 Experimental protocol (the same in the three seasons).

Details described in a previous paper (Tsumura et al., 2005a).

*: the sampling time when the head of chyme is assumed to enter the cecum

Table 3 Nutrient composition of breakfast

Total weight	540 g
Total energy	367 kcal
Protein	12.4 g
Fat	2.5 g
Carbohydrate*	72 g
(* dietary fiber)	
	7 g

subjects ingested an indigestible trisaccharide solution (200 ml of water containing 6 g of commercially available lactosucrose; Ensui Co. Ltd., Shizuoka, Japan) at the same time as breakfast on Day 1. Every subject had the two meals in the same order each season. As subject's end-alveolar breath samples were collected every 20 minutes from 08:50 into special airtight bags using the Alveolar Gas Collection System AGC-3000 (Breath Lab Co. Ltd., Nara, Japan) and hydrogen concentrations were measured by gas chromatography (Breath Gas Analyzer model BGA-1000; Breath Lab Co. Ltd., Nara, Japan). The area under the curve when hydrogen concentration in the breath was plotted against time (abbreviated as AUC) was used to represent the amount of hydrogen resulting from

fermentation of unabsorbed carbohydrate by micro flora in the large bowel. AUC was calculated according to the trapezoidal rule (Rumessen et al., 1989) and expressed in units of parts per million · hour (ppm · hr). We defined AUC values corresponding to the breakfast meal or lactosucrose solution as the AUC for 3 hours from the point when the head of chyme was considered to have first entered the cecum. In the examination for young Japanese subjects, we defined the AUC for 3 hours and 20 minutes (we collected one more end-alveolar breath sample from young Japanese subjects than for Thai subjects, Tsumura et al., 2005a). The amount of unabsorbed dietary carbohydrate (UDC) from the morning meal, evaluated as the “lactosucrose equivalent (g),” was calculated by the following equation: $6 \times (\text{AUC for breakfast} / \text{AUC for 6 g of lactosucrose})$. The ratio of UDC from the morning meal to its total carbohydrate content was calculated on the assumption that 7 g of dietary fiber in the meal are also fermented in the colon by its micro flora (Eastwood, 1999). As a result, the percentage of UDC from the morning meal was calculated by the following equation: $\text{UDC (lactosucrose equivalent, grams)} / 72 \times 100$.

Data analyses

All data were expressed in terms of means $\pm$ standard deviation (SD). Seasonal variations in the OCTT for both test meals and the amount of UDC (and its percentage of total carbohydrate) from the breakfast of Thai subjects were analyzed by one-factor (season) dependent measures analysis of variance (ANOVA). Comparisons between the two groups', Thai and Japanese, mean values of the OCTT for both test meals and the amounts of UDC (and its percentage of total carbohydrate) from breakfast were performed by two-factor (country and season) independent measures analysis of variance. We carried out the statistical analyses using SPSS ver.17.0 software. A p value of <0.05 was considered to be statistically significant.

Results

Seasonal variations in UDC and OCTTs of Thai subjects

Among sixteen participants, fourteen participants successfully completed the study, which lasted three seasons (over the course of one full year). Figure 2 depicts UDC values as lactosucrose equivalent (g), percentages of UDC (%) in total carbohydrate from breakfast ($\text{UDC}/72 \times 100$) and also their means and standard deviations for each Thai subject (closed circle). UDC values (and their percentages) in the “hot,” “rainy,” and “dry” seasons were 3.8 ± 1.6 g ($5.3 \pm 2.2\%$), 3.8 ± 1.4 g ($5.3 \pm 1.9\%$) and 3.1 ± 2.0 g ($4.4 \pm 2.7\%$), respectively. One-factor (season) ANOVA values indicated that there were no significant seasonal variations in the amount of UDC [$F(2, 24) = 0.689$, $p = 0.512$]. Table 4 compares the OCTT values in the three seasons for both test meals and the difference between the OCTTs of breakfast and the values of soluble lactosucrose (it was difficult to define one subject's OCTT of both meals, we therefore carried out one-factor (season) dependent measures analysis of variance using thirteen OCTT values). One-factor (season) dependent measures analysis of variance showed that there were no significant seasonal

Fig. 2 Amounts and percentages of UDC (gram, lacto sucrose equivalent) for each subject after breakfast (●: Thai and ○: Japanese); means of UDC (■: Thai and □: Japanese with SD bars) for the three seasons.

Table 4 OCTT of breakfast and lactosucrose solution of Thai and Japanese subjects in three seasons

		<i>n</i>	A: OCTT of breakfast (minutes)	B: OCTT of lactosucrose solution (minutes)	Difference between A and B (minutes)
Thai subjects' group	“hot” season				
	April–May	13	226 $\pm$ 66	94 $\pm$ 43	124 $\pm$ 54
	“rainy” season				
	August–September	14	251 $\pm$ 89	92 $\pm$ 35	145 $\pm$ 86
Japanese subjects' group	“cooler dry” season				
	November–December	13	234 $\pm$ 40	106 $\pm$ 40	127 $\pm$ 58
	spring				
	April–May	18	244 $\pm$ 60	167 $\pm$ 73	78 $\pm$ 81
	summer				
	July–August	15	224 $\pm$ 50	149 $\pm$ 68	75 $\pm$ 67
	autumn				
	October–November	14	214 $\pm$ 51	139 $\pm$ 62	76 $\pm$ 71

variations in the OCTT values of breakfast [$F(2, 22)=0.176$, $p=0.840$], in the lactosucrose solution [$F(1.35, 14.83)=0.862$, $p=0.401$] or in the difference between these two OCTT values [$F(2, 22)=0.625$, $p=0.545$]. In the breath hydrogen test, the OCTT value for breakfast indicates the length of time taken for the chyme to pass through the stomach and the small intestine, while the OCTT for the lactosucrose solution indicates the length of time for the soluble oligosaccharide to pass through the small intestine only because soluble oligosaccharides are not retained in the stomach (Kondo et al., 1994). Therefore, where no significant seasonality was found in the OCTT values, the gastrointestinal motility might be stable in Thai subjects (for the three seasons).

These results show: (1) there were no significant seasonal variations in the amounts of unabsorbed dietary carbohydrate from breakfast in Thai subjects; (2) there were no significant seasonal variations in the oro-cecal transit times of breakfast or the lactosucrose solution in Thai subjects.

Comparison of UDC and OCTTs between Thai and Japanese subjects

Figure 2 compares the seasonal changes in UDC values as lactosucrose equivalent (g) and percentages of UDC (%) to total carbohydrate from breakfast over three seasons between Thai (closed circle) and Japanese subjects (open circle). The UDC values and their percentages to total carbohydrate of the breakfast of Japanese subjects in Fig. 2 were recalculated to adjust them to the values for 3 hours because we calculated the AUC of Japanese young subjects for 3 hours and 20 minutes in the examination of 2004 in Japan (Tsumura et al., 2005a). The UDC values (% to total carbohydrate of breakfast) of Thai subjects and Japanese subjects in the “hot,” “rainy” and “dry” seasons were: 3.8 ± 1.6 g ($5.3 \pm 2.2\%$), 3.8 ± 1.4 g ($5.3 \pm 1.9\%$) and 3.1 ± 2.0 g ($4.4 \pm 2.7\%$); 6.1 ± 2.1 g ($8.5 \pm 3.0\%$), 6.4 ± 3.3 g ($8.9 \pm 4.6\%$) and 4.3 ± 1.9 g ($6.0 \pm 2.7\%$), respectively. It is apparent that the UDC values of the Thai group are lower than those of the Japanese group; two-factor (country and season) ANOVA showed that there was no significant interaction between country and season [$F(2, 80)=0.845$, $p=0.433$], but there was a significant main effect for the country [$F(1, 80)=18.663$, $p<0.001$]. This indicates that the amount of unabsorbed carbohydrates that passed into the cecum was less than that of the Japanese subjects. In other words, Thai subjects absorbed carbohydrates from breakfast more efficiently than Japanese subjects in the three seasons.

Table 4 compares the seasonal changes in the OCTT values of breakfast, the OCTTs of the lactosucrose solution, and the difference between the OCTTs of the breakfast and that of lactosucrose solution between Thai and Japanese subjects. Two-factor (country and season) ANOVA showed that there was no significant interaction between country and season in the OCTT values of breakfast [$F(2, 72)=0.947$, $p=0.393$]. In addition, there was no main effect for the country [$F(1, 72)=0.001$, $p=0.971$] or for the season [$F(2, 72)=0.247$, $p=0.782$]. In contrast, the OCTT values of the lactosucrose

solution indicated a significant main effect for the country [$F(1, 72)=13.831$, $p<0.001$]. Conversely, there was no significant correlation between country and season [$F(2, 72)=0.984$, $p=0.379$] in the OCTT values of the lactosucrose solution. (Consequently, the difference between the two test meals of the Thai group was significantly shorter than that of the Japanese group, $p<0.001$).

Discussion

Seasonal variations in UDC and OCTTs of Thai subjects

In this study, we found that there were no significant seasonal variations between “hot,” “rainy,” and “dry” seasons in the amounts of unabsorbed dietary carbohydrate from the intestine after breakfast in young female Thai subjects as shown in Fig. 2. In addition, we found that there were no seasonal variations in the oro-cecal transit times for either breakfast or the soluble indigestible trisaccharide (see Table 4). In the breath hydrogen test, the OCTT values for breakfast indicated the length of time taken for the chyme to pass through the stomach and the small intestine; therefore, these results indicate that gastrointestinal activity for the digestion and absorption of dietary carbohydrates, which includes secretion of carbohydrate-digesting enzymes and gastrointestinal-motility activity, did not vary significantly in the three seasons. In this study we examined the amounts of unabsorbed dietary carbohydrate from the intestine and the oro-cecal transit times in three seasons: the so-called “hot,” “rainy,” and “dry” seasons, in Chiang Mai, Thailand, where each season has a smaller difference in temperature compared to those of Japan and Poland. (Thailand has a warm, tropical climate affected by an annual monsoon, with a rainy season from June to October and a dry season for the rest of the year.) As described in the Introduction, the annual average temperature in Chiang Mai is around 26°C and the mean monthly temperature is relatively constant when compared to those of Japan and Poland (the difference in temperature is less than 8°C). From the viewpoint of human biology, climate varies widely across geographic space, and thus, evolutionary theory predicts that populations will differ biologically in ways that reflect adaptation to seasonal change in the local environment. Of course we need further examination in different climate regions, but the results may support our hypothesis that seasonal variation in the efficiency of carbohydrate absorption in the intestine may reflect human adaptation and/or a response to seasonal change in the living environment. Concerning the circannual rhythm of human nutrition, Haus et al. (1988) found a seasonal change in the insulin response to normalized diets in normal subjects living in Minnesota, USA—the insulin response was strongest and fastest in autumn, while it was weakest and slowest at the end of winter. Also, Griffith found a circannual rhythm of the human Respiration Quotient (RQ) and showed that RQ was highest from the middle of summer to the middle of autumn in Buffalo, USA (1929), indicating that the people metabolize carbohydrates most efficiently and predominantly in these

periods of the year. Additionally, both cities are in the northern part of the USA where there are four distinct seasons. This seasonality could be one of the physiological adaptations to annual environmental change and be related to the behavioral rhythm of animals that hibernate (Sargent, 1968). From another point of view, therefore, consistency of climate may provide Thai people with a relatively constant annual food supply and adaptation to this constant food supply may result in no seasonal variations in carbohydrate digestion and absorption, as observed in our Thai subjects. In order to obtain more evidence for human nutritional adaptation and/or response to seasonal environment change, we need to examine and compare (1) seasonal variation in hormonal response such as insulin response to the same normalized diets in normal subjects as described by Hans et al. (1988), (2) seasonal variation in food intake, especially in carbohydrate intake, and (3) seasonal variation in the metabolic ratio between carbohydrate and lipid in different climate zones.

Comparison of UDC and OCTTs between Thai and Japanese subjects

Figure 2 compares the seasonal changes in UDC values as lactosucrose equivalent (g) and percentages of UDC (%) to total carbohydrate from breakfast over three seasons between Thai (closed circle) and Japanese subjects (open circle). In any season both UDC values and percentages of UDC to the total carbohydrate of breakfast for Thai subjects were lower than those of Japanese subjects. As described in the "Introduction", the amounts of UDC of Japanese subjects were smallest in autumn and the values and percentages were 4.3 ± 1.9 g and $6.0 \pm 2.7\%$, respectively (Tsumura et al., 2005a). The amounts of UDC and the percentages of Thai subjects in the three seasons were lower than the lowest values of Japanese subjects in the corresponding three seasons, which indicates that the efficiency of carbohydrate digestion and absorption of dietary carbohydrates in the breakfast of Thai subjects was better than that of Japanese in any season. From the viewpoint of nutritional physiology, inter-populated variations in the efficiency of carbohydrate digestion and absorption may be related to the level of everyday consumption of starchy food because Perry et al. (2007) found that the copy number of the salivary amylase gene (AMY1) correlated positively with salivary amylase protein level and that individuals from populations with high-starch diets have, on average, more AMY1 copies than those with traditionally low-starch diets. We carried out a food intake survey using a Food Frequency Questionnaire with Japanese subjects along with the breath hydrogen test for four seasons, 2004 (Tsumura et al., 2005a), and Watanabe et al. reported the result of food intake survey of Chiang Mai University students, 2006 (Watanabe et al., 2007). The nutrient intake results of Japanese subjects in winter were 1731.4 ± 380.3 kcal (total energy), 55.6 ± 10.8 g (protein), 55.6 ± 16.6 g (lipid), and 243.6 ± 68.6 g (carbohydrate), while the results of female Thai students reported by Watanabe were 1741.8 ± 297.3 kcal, 56.7 ± 12.7 g, 42.2 ± 12.0 g, and $283.8 \pm$

49.6 g, respectively. It is very hard to compare these data because in Thailand the food intake survey was carried out only in September and the consumption of carbohydrates of female Thai students was higher than that of Japanese subjects, while the total energy intake was almost the same between the two groups. Therefore, the difference in carbohydrate consumption between the two groups may partly explain the difference in the UDC values and the percentages between the Japanese and Thai subjects. Concerning the seasonal variations in the nutrient intake of young female Thai students, we are now carrying out a study with a group of female students at Chiang Mai University, School of Medicine. From the other point of view, differences in the environmental light condition might cause the difference in the UDC values and the percentages between the Japanese and Thai subjects, as we obtained the finding that daytime dim-light exposure caused less absorption of dietary carbohydrate and less induction of gastro-myoelectric activity compared to daytime bright light exposure (Sone et al., 2003). As shown in Table 2, total sunshine duration in each season in Chiang Mai is longer than that of Osaka, Japan. Therefore it is interesting to take account of the effect of sunshine duration in the difference in the UDC values and the percentages between the Japanese and Thai subjects, though we have not recorded the actual exposures to bright light of each subject and it is not yet clear that bright light exposure has a long-term positive effect on gastrointestinal activity.

Table 4 compares seasonal variations in the OCTT values of the breakfast, the OCTTs of the lactosucrose solution, and the difference between the OCTTs of breakfast and that of the lactosucrose solution between Thai and Japanese subjects. It is apparent that the OCTT values of breakfast were not different between the two groups, but the values of the lactosucrose solution for the Thai subjects were significantly shorter those of the Japanese subjects. Consequently, the difference between the OCTTs of breakfast and the oligosaccharide solution of Thai subjects was significantly longer than that of Japanese subjects. Anthropological indices, such as height and weight, were not different between the two groups as shown in Table 1. And, as described in the "Introduction", in the breath hydrogen test, the OCTT value for breakfast indicates the length of time taken for the chyme to pass through the stomach and the small intestine, while the OCTT value for oligosaccharide indicates the length of time taken for the soluble carbohydrate to pass through the small intestine because soluble carbohydrate is not retained in the stomach. Therefore, the difference between the OCTT values of breakfast and the oligosaccharide solution may reflect the longer retention time of chyme in the stomach for Thai subjects than Japanese subjects. This longer retention of chyme in the stomach is one of the reasons why Thai subjects have better carbohydrate digestion and absorption compared to the Japanese.

In conclusion, we found that there is no seasonality in seasonal variation in amount of unabsorbed dietary carbohydrate from the intestine after breakfast in young female

Thai subjects and their efficiency was better than those of Japanese subjects in any three seasons.

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Correspondence to: Yoshiaki Sone, Graduate School of Human Life Science, Osaka City University, 3–3–138 Sugimoto-cho, Sumiyoshi-ku, Osaka 558–8585, Japan

Phone: +81–6–6605–2854

Fax: +81–6–6605–2854

e-mail: sone@life.osaka-cu.ac.jp