Classification of common foods consumed by Thais based on textural properties

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Abstract

The role of food textures on human masticatory morphologies and functions has been studied extensively, however, reference data on the textural properties of hard/chewy foods is lacking. Varieties of international foods are generally consumed by Thais these days, providing an opportunity to develop textural property tables of hard-to-chew foods for Asians. Under this aim, foods were categorized as meats, vegetables and fruits, and starches and snacks. Textural properties of eighty-eight perceived hard-to-chew foods listed by a panel of variety backgrounds were tested by means of a Universal Testing Machine, under the Texture Profile Analysis (TPA) mode. Descriptive statistics of five textural attributes (hardness, cohesiveness, springiness index, chewiness, and gumminess) of each food item were summarized. The effects of cooking methods as well as food types were tested. Items of foods within the same inter-quartile range, based on hardness and chewiness, were grouped in order to establish a table, which can be internationally used for further studies relating hard/chewy food consumption behaviour and dental variables of interest.

Keywords: *Thai foods, textural properties, hard foods, chewy foods, texture profile analysis*

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Introduction

Food texture is defined as the sensory manifestation of the structure of the food and the manner in which this structure reacts to the applied forces.[1] It is a physical property of foods relating to the deformation, disintegration, and flow under force,[2] measured objectively by the functions of time, mass, and distance.[3] The attributes includes a variety of characteristics, such as, hardness, cohesiveness, springiness, gumminess and chewiness.[4] Hardness, by sensorial definition, is the force required to compress a food between molars. Chewiness is the energy required to chew the food into a state ready for swallowing.[4] These two parameters explain masticatory activity differently A larger amount of force is needed to break down high hardness foods, where extensive and prolonged mastication is necessary to masticate foods with high chewiness.

In terms of oral science, researchers have related the influence of food hardness and chewiness to several aspects. Masticatory muscle activities, chewing strokes and time were found to be positively related to the hardness of foods.[5] The ability to chew hard food has been used as one of the several attributes to determine the patients' perception to their new prosthesis,[6-12] and to detect temporomandibular dysfunction.[13, 14] It was later revealed that not only hardness, but also elasticity has an influence on the neuromuscular activity during mastication in human.[15, 16] Many anthropological studies have backed up a theory that a high prevalence of malocclusion in modern human arises from the lack of chewing stress in the modern soft, refined and processed diet resulting in the lack of stimulation and direction provided to the growing jaws and erupting teeth.[17-20] The statement has been supported by several animal experiments.[21-27]

Despite the important role of food texture on human dental health studies, to date, reference data on the textural properties of hard/chewy foods is sparse. Several studies intuitively picked foods considered to be hard or chewy without testing for the actual values of the physical properties.[8-10,] Moreover, some test foods, such as raw carrot, nuts, cheeses, and apple, were common to westerners, but not so to subjects of other cultures. Without clear information on comparability of food texture, comparing chewing ability between studies would be doubtful. Therefore, it is the aim of this study to develop textural property tables of hard-to-chew foods based on high variety of food consumed by Thais. Attention was especially focused on hardness and chewiness, since these two parameters are important for the assessment of masticatory activities.[15] In anticipation, the information can be internationally used as a source of reference for studies relating hard/chewy foods consumption and dental variables of interest.

Materials and methods

Study site

The study was undertaken in Hatyai city, one of the largest cities locating in the southern part of Thailand. It is a center of development and business in the lower region of the country. Hatyai's population composes of a mixture of Thais, Chinese, Malays, and, to a lesser extent, Westerners. Urban citizens mostly work in the business sector and live a modern lifestyle, although those living in surrounding rural areas are typically agriculturers and are more inclined to the traditional life. With regard to eating practice, Thai and Chinese foods are the

most common dishes for general population. However, Malay and Western foods are not unusual. International foods are available over the city these days.

Panel opinion and food selection

Individuals of various professions, initially ten people, were invited to form a panel. Each panellist was requested to give a list of foods with cooking methods that they perceived as hard-to-chew for children. The condition was limited to children because they were assumed to have less masticating ability than adults, so even less perceived hard-to-chew foods would not be missed. Hard-to-chew foods were explained as those that are firm and not easy to break when chewing, or those that require a long time to chew before ready for swallowing. More panellists were recruited until the list became saturated. Finally, 334 food items came from 43 panellists (2 food scientists, 2 nutritionists, 2 primary school teachers, 2 pediatricians, 2 nurses, 4 cooks, 6 dentists and 23 mothers of young children; age ranged between 24.7 – 45.4 years old). Only foods that were mentioned by more than 4 panellists, altogether 88 items, were tested for textural properties.

Texture profile analysis (TPA) of foods

A Lloyd ® Universal Testing Machine (LRS Plus model, AMETEK Lloyd Instruments Ltd, Hampshire, UK) equipped with a 5 kN load cell was used to perform the TPA of foods. Ten samples per food item were tested. To ensure the coverage of the variability of foods, each food item was randomly purchased from more than one store. The sample was prepared to a shape of 1 cm cube. Items originally smaller than 1 cm were tested under their natural form. Those unpreparable into a cube form were prepared as close to 1 cm of thickness as possible. Fresh food samples were tested immediately after purchase. In case of the testing machine being occupied, the foods would be stored in the refrigerator for not more than 6 hours. For cooked foods, the sample was tested at the ready for serving condition.

During the test, each sample was carefully placed under the cylindrical-shape probe (2.5 cm diameter). The sample was then compressed twice to 50% of its original height at a speed of 30 mm/min. The dual compression simulates first two chews on the food and the output is a curve of force versus time. The following parameters were calculated based on definitions of Bourne3:

Hardness (N) [H]: The force required to compress the sample to a given distance; the peak force during the first compression.

Cohesiveness (dimensionless) [C]: The ratio of work done during the second compression divided by the work done during the first compression; the indication of the visco-elasticity of a sample.

Springiness index (dimensionless) [SI]: The ratio of the height that the sample springs back after the first compression to the maximum deformation performed; the indication of the recovery properties of a sample. Chewiness (N mm) [Chew]: The product of Hardness, Cohesiveness and Springiness; the work required to chew a solid food into a state of ready for swallowing. Gumminess (N) [G]: the product of hardness and cohesiveness; the force required to break down a semi-solid food for swallowing. All these parameters were determined by Nexygen ® material testing software (AMETEK Lloyd Instruments Ltd, Hampshire, UK). Finally, a textural property table was established.

Statistical analysis

R statistical package (version 2.4.1) was used. Foods were grouped into three categories (meats, vegetables & fruits, starches & snacks). Five textural attributes of each tested food were expressed as mean and 95% confidence interval. The effects of different cooking methods on the same food type, as well as the effects of different food types with similar cooking method were evaluated by Mann-Whitney test or Kruskal-Wallis test. Finally, food items were grouped based on the pooled inter-quartile range (IQR) of hardness and chewiness to produce an exchange table. This table groups food items with similar level of difficulty to chew in the same cell.

Results

The details of the mean and 95% CI of hardness (H), cohesiveness (C), springiness index (SI), chewiness (Chew), and gumminess (G) of 88 foods, categorized as meats, vegetables & fruits, starches and snacks, are presented in Table 1. All categories yielded wide ranges of hardness although meats had the lowest median and the shortest range ($p = 0.04$, ANOVA). Chewiness among different food categories was more distinctive. Meats showed considerably higher median than the other categories ($p < 0.01$, ANOVA).

In Table 2, given the same food type, different cooking methods had an effect on chewiness to a higher extent than on hardness. On the other hand, Table 3 shows that, given the same kind of cooking method, hardness and chewiness were not significantly different among meat types. However, pork was generally harder than chicken and fish after mincing and mixed with starch to produce balls. Variation of vegetables & fruits' hardness and chewiness were remarkable given the same means of cooking such as roasting and stir frying.

Table 4 present the two-way classification of tested foods by pooled inter-quartile range of hardness and chewiness. Foods were dispersed along the range of hardness and chewiness.

Discussion

The results from the present study show that tested foods had a wide range of hardness and chewiness. Although meats had the lowest median and the shortest range of hardness, they showed distinctively higher degree of chewiness than vegetables & fruits and starches & snacks. Cooking methods and food types played a role on both attributes. Tested foods were dispersed along the inter-quartile range of hardness and chewiness parameters. Even though all tested foods were perceived to be hard-to-chew according to the panellists, the ranges of hardness and chewiness attributes derived from TPA were broad, demonstrating the diversity of individuals' sensory perception on textural parameters. It was postulated that the way a person defines texture is shaped by several aspects including physiological factors, socially and culturally learned expectations, and psychologicalfactors.31 Thus, instrumental approach is essential to obtain reliable and accurate data, which is an important requirement when these data are to be used as one of the explanatory variables to relate the effect of food texture on an outcome variable.

Although cooking methods and food types had an effect on textural properties, which were in concordance with reports from several previous studies,32-36 it seemed that these effects may not necessarily overcome the within-category properties, such as structural, physiological, and biochemical

characteristics. A clear example is apparent in meats, as they showed values of chewiness distinct from the other categories. Food familiarity and acceptability in a particular cultural setting is an issue of concern when selecting test foods for a study. For example, roasted almond and fresh carrot have been commonly used as test foods in many studies,[6, 8-10, 15, 28, 29, 37, 38] but may not be suitable for subjects of Asian cultures by whom these two foods are not commonly consumed. The established table in the present study provides pools of exchangeable food items grouped by hardness and chewiness which may be useful for the selection of appropriate test foods for studies in particular cultures. Guava and unripe mango could be used as substitutes for almond and carrot as they yield comparable degree of hardness and chewiness, and advantageously, they are commonly eaten fruits among Asians.

The other consideration is the use of meat items as test food. Special attention has to be paid when selecting meat for studies requiring subjects to chew, because of cultural difference. The guideline table in this study provides textural properties of several meat types. Meat with comparable properties can be substituted by one another when the studies are performed in different non-vegetarian cultures.

While most previous studies were confined to a small items of foods with method of food selection based on researchers' decision,[15, 16, 39] ours using panellists with varied background could cover wider ranges of textural attributes. Moreover, further selection of tested items mentioned by more than 4 panellists could increase the likelihood that the items were among those commonly consumed by people.

One limitation encountering the establishment of textural property tables is the ability to deal with variability of foods. Foods differ in texture depending on several factors, such as, the origin of foods (species, age at harvest or slaughter, parts), preparation methods (fermenting, marinating, drying, etc), cutting methods (slicing, mincing, chopping, pounding, milling, etc), cooking methods (eaten raw, boiling, parboiling, stir frying, roasting, etc) and lag-time between cooking and eating. Even though attempt was made to cover this variability as much as possible, it is unlikely to entirely eradicate all these factors.

Conclusion

Five parameters of textural property of 88 perceived to be hard-to-chew food items commonly consumed by Thais were established. Meats, vegetables & fruits, and starches & snacks had overlapping hardness but quite distinct chewiness. The textural properties could be modified by cooking methods. Finally, a table for foods of similar hardness and chewiness properties was established.

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Table 1 Mean and 95% CI of the textural properties of vegetables and fruits (n=40)

Foods Vegetables and fruits	**Hardness (N)**		**Cohesiveness (dim.less)**		**Springiness Index (dim.less)**		**Gumminess (N)**		**Chewiness (N mm)**	
Almond, roasted	447.27	(362.99-531.55)	0.05	(0.04-0.06)	0.35	(0.32-0.38)	24.40	(16.17-32.63)	36.75	(22.05-51.45)
Apple, green	44.79	(41.55-48.02)	0.05	(0.04-0.06)	0.83	(0.72-0.94)	2.06	(1.67-2.45)	4.21	(3.14-5.29)
Apple, red	36.95	(30.38-43.51)	0.02	(0.01-0.03)	0.69	(0.46-0.92)	0.59	(0.49-0.69)	0.78	(0.49-1.08)
Asparagus, stir fried	48.12	(43.41-52.82)	<0.01	(<0.01-0.02)	0.16	(0.14-0.18)	0.10	(0.10-0.20)	0.10	(<0.10-0.20)
Baby corn, stir fried	60.96	(48.71-73.21)	0.06	(0.5-0.07)	0.24	(0.22-0.26)	3.53	(2.45-4.61)	4.21	(2.55-5.88)
Broccoli, stir fried	116.33	(92.41-140.24)	0.04	(0.03-0.05)	0.51	(0.39-0.63)	4.41	(2.74-6.08)	8.43	(2.55-14.31)
Cabbage, raw	129.85	(106.23-153.47)	0.12	(0.10-0.14)	0.52	(0.47-0.57)	16.66	(11.76-21.56)	22.15	(15.19-29.11)
Cantaloupe	41.94	(26.17-57.72)	0.04	(0.03-0.05)	0.25	(0.20-0.30)	1.57	(0.98-2.16)	2.35	(1.27-3.43)
Carrot, raw	273.62	(226.58-320.66)	0.06	(0.05-0.07)	0.81	(0.42-1.20)	15.68	(11.66-19.70)	46.16	(31.95-60.37)
Cashew nut, roasted	137.79	(93.49-152.68)	0.01	(0.0-0.02)	0.18	(0.13-0.23)	1.96	(0.20-3.72)	1.47	(0.20-2.74)
Cauliflower, stir fried	284.98	(244.22-325.75)	0.06	(0.05-0.07)	0.45	(0.38-0.52)	7.35	(2.35-12.35)	22.93	(22.34-23.52)
Papaya, unripe	76.83	(53.70-99.96)	0.10	(0.08-0.12)	0.51	(0.47-0.55)	7.84	(4.21-11.47)	6.76	(3.33-10.19)
Potato, deep fried	27.73	(18.62-36.85)	0.09	(0.07-0.11)	0.35	(0.20-0.50)	2.25	(1.57-2.94)	5.39	(2.45-8.33)
Peanut, roasted	38.51	(31.46-45.57)	<0.01	(<0.01-0.01)	0.16	(0.03-0.35)	<0.10	(<0.10-0.10)	<0.10	(<0.10-0.10)
Pickled vegetable	35.48	(30.38-40.57)	0.03	(0.02-0.04)	0.20	(0.18-0.22)	0.88	(0.59-1.18)	0.69	(0.98-0.39)
Pineapple	41.94	(31.65-52.23)	0.06	(0.05-0.07)	0.27	(0.19-0.35)	2.35	(1.67-3.04)	5.98	(1.86-10.09)
Pummelo	19.11	(13.52-24.70)	0.06	(0.05-0.07)	0.32	(0.28-0.36)	1.18	(0.78-1.57)	2.35	(0.98-3.72)
Pumpkin, parboiled	58.60	(31.16-86.04)	0.03	(0.02-0.04)	0.24	(0.11-0.37)	1.37	(0.59-2.16)	1.67	(0.29-3.63)
Rose apple	60.27	(49.00-71.54)	0.05	(0.04-0.06)	0.37	(0.30-0.44)	2.74	(2.06-3.43)	6.08	(4.61-7.55)
Snap bean, stir fried	61.15	(54.98-67.33)	0.08	(0.07-0.09)	0.56	(0.47-0.65)	4.80	(3.72-5.88)	15.19	(9.80-20.58)
Sweet corn, parboiled	27.34	(21.07-33.61)	0.03	(0.02-0.04)	0.38	(0.28-0.48)	0.78	(0.59-0.98)	0.69	(0.39-0.98)

Table 2 Effects of cooking methods on food hardness and chewiness

Food types / cooking methods	Hardness			Chewiness		
	median (N)	IQR [a]	p-value [b]	median (N mm)	IQR [a]	p-value [b]
Beef						
Parboiled	30.0	20.6-62.1	0.08	15.4	8.4-19.8	0.07
Stewed	15.1	12.5-20.5		8.2	4.5-9.9	
Chicken						
Stir fried	26.4	19.3-29.0	0.17	19.5	16.3-21.0	0.02*
Deep fried	30.4	25.7-34.2		25.6	22.4-29.9	
Pork						
Shredded	31.7	23.1-58.7	0.35	15.0	11.9-26.0	0.02*
Shredded & sweetened	46.0	37.8-54.6		36.2	25.8-42.3	
Pork						
Grilled	21.1	19.7-25.2	0.02*	17.1	15.3-21.3	0.02*
Stir fried	34.0	21.7-38.3		19.5	13.7-24.5	
Stewed	16.8	10.7-22.0		6.2	3.8-11.8	
Yard long bean						
Parboiled	118.6	90.8-138.3	0.65	8.3	6.4-11.0	<0.01**
Raw	110.1	68.1-135.6		24.8	13.4-27.2	

[a] IQR = Inter-quartile range

[b] Mann-Whitney test or Kruskal-Wallis test

Statistical significant : * $p<0.05$, ** $p<0.01$

Table 3 Effects of food types on hardness and chewiness

Cooking methods / food types	Hardness			Chewiness		
	median (N)	IQR [a]	p-value [b]	median (N mm)	IQR [a]	p-value [b]
Jerky						
Beef	34.4	28.8-48.5	0.63	45.9	30.4-67.8	0.12
Pork	45.2	33.0-56.1		24.5	12.9-54.9	
Shredded						
Beef	23.9	16.3-28.0	0.12	27.0	19.2-33.4	0.25
Pork	31.7	23.1-58.7		15.0	11.9-26.1	
Stewed						
Beef	15.1	12.5-20.5	0.90	8.2	4.5-9.9	0.78
Pork	16.8	10.7-22.0		6.2	3.8-11.8	
Stir fried						
Chicken	26.4	19.3-29.0	0.19	19.5	16.3-21.0	0.97
Pork	34.0	21.7-38.3		19.5	13.7-24.5	
Sausage						
Chicken	43.9	40.2-45.1	0.04 *	64.4	58.2-67.8	0.53
Pork	46.9	43.9-20.2		56.9	53.3-67.3	
Ball						
Beef	10.3	9.0-11.8	<0.001 ***	15.5	12.7-18.4	<0.001***
Fish	7.5	7.1-8.0		8.7	8.3-10.2	
Pork	15.3	12.7-17.7		20.0	14.6-26.2	
Roasted						
Almond	429.9	340.7-566.3	<0.001 ***	33.0	17.6-48.7	<0.001***
Cashew nut	119.4	101.0-185.4		0.2	<0.01-2.5	
Peanut	38.5	35.0-42.6		<.0.01	<0.01	
Stir fried						
Asparagus	45.0	41.3-53.0	<0.001 ***	0.1	0.01-0.1	<0.01**
Broccoli	102.1	89.7-128.4		5.4	3.9-6.8	
Cauliflower	315.4	252.7-335.9		21.4	16.3-26.2	
Chinese kale	258.2	213.7-286.4		14.1	9.9-15.9	

[a] IQR = Inter-quartile range

[b] Mann-Whitney test or Kruskal-Wallis test

Statistical significant : * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 4 Hardness (H) in N and chewiness (C) in N*mm of meat items categorized by inter-quartile range (IQR)

H / C	1st IQR (H < 26.97)	2 nd IQR (26.97 ≤ H < 48.07)	3 rd IQR (48.07 ≤ H < 104.4)	4 th IQR (H ≥ 104.4)
1st IQR (C < 2.35)	-	-	-	Ching chang fish
2 nd IQR (2.35 ≤ C < 8.87)	Beef, stewed	-	Pork cartilage, boiled Pork, cracking	Pork, crispy sheet
3 rd IQR (8.87 ≤ C < 24.35)	Beef ball Chicken, boiled Chicken, stir fried Fish ball Pork ball Pork, grilled Pork, stewed Squid, parboiled	Beef, parboiled Pork, shredded Pork, stir fried	-	-
4 th IQR (C ≥ 24.45)	Beef, shredded	Beef, jerky Chicken, deep fried Chicken, sausage Pork, jerky Pork, sausage	Chinese sausage (Gun-chiang) Pork, red roasted Pork, streaky	Prawn, deep fried Shrimp, dried

การจัดกลุ่มอาหารสามัญที่คนไทยรับประทานตามคุณสมบัติเนื้อสัมผัส

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บทคัดย่อ

ถึงแม้จะมีการศึกษาจำนวนหนึ่งที่พบบทบาทของเนื้อสัมผัสอาหารต่อระบบบดเคี้ยว แต่ฐานข้อมูลอ้างอิงเกี่ยวกับคุณสมบัติความแข็งและความเหนียวของอาหารยังมีอยู่น้อย เนื่องจากปัจจุบันสังคมไทยมีความเป็นสากลมากขึ้น มีการเปิดรับวัฒนธรรมการรับประทานอาหารจากต่างประเทศที่หลากหลายมากยิ่งขึ้น จึงเป็นโอกาสที่ดีในการสร้างฐานข้อมูลคุณสมบัติเนื้อสัมผัสของอาหารประเภทที่เคี้ยวยากของชาวเอเชีย การศึกษานี้ได้รวบรวมอาหารจำนวน 88 ชนิดที่ได้รับความเห็นจากผู้ตอบแบบสอบถามจากหลากหลายภูมิหลังว่าเป็นอาหารที่เคี้ยวยาก แล้วแบ่งกลุ่มอาหารออกเป็นกลุ่มเนื้อสัตว์ กลุ่มผักผลไม้ และกลุ่มแป้งหรือของขบเคี้ยว อาหารเหล่านี้ถูกทดสอบคุณสมบัติเนื้อสัมผัสด้วยการวิเคราะห์แบบเทกซเจอร์โพรไฟล์ (Texture Profile Analysis) บนเครื่องยูนิเวอร์ซัลเทสติ้ง (Universal Testing Machine) จากนั้นคุณสมบัติของเนื้อสัมผัสห้าประการ (Hardness, Cohesiveness, Springiness, Chewiness, gumminess) ถูกนำมาจัดเรียงเป็นตาราง อาหารที่มีคุณสมบัติ Hardness และ Chewiness ในช่วงอินเตอร์ควอไทล์เดียวกัน จะถูกจัดอยู่ในกลุ่มเดียวกันเพื่อใช้เป็นข้อมูลอ้างอิงในการศึกษาความสัมพันธ์ระหว่างคุณสมบัติเนื้อสัมผัสของอาหารกับตัวแปรอื่นๆ ในอนาคต

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