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Categorization of Coconut Milk Products by Their Sensory Characteristics

Saowapark Wattanapahu[1], Thongchai Suwonsichon[1,*], Wannee Jirapakkul[2] and Sumaporn Kasermsumran[3]

ABSTRACT

Coconut milk is extensively used as a major ingredient of savory foods and desserts in many countries. The sensory characteristics of coconut milk have a substantial effect on consumer acceptance. The objectives of this investigation were to develop a lexicon of coconut milk products produced by different tempering processes and to categorize coconut milk products based on their sensory properties. Twelve samples consisting of two unheated, four pasteurized, three UHT, one sterilized and two spray dried were collected and determined. Eight highly trained panelists described the sensory characteristics of the coconut milk samples. The results demonstrated that there were 17 attributes: smoothness, overall coconut milk odor, sweetness of coconut milk odor, freshness odor, coconut oil odor, cooked odor nutty odor, overall coconut milk flavor, freshness flavor, oily flavor, cooked flavor, sweet flavor, nutty flavor, viscosity, fat feel, dryness, lip and mouth feel. All 17 sensory attributes were significantly different ($P < 0.05$) among coconut milk samples. The results of hierarchical cluster analysis (HCA) and principal component analysis (PCA) demonstrated that PCA reduced the 17 sensory attributes into two independent principal components (PCs), which accounted for 87.30% of the explained variance. These two PCs with HCA could classify the 12 samples into five groups related to their tempering processes.

Keywords: coconut milk, tempering process, descriptive sensory analysis, principal component analysis, cluster analysis

INTRODUCTION

Coconut milk, a white opaque liquid, is an emulsion of natural oil in water, extracted from shredded coconut endosperm (*Cocos nucifera* L.) either with or without the addition of water (Simuang *et al*., 2004; Tangsuphoom and Coupland, 2005). Coconut milk plays an important role in many traditional foods of many regions such as Southeast Asia, South America, Middle America, the Middle East and the Pacific region. Not only is coconut milk used as a food ingredient, but also it is an important substance for health promotion and medicine. Coconut milk fat has been reported to improve digestion and bowel function, support tissue repair and immune system functions, help protect the body from breast, colon and other cancers, improve the cholesterol ratio, reduce the risk of heart disease and increase the metabolic rate of body fat, among

[1] Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
[2] Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, Bangkok 10900, Thailand.
[3] Kasetsart Agricultural and Agro-Industry Product Improvement Institute, Kasetsart University, Bangkok 10900, Thailand.
* Corresponding author, e-mail: fagitcs@ku.ac.th

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other benefits (Amarasiri and Dissanayake, 2006). As a consequence, the world market for coconut milk has increased from USD 1.2 billion in 2008 to USD 1.3 billion in 2010 (Author unknown, 2010).

Nowadays, there are many varieties of commercial coconut milk products produced by different tempering processes such as pasteurization, UHT, sterilization and a spray-dried method. The tempering process has an effect on the coconut milk qualities and prolongs shelf life when compared with unheated coconut milk samples (Seow and Gwee, 1997). Not only does the tempering process influence the coconut milk qualities, it also affects the physicochemical properties, sensory properties, aromatic properties and consumer acceptance. Many researchers have focused on many properties of coconut products, for example, emulsion stability (Tangsuphoom and Coupland, 2008) and homogenization, types of stabilizer, the tempering process and the effect of packaging and storage conditions on product qualities (Saleem *et al*., 2004; Tangsuphoom and Coupland, 2005; Waisundara *et al*., 2007). However, the current research identified only one report that described the sensory properties of coconut (Saleem *et al*., 2004); no existing scientific studies have recorded or reported on the sensory definition and evaluation techniques in coconut milk products. Understanding the sensory characteristics of coconut milk is essential for manufacturers and researchers. One of the powerful techniques to characterize the sensory properties of products is descriptive sensory analysis (DA).

DA is one of the most comprehensive and informative tools used in sensory analysis. DA techniques can provide complete sensory descriptions of products, determine how an ingredient or process change affects the product's characteristics and identify key sensory attributes that promote product acceptance (Lawless and Heyman, 1998). These techniques have been used to characterize many food products such as pasteurized milk (Gandy *et al*., 1995), cheese (Talavera-Bianchi and Chambers, 2008), commercial chocolate milk (Thompson *et al*., 2004), cheddar cheese (Young *et al*., 2005), spreadable cheese (Sara *et al*., 2011), sweet tamarind (Oupadissakoon *et al*., 2010) and steaks (Shawn *et al*., 2004). DA produces a large amount of raw data. Multivariate analysis techniques such as principal component analysis (PCA) and cluster analysis (CA) are needed to understand sensory descriptive analysis.

PCA is used to reduce the dimensionality of a data set. It involves a mathematical procedure that transforms a number of correlated variables into a smaller number of variables that are called principal components (PCs). In contrast, CA is used to identify groups of samples with similar sensory attributes. A combination of these two techniques can be applied in many useful ways including profiling specific important product attributes. PCA in combination with CA and a bi-plot can be the most effective tool for the exploration of data. Many researchers have applied PCA and CA to the sensory properties of food products such as kaya (Phang and Chan, 2009), peanuts (Young *et al*., 2005), ultra high temperature processing (UHT) milk (Oupadissakoon *et al*., 2009) and cheeses (Talavera-Bianchi and Chambers, 2008).

The objectives of the current study were: 1) to develop a sensory lexicon of coconut milk products, 2) to compare the sensory property differences among samples and 3) to categorize them based on their sensory properties and their tempering processes. This investigation will be beneficial to food manufacturers, food caterers, chefs and researchers formulating satisfactory savories and desserts.

MATERIALS AND METHODS

Materials

Coconut milk samples having different tempering processes were collected from supermarkets around Bangkok, Thailand. Raw or unheated coconut milk samples were purchased from fresh markets 2 hr before testing. All samples were purchased in the same lot and were immediately stored in a refrigerator at approximately 4 ± 1 °C before study. There were 12 samples in this study consisting of 2 raw products (F1 and F2), 4 pasteurized products (Pa1 to Pa4), 3 UHT products (U1 to U3), 2 spray-dried products (Po1 and Po2) and 1 sterilized product (C1). Table1 lists all the samples, processing types, ingredients, fat content using Method 989.05, the modified Mojonnier method for dairy products from AOAC (2000) and total soluble solids in degrees Brix which were measured by a digital refractometer (NI; Atago Co.; Tokyo, Japan).

Methods

Sample preparation

Spray-dried samples were dissolved before testing according to the instructions on the packaging labels. Samples of 256 g (Po1) or 225 g (Po2) of spray-dried coconut milk were each dissolved in 500 mL of hot water (80 °C) and stirred with a precision stirrer (Glas-Col; Terre Haute, IN, USA) at a speed of 500 rpm for 5 min. Each coconut milk sample was homogenized at 2500 rpm for 3 min with the precision stirrer to eliminate phase separation, inconsistency and non uniformity. Amounts of 600 mL of each sample of F1 and F2, Pa1 to Pa4, U1 to U3 and C1 were poured into separate 1,000 mL beakers and indirectly heated in a water bath until the temperature reached 50 ± 2 °C for 5 min and were homogenized under the same conditions as the spray-dried samples.

Portions (25 mL) of all homogenized samples were immediately transferred into 75 mL plastic cups, covered with clean plastic lids, labeled with a unique 3-digit random number and kept at 45 ± 2 °C in a water bath, before being served to each panelist.

Panelists

Eight highly trained panelists aged 36–54 yr from the Kasetsart University Sensory and Consumer Research Center, Bangkok, Thailand participated in this study. Each panelist had a minimum of 600 hr of general sensory training and had more than 2 yr of experience in sensory evaluation of food products such as chocolate milk, orange juice, sauces, butter cake, rice products and Thai desserts.

Development of lexicon

The sensory characteristics terminology for the coconut milk was initially developed using five coconut milk products—namely, F1, Pa3, U1, C1 and Po2. Each panelist received and evaluated coconut milk samples and recorded the descriptor, terminologies and definition. After individual evaluation, the panel leader led a discussion that reached an agreement on the descriptors presented in the samples. Then, the developed lexicon was used in the evaluation session. Each panelist identified the sensory characteristics and scored the intensity of each attribute on a 15-point numerical scale, which was then used to determine the consensus mean intensity of each reference.

Sample evaluation

All samples were evaluated in triplicate**.** The panelists randomly evaluated three coconut milk samples per session with two testing sessions daily. In total, there were 12 sessions involving 6 d of testing. Each sample was labeled with a three digit code before serving. Panelists received one sample at a time in the same order. They were asked to rate the intensities of each attribute on a 15-point numerical scale with 0.5 increments, where 0 represented the attribute being not detected and 15 represented the attribute being extremely strongly detected. All panelists were required to cleanse their palates with purified water and white bread to eliminate carryover**.** The panelists were given a 5 min break between samples and a 1 hr break between the two daily sessions. The mean scores of each sample attribute were computed and subjected to further statistical analysis.

Table 1 Coconut milk products used for descriptive analysis.

Sample name	Processing type	Ingredients[1]	Date of manufacture (day-month-year)	Expiry date (day-month-year)	Fat content (%)	TSS (°Brix)
F1	Unheated	White shredded coconut meat 75% and water 25%	-	-	21.00	10.8
F2	Unheated	Dark shredded coconut meat 75% and water 25%	-	-	19.00	11.4
Pa1	Pasteurization	Coconut milk 100%	29-11-10	13-12-10	15.75	11.8
Pa2	Pasteurization	Coconut milk 100%	27-11-10	11-12-10	15.50	11.6
Pa3	Pasteurization	Coconut milk 97.0 %, sodium caseinate 2.0%, potassium metabisulfide 0.02% and other 0.08%	28-11-10	12-12-10	16.50	14.0
Pa4	Pasteurization	Coconut milk 100%	29-11-10	13-12-10	14.50	12.0
U1	UHT	Coconut milk 99.97% and preservative 0.03%	07-10-10	07-10-12	17.30	12.2
U2	UHT	Coconut milk 99.95% and preservative 0.03%	02-09-10	02-09-12	15.50	11.8
U3	UHT	Coconut milk 100%	17-09-10	17-09-12	15.50	12.6
Po1	Spray drying	Coconut cream 90.0%, dextrin 8.0% and sodium caseinate 2.0%	02-10-10	02-10-12	18.30	13.6
Po2	Spray drying	Coconut cream 85.2%, glucose syrup 11.8%, sodium caseinate 2.0%, silicon dioxide 0.5% and di-potassium phosphate 0.5%	13-10-10	13-10-12	14.50	14.4
C1	Sterilization	Coconut cream 99.98% and potassium meta bisulfide 0.02%	15-6-10	16-6-13	22.00	15.2

UHT = ultra high temperature; TSS = total soluble solids.

[1] Ingredients as listed on packaging label.

Statistical analysis

A completely randomized design was used for the experiment. Analysis of variance using SPSS® for Windows Version 12 (SPSS Inc., Chicago, USA) was applied to determine significant differences among samples. Duncan's multiple range test was used to determine the significant difference ($P < 0.05$) among attributes and coconut milk samples. PCA with varimax rotation was used to reduce the dimensionality of the data set to a small number of PCs with high correlation. PCA bi-plots of major principal components were drawn to demonstrate the differences and similarities among the samples. HCA with Euclidean distance and average between-groups linkage was also used to classify the coconut milk samples into subgroups that had similar sensory properties. Both PCA and HCA were conducted using XL-Stat version 2006 software (Addinsoft; New York, NY, USA).

RESULTS AND DISCUSSION

Development of coconut milk lexicon

Seventeen attributes were generated to describe the sensory characteristics of coconut milk and they were classified into four categories which were appearance, odor, flavor and texture. The final lexicon is listed in Table 2.

Descriptive analysis

The mean scores of descriptive sensory attributes from the 12 coconut milk samples were significantly different among samples as shown in Table 3. The attribute of appearance smoothness for the unheated coconut milk samples (F1 and F2) had the highest values ($P < 0.05$). The appearance smoothness attribute of coconut milk depends on the emulsion stability which is stabilized by globulins and albumins proteins and phospholipids (Onsaard *et al.*, 2005). Tangsuphoom and Coupland (2008) reported that heating coconut milk increased the degree of flocculation that resulted in protein denaturation and aggregation; this results in the breakdown of the lamella of the surface of the protein-bond oil droplet, so that the droplet can coalesce into a large droplet and then flocculate. Additionally, the droplets increased their particle size and accumulated as a creamy layer which changed the appearance of the coconut milk (Seow and Gwee, 1997).

The odor and flavor characteristics among the samples were also related to the tempering process. The unheated coconut milk samples (F1 and F2) had the highest intensities of freshness odor (Fresh_O), overall coconut milk flavor (Over_F) and freshness flavor (Fresh_F). These attributes were generated from delta-lactone, n-octanol, dodecanoic acid and decanoic acid, which are the major volatile compounds in fresh coconut meat and they are identified with the attributes of fresh aromatic, creamy aromatic, sweet aromatic, nutty aromatic and waxy odor (Fang and Walter, 1979; Shaikh, 2002). These volatile substances are oxidized to aldehyde and ketonic substances at high temperature (over 75 °C) which are identified in the coconut oil odor and nutty odor (Hassan, 1987), while a very high temperature process (over 85 °C) induces sugar degradation to 5-methyl thiazole and expedites the Strecker degradation of amino acid to pyrazines and furans represented by the cooked odor (Kellard *et al.*, 1985; Shaikh, 2002). The results in Table 3 show that high tempering of coconut milk (U1 to U3, Po1, Po2 and C1) produced higher intensities of coconut oil odor (Coco_O), cooked odor (Cook_O), nutty odor (Nut_O), coconut oil flavor (Oil_F), cooked flavor (Cook_F) and sweetness flavor (Sweet_F) than the unheated coconut milk (F1 and F2) and pasteurized (Pa1 to Pa4) samples.

Texture properties were also significant among samples. The fat content and total soluble solids (Table 1) influenced these differences. The C1 sample, having the highest fat content and total soluble solids, had the highest values of viscosity, fat feel, dryness and lip and mouth feel. Simuang *et al.* (2004) studied the effect of fat content and temperature on the apparent viscosity of coconut

Table 2 Terminologies, definitions and reference standards for coconut milk sensory characteristics.

Attribute	Abbrev-iation	Definition	Reference standard[1] with intensities[2]
Appearance			
Smoothness	Smoot_A	Geometric property related to the perception of the size and form of the particles.	5% non dairy creamer solution = 3.0 15% non dairy creamer solution = 6.0
Odor			
Overall coconut milk	Over_O	The aromatics associated with products made from squashy shredded coconut meat.	Raw coconut milk = 6.5
Sweet of coconut milk	Sweet_O	The sweet aromatics associated with raw coconut milk.	Raw coconut milk = 3.0
Freshness	Fresh_O	The overall rounded coconut milk notes, commonly associated with raw coconut milk.	Raw coconut meat = 6.0
Coconut oil	Coco_O	The oily aromatics reminiscent of coconut oil.	Virgin coconut oil = 4.0
Cooked	Cook_O	The combination of brown aromatic notes associated with heated coconut milk.	15 min. heated raw coconut milk at 85 °C = 2.0 45 min. heated raw coconut milk at 85 °C = 5.5
Nutty	Nut_O	Non specific, slightly sweet, brown character often found in nuts.	Synthetic red bean 500 ppm in coconut skim milk = 5.0 (Givaudan c0013779)
Flavor			
Overall coconut milk	Over_F	The flavor associated with products made from squashy shredded coconut meat.	Shredded raw coconut meat = 6.0
Freshness	Fresh_F	The overall rounded flavor coconut milk, commonly associated with raw coconut milk.	Raw coconut meat = 7.0
Oily	Oil_F	The oily flavor reminiscent of coconut oil.	Virgin coconut oil = 4.0
Cooked	Cook_F	The combination of brown flavor notes associated with heated coconut milk.	15 min. heated raw coconut milk at 85 ˚C = 3.0 45 min. heated raw coconut milk at 85 ˚C = 6.5
Sweet	Sweet_F	Fundamental taste factors associated with a sucrose solution.	2% sucrose solution = 2.0 5% sucrose solution = 5.0
Nutty	Nut_F	The non-specific flavor, slightly sweet, brown character often found in nuts.	Synthetic red bean 500 ppm in coconut skim milk = 6.0 (Givaudan c0013779)
Texture			
Viscosity	Vis_T	Mechanical property perceived when flowing as the product moves across the tongue and the palate.	Condensate milk = 3.0 Whipping cream = 5.0
Fat feel	Fat_T	Combined perception of fat, smoothness and viscosity.	Condensate milk = 3.5
Dryness	Dry_T	A measure of dry, dryness sensation in the mouth.	Sweet condensate milk = 2.0 Palm sugar = 6.0
Lip and mouth feel	Lip_T	The mouth feel of the product, once swallowed, consists of the perception obtained from a thin layer covering the palate.	Condensate milk = 2.0 Virgin coconut oil = 10.0

[1] Reference standards were prepared 24 hr before the testing session.

[2] Intensity based on a 15 point numerical scale with 0.5 increments, where 0 = attribute not detected and 15 = attribute extremely strongly detected.

Table 3 Means scores (± SD) of sensory attributes of 12 coconut milk samples.

Attributes[1]	Type of tempering process											
	Unheated product		Pasteurization				UHT			Spray drying		Sterilization
	F1	F2	Pa1	Pa2	Pa3	Pa4	U1	U2	U3	Po1	Po2	C1
Appearance												
Smoot_A	8.19±0.13^{a}	7.68±0.24^{a}	6.31±0.17^{cd}	7.33±0.30^{b}	7.36±0.65^{b}	6.41±0.59^{cd}	5.86±0.45^{cd}	5.99±0.42^{cd}	5.09±0.21^{e}	7.08±0.41^{bc}	6.71±0.56^{c}	5.74±0.18^{de}
Odor												
Over_O	6.99±0.20^{a}	6.37±0.23^{ab}	5.08±0.24^{d}	6.13±0.54^{ab}	6.66±0.49^{ab}	5.81±0.34^{bc}	5.48±0.21^{cd}	5.04±0.23^{d}	5.99±0.25^{bc}	5.98±0.21^{bc}	5.93±0.28^{bc}	4.02±0.15^{e}
Sweet_O	4.34±0.16^{cd}	4.60±0.17^{c}	4.53±0.10^{c}	3.44±0.11^{d}	4.52±0.33^{c}	4.46±0.13^{b}	5.09±0.34^{bc}	4.66±0.17^{c}	4.76±0.21^{c}	5.07±0.12^{bc}	5.34±0.24^{ab}	3.10±0.12^{d}
Fresh_O	6.55±0.11^{a}	6.23±0.16^{a}	4.26±0.13^{b}	4.52±0.18^{bc}	4.92±0.27^{b}	4.47±0.25^{b}	3.87±0.14^{cd}	4.08±0.17^{c}	4.41±0.14^{b}	5.78±0.31^{a}	4.04±0.17^{c}	3.14±0.11^{d}
Coco_O	0.36±0.02^{e}	0.34±0.05^{e}	2.88±0.44^{d}	2.75±0.12^{d}	2.88±0.12^{d}	2.50±0.14^{d}	4.44±0.30^{a}	4.03±0.19^{ab}	3.85±0.12^{bc}	3.87±0.11^{bc}	3.41±0.13^{c}	4.32±0.16^{ab}
Cook_O	1.31±0.09^{e}	1.24±0.08^{e}	3.99±0.26^{c}	3.92±0.11^{c}	4.29±0.34^{c}	3.09±0.12^{d}	6.01±0,51^{a}	5.08±0.20^{b}	5.81±0.32^{a}	5.15±0.23^{b}	4.96±0.27^{b}	6.03±0.27^{a}
Nut_O	4.84±0.21^{bc}	4.44±0.26^{c}	4.66±0.17^{bc}	5.00±0.25^{bc}	4.71±0.51^{bc}	5.31±0.21^{b}	4.93±0.09^{bc}	4.99± 0.17^{bd}	5.22±0.28^{bc}	4.57±0.27^{bc}	4.70±0.16^{bc}	6.42±0.29^{a}
Flavor												
Over_F	8.76±0.52^{a}	8.62±0.78^{a}	6.51±0.47^{b}	5.73±0.13^{c}	6.71±0.48^{b}	5.72±0.61^{c}	5.96±0.16^{bc}	6.71±0.43^{b}	6.69±0.46^{b}	6.16±0.51^{bc}	6.37±0.53^{bc}	6.73±0.30^{b}
Fresh_F	7.64±0.47^{a}	7.02±0.52^{b}	4.31±0.25^{d}	3.64±0.33e	5.57±0.52^{c}	4.88±0.19^{cd}	3.84±0.18^{e}	3.68±0.11^{e}	4.48±0.17^{cd}	4.53±0.29^{cd}	4.51±0.21^{cd}	3.23±0.13^{e}
Oil_F	0.80±0.06^{c}	1.00±0.05^{c}	1.63±0.06^{ab}	1.10±0.04^{bc}	1.24±0.07^{ab}	1.97±0.08^{a}	1.94±0.08^{a}	2.07±0.11^{a}	1.21±0.08^{bc}	1.24±0.08^{bc}	1.86±0.10^{a}	1.46±0.07^{ab}
Cook_F	1.52±0.11^{d}	1.47±0.10^{d}	4.33±0.17^{c}	4.96±0.31^{bc}	4.33±0.18^{c}	4.25±0.18^{cd}	5.25±0.28^{b}	5.14±0.19^{b}	5.96±0.20^{a}	4.31±0.21^{c}	4.53±0.21^{c}	6.52±0.23^{a}
Sweet_F	0.19±0.04^{e}	0.23±0.04^{e}	2.40±0.13^{d}	2.50±0.14^{d}	2.98±0.11^{c}	2.78±0.11^{c}	3.70±0.17^{b}	2.85±0.10^{c}	3.28±0.10^{bc}	3.71±0.17^{b}	4.10±0.18^{a}	2.98±0.17^{c}
Nut_F	2.31±0.26^{abc}	2.57±0.19^{ab}	1.99±0.12^{c}	2.13±0.12^{bc}	1.52±0.09^{d}	2.13±0.13^{bc}	1.59±0.08^{d}	1.96±0.11^{c}	1.56±0.09^{d}	2.79±0.11^{a}	2.13±0.10^{bc}	1.70±0.07^{c}
Texture												
Vis_T	3.70±0.19^{b}	3.54±0.21^{bc}	3.50±0.21^{bc}	3.31±0.21^{c}	2.98±0.11^{d}	2.91±0.12^{d}	3.41±0.14^{bc}	3.84±0.10^{b}	3.65±0.12^{b}	3.53±0.14^{bc}	3.95±0.11^{b}	5.97±0.34^{a}
Fat_T	0.56±0.07^{c}	0.36±0.05^{c}	0.68±0.04^{bc}	1.19±0.07^{b}	0.64±0.05^{c}	0.44±0.02^{c}	1.67±0.09^{a}	1.40±0.09^{ab}	1.01±0.08^{b}	0.68±0.04^{bc}	1.01±0.06^{b}	1.95±0.11^{a}
Dry_T	3.68±0.18^{bc}	3.96±0.20^{ab}	3.72±0.11^{bc}	4.00±0.28^{ab}	3.69±0.27^{bc}	3.69±0.12^{bc}	3.94±0.11^{ab}	3.51±0.12^{bc}	3.59±0.12^{bc}	3.30±0.10^{bc}	3.07±0.10^{c}	4.42±0.12^{a}
Lip_T	3.70±0.21^{bc}	3.21±0.19^{c}	3.49±0.10^{bc}	4.17±0.16^{b}	4.49±0.19^{b}	3.72±0.11^{bc}	4.65±0.15^{b}	4.18±0.18^{b}	4.04±0.18^{b}	3.60±0.18^{bc}	3.63±0.14^{bc}	5.37±0.20^{a}

[1] Attribute abbreviations are provided in Table 2.

UHT = ultra high temperature.

[abcde] Means within the same row followed by different superscript letters indicate significant differences ($P < 0.05$).

milk. They found that increasing the fat content increased the apparent viscosity. The sensory properties of coconut milk products are presented by their thermal processing types in Figure 1. These results imply that the type of thermal processing, ingredients and sample compositions influence the sensory characteristics of coconut milk, so that the type of processing might affect the consumer acceptance of products containing coconut milk as a major ingredient.

Principal component analysis and cluster analysis

The first two PCs accounted for 87.30% of the total variance (PC1, 67.79 and PC2, 19.51%). PC1 was positively related to the smoothness of appearance (AS), overall coconut milk odor (Over_O), freshness odor (Fresh_O) and freshness flavor (Fresh_F), while being negatively associated with cooked odor and flavor (Cook_O and Cook_F), nutty odor and flavor (Nut_O and Nut_F) and fat feel (Fat_T). PC2 was positively related to coconut oil odor (Coco_O) and overall coconut milk flavor (Over_F), while being negatively associated with viscosity (Vis_T), dryness (Dry_T), and lip and mouth feel (Lip_T).

HCA was used to group samples based on their similarity (Figure 2) and the bi-plot of the two PCs is shown in Figure 3. Twelve samples were classified into five clusters which were associated with the tempering process. Cluster 1 consisted of

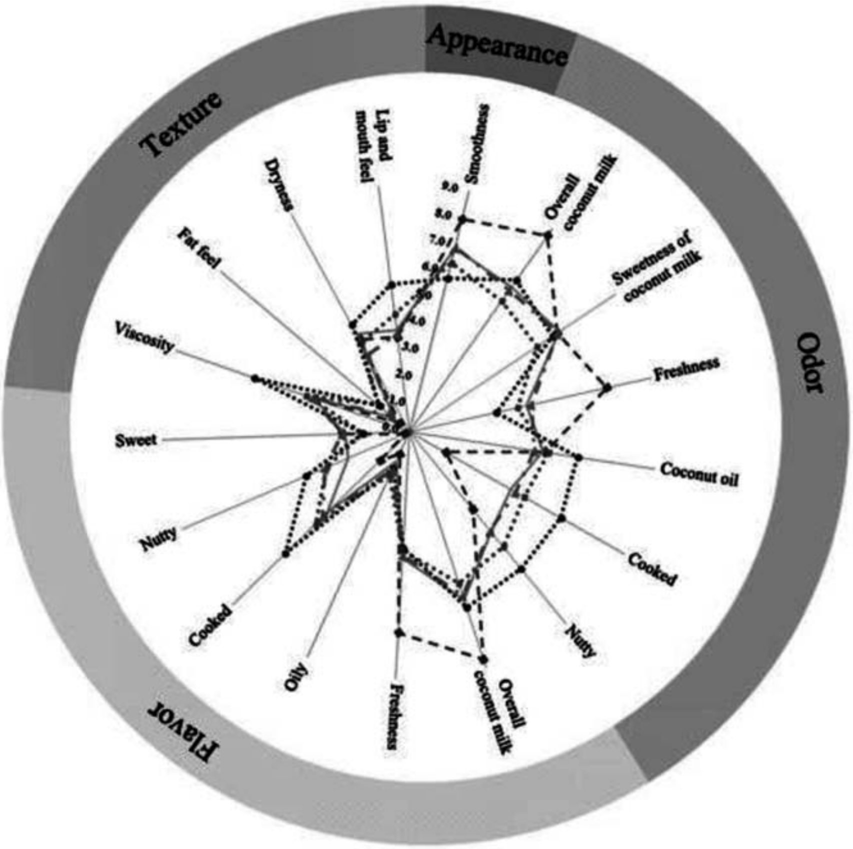

Figure 1 Wheel of coconut milk sensory profiles. (--♦-- = fresh samples; —▲— = pasteurized samples; — = spray drying samples; ▪▪●▪▪ = sterilized samples; ·· ■ ·· = Ultra high temperature (UHT) samples).

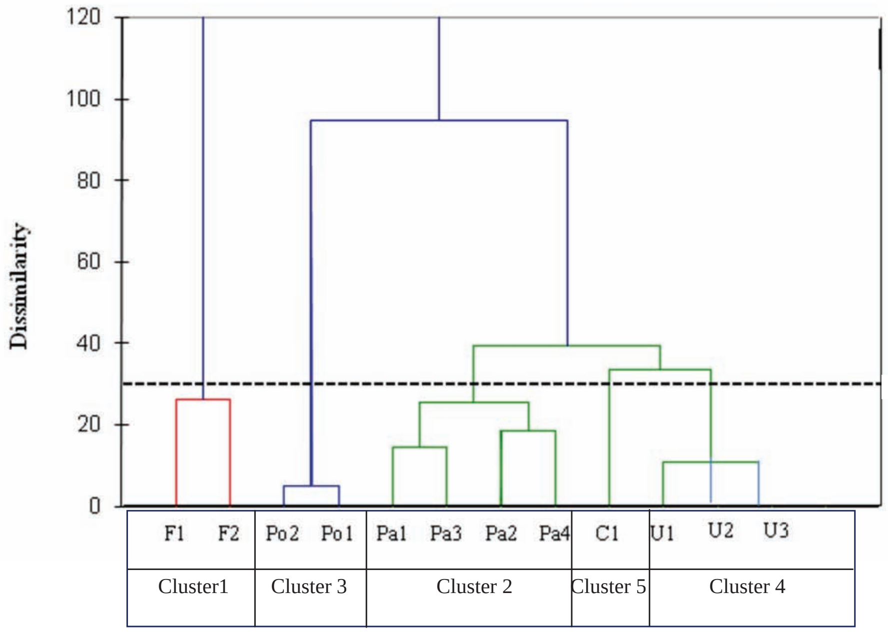

Figure 2 Dendrogram results of hierarchical cluster analysis of coconut milk product samples (F1, F2, Po1, Po2, Pa1 to Pa4, C1, U1 to U3; Table 1 provides detailed descriptions of the samples).

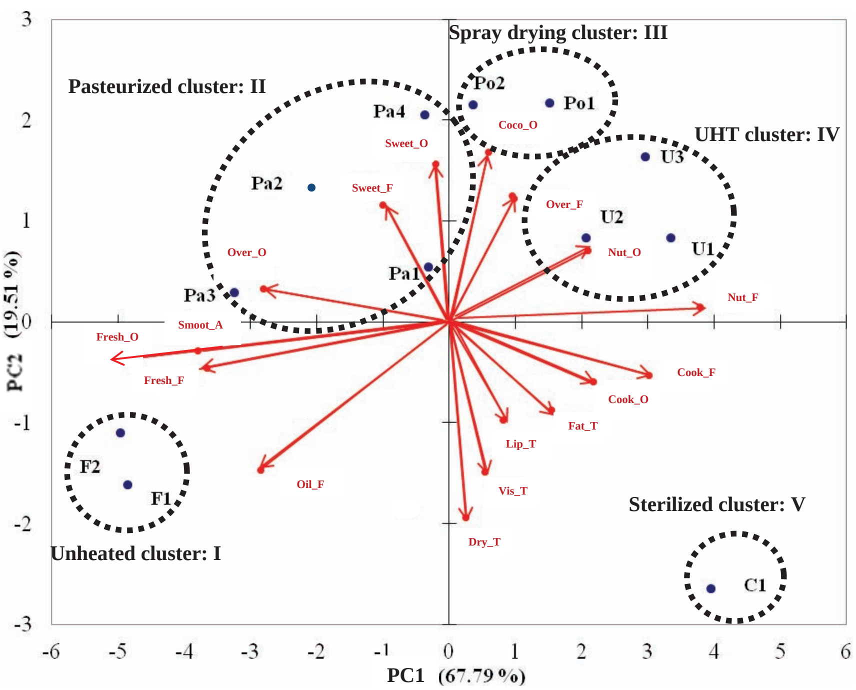

Figure 3 Bi-plot of coconut milk samples (F1, F2, Po1, Po2, Pa1 to Pa4, C1, U1 to U3; Table 1 provides detailed descriptions of the samples) on principal component (PC) axes using PC1 and PC2 to describe sensory attributes (abbreviations are described in Table 2) and grouping (UHT = Ultra high temperature).

the F1 and F2 samples. They had high smoothness of appearance, freshness odor and flavor, overall coconut milk odor and flavor.

Cluster 2 consisted of the Pa1 to Pa4 samples. They had moderate intensities in all sensory attributes except cooked odor, cooked flavor, freshness flavor and viscosity because their attributes were related to the fatty acid ester generated from the free fatty acid at 75 °C.

Cluster 3 (Po1 and Po2) had a sweet odor which was generated from some ingredients such as maltodrextrin, corn syrup and sodium caseinate.

Cluster 4 (U1 to U3) was characterized by samples having a coconut oil odor and cooked flavor (except for U3) being generated in the high tempering process and Maillard reaction, respectively.

Cluster 5 (C1) had a strong cooked odor and flavor, nutty odor and flavor, viscosity, fat feel and lip and mouth feel. These attributes were related to the high fat content and the high tempering process.

CONCLUSION

The results of the descriptive sensory analysis involving attributes, definitions and references provided a useful foundation for further sensory study and consumer research. The results of the study demonstrated that the freshness odor, cooked odor, freshness flavor, cooked flavor and smoothness of appearance associated with the tempering process of coconut milk products greatly impact on the sensory characteristics. Additionally, this study provided information for manufacturers and researchers. Further research on coconut milk, product development and consumer acceptance is required.

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