Comparison of Sensory Characteristics of Mung Bean Sprouts and Sunflower Sprouts

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Abstract

Sprouts have been used as a dietary food source among health conscious consumers around the world. Many types of sprouts have been consumed such as alfalfa and mung bean sprouts. Sunflower sprout is a new type of sprout that is popular in Thailand in last few years. Nutritional properties of sprouts were studied but sensory characteristics of sprouts are limited. The objective of this research was to study the differences of sensory characteristics towards the top two most famous types of sprouts in Thailand including mung bean and sunflower sprouts. Sensory descriptive analysis was performed with 10 sprout samples in both fresh and cooked forms. Twenty seven attributes were developed and rated by trained panelists (n=12). The data was analyzed with analysis of variance and principal component analysis. The major factors affecting sensory characteristics of the samples were type of sprout and effect of heat treatment. Mung bean sprouts had a stronger intensity of yellow color of leaves, stem diameter, yam bean-like aroma, beany aroma, bean sprout aroma identity, sweetness, and juiciness than those characteristics in sunflower sprouts. In contrast, sunflower sprouts were generally characterized by having a higher intensity of green color of leaves and stem, leaf thickness, stem length, curvy shape of stem, sunflower oil flavor, sunflower identity flavor, fresh/cool aroma, astringent, overall flavor intensity, fibrousness, and hard to swallow than those attributes in bean sprouts. After blanching, sunflower sprouts tended to have a lower intensity of white color of stem, waxy appearance, curvy shape of stem, fresh/cool aroma, crunchiness, overall flavor intensity, hard to swallow whereas green color of leaves, green aroma, and juiciness increased.

Keywords: Mung bean, Sunflower, Sprout, Sensory evaluation, Descriptive analysis

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1. Introduction

Sprouts are young living vegetables germinated from the seeds of various plants such as vegetables, spices, grasses, and some legumes. Many types of sprouts are now available in the markets as some healthy choices for consumers including alfalfa sprouts, wheat grass, mung bean sprouts, soy bean sprouts, pea sprouts and sunflower sprouts. Sprouts are produced from the germination process. Many factors should be considered for sprouting the plant seeds such as light, temperature, humidity, watering and time.

The germination process starts with the seeds fully absorb water and then the metabolic activity in the seeds increase leading to complex biochemical changes (Hübner and Arendt, 2013). Then, the reserve chemical components in the seeds are broken down by hydrolytic enzymes into simple compounds such as polymeric carbohydrates (starch) into simple carbohydrates (sugars), fats into fatty acids and protein into amino acids (Chavan *et al.,* 1989). As the seeds are nutritionally transformed through the process of sprouting, consumers can have more bioavailability of nutrients and some health benefits from consuming sprouts. Each particular sprout variety is composed of their own complex of vitamins, phytochemicals, minerals, antioxidants, and unique health enhancing constituents. With their functional properties, some types of sprouts assist in boosting the immune system and metabolism (Paśko *et al*., 2018). Those sprouts that have high in chlorophyll are especially effective for removing toxins from the cells (Akbas *et al*., 2017; Viacava and Roura, 2015). Some micro green sprouts are also high in dietary fiber which help improve the digestive system (Zieliński *et al.,* 2005). Nowadays, many health institutions have approved sprout consumption as part of a health promoting diet to help in the treatment of serious diseases and chronic illnesses (Sangronis and Machado, 2007)

In Asian countries, one of the most common types of sprout that Asian people regularly consume is mung bean sprout. Asian people use mung bean sprouts as a raw material in various dishes from fresh form as the side dish or salad to cooked form in stir-fried dishes, noodle, or some types of soup. The reasons that consumers prefer to consume mung bean sprout might be due to its abundant nutrients and functional properties, such as protein, lipids, vitamins, fibers, and phytochemcals. Huang *et al.,* (2014) reported that L-ascorbic acid, phenolics, antioxidants and isoflavones in mung bean were significantly increased through biochemical reactions during germination.

Nowadays, consumers around the world pay more attention in selection and consumption of healthy foods. This eating trend leads them to consider a new type of ingredient that is safe and contains some health benefits to their bodies. Sunflower sprouts are the new alternative choice that has introduced to the market since last few years. Two types of unhulled sunflower seeds predominate in the marketplace: black (oilseed) and striped (non-oilseed). Both types of sunflower seeds have been used to cultivate sunflower sprouts. Striped seeds are far larger than black seeds, and so are their sprouts. However, sprouts from oil seed variety are more famous and abundant than sprouts from non-oil seed variety due to its high germination rate. According to Márton *et al.,* (2010), sunflower sprouts contain essential fatty acids with linoleic acid presented at the highest concentration of 65.0% and α-linoleic acid at the lowest concentration of 0.4% in three days old sprouts. Sarich (2013) indicated that sunflower sprout is a good source of protein, vitamins (A, D, E), minerals, amino acids, antioxidants and lecithin in terms of nutrient content.

Many studies on nutritional properties of mung bean sprouts and sunflower sprouts were published. However, the sensory characteristics of both types of sprouts have been less investigated. Therefore, determining the sensory characteristics of various types of sprouts will help researchers and sprout producers to understand the differences of characteristics in each type of sprout. The objectives of this study were (1) to characterize and quantify sensory characteristics of sunflower sprouts and mung bean sprouts, (2) to study the effect of heat treatment (blanching) to sensory characteristics of sprout samples.

2. Materials and Methods

2.1 Materials

Sprout samples used in this research were two varieties of sunflower sprout; oil seed and non-oilseed variety and one variety of mung bean. Oilseed sunflower seeds are small and have all black color with a high oil content, meanwhile big seed variety or known as confectionary seeds are large black and white striped seeds which are usually roasted for snacks (Deane 2013). Fresh sunflower sprouts (oilseed variety) from two sunflower sprout producers were purchased from wholesale market, another fresh sunflower sprout sample (non-oilseed variety) was purchased directly from the local sprout producer, and mung bean sprouts from two vendors were purchased from fresh market in Chiang Rai, Thailand.

Both types of sprout were subjected to Quantitative Descriptive Analysis (QDA). A set of 10 samples of raw and cooked (blanched) version of sprouts was given to each panelist to assess according to the developed sensory attributes. The detailed information for each sample is given in Table 1.

Table 1 Information on the 10 sprout samples used in this study

Type of sprout samples	Sample preparation
Mung bean sprout: vendor A (**Fresh Mung A**)	Fresh
Mung bean sprout: vendor A (**Cooked Mung A**)	Blanched in boiling water for 10 seconds
Mung bean sprout: vendor B (**Fresh Mung B**)	Fresh
Mung bean sprout: vendor B (**Cooked Mung B**)	Blanched in boiling water for 10 seconds
Sunflower sprout: non-oil seed variety (**Fresh Sun Snack**)	Fresh
Sunflower sprout: non-oil seed variety (**Cooked Sun Snack**)	Blanched in boiling water for 45 seconds
Sunflower sprout: oil seed variety brand A (**Fresh Sun Oil A**)	Fresh
Sunflower sprout: oil seed variety brand A (**Cooked Sun Oil A**)	Blanched in boiling water for 45 seconds
Sunflower sprout: oil seed variety brand B (**Fresh Sun Oil B**)	Fresh
Sunflower sprout: oil seed variety brand B (**Cooked Sun Oil B**)	Blanched in boiling water for 45 seconds

Note: *According to preliminary study of blanching process, sunflower sprout samples are needed longer time for blanching in order to prevent browning reaction and maintain bright green color of leaves and stems.

2.2 Sample preparation

Samples of sunflower and mung bean sprout were stored in a refrigerator at 4°C immediately after purchase to prevent discoloration. Sprouts that showed any defects were excluded from the experiment. Afterwards, for a set of sensory panel, around 200 grams of each sprout was washed throughly to remove dirt and contaminants and then rinsed. In order to keep the sprouts fresh before tasting, raw sprout samples were immersed in water at room temperature inside a bowl. Water was changed every one hour to prevent sprout fermentation.

For cooked samples, water was boiled in cooking pot. Mung bean sprouts samples were blanched for 10 sec and sunflower sprout samples were blanched for 45 sec in boiling water and drained in a sieve. Blanched sprouts were moved from the sieve to a separate bowl filled with cold water (0–4°C) to stop the cooking process.

For serving, 8 to 10 sprouts were picked and pat dried to remove as much surface water as possible before filling them in coded sampling cups. Each sample weighed approximately 5 grams of sprouts for each cup and was given to panelist for tasting at room temperature. Each cup was coded with a 3-digit random number. A glass of pure water, white bread and carbonated water/soda water were served to clean the palate between samples.

2.3 Panel selection and training

Twelve judges (5 males and 7 females; age range 25–46 years old) who were interested in the sensory evaluation of sunflower sprout and mung bean sprout were drawn from scientists and officers working at Mae Fah Luang University, Chiang Rai, Thailand. Panelists were selected based on their ability to discriminate the basic tastes and their availability. Panel members were directed to judge each sample and quantify all sensory attributes by using 12-centimeter unstructured line scale at sensory evaluation room, Mae Fah Luang University. During the training sessions, the panelists were exposed to various types of sprouts to become familiar with all possible types of sprouts used in this study. The panelists were trained to discriminate and rated the intensity of each sensory characteristic until consensus agreement was obtained among them. When a panelist showed inconsistency with the rest of the group, additional training was provided. Twelve training sessions were conducted within 2.5 months, and each session took approximately 1 h. The panelists developed 27 descriptors of the sensory attributes of sunflower sprout and mung bean sprout samples. The definitions of attributes and reference samples are listed in Table 2.

2.4 Actual evaluations

All panelists evaluated the sensory characteristics of the mung bean and sunflower sprout samples according to the sensory attributes they developed during the training sessions. The appearance attributes were evaluated first followed by the aroma, flavor, taste, texture and after taste/ after feel attributes. All three replications were conducted in the individual sensory evaluation booths to avoid possible bias from environment under the normal white light at sensory evaluation room, Mae Fah Luang University.

The intensity of each sensory attribute except colors was rated on a 12-centrimeter line scale with the left end labeled as “low” and the right end labeled as “high”. For color measurements, color shade scales were used for each color attribute. The panelists were instructed to test at least 5–8 sprouts from each sprout sample. The order of presentation of the samples was completely randomized to balance out any potential serving order or carry-over effects. Each replication consisted of three sets of samples (4 samples for the first set, and 3 samples for the second and the third set). A 5-min break was provided between sets of samples. The panelists were asked to rinse their mouth with some white bread or carbonated water before tasting the first sample and in between sample tasting.

Table 2 Definitions and reference samples of the sensory descriptive attributes of sunflower sprout and mung bean sprout samples

Sensory attributes	Definitions	Reference samples
Appearance		
White color of stem	Intensity of whiteness of stem	Color shade scale (dull-bright)
Green color of stem	Intensity of greenness of stem	Color shade scale (white-green)
Yellow color of leaves	Intensity of yellowness of leaves	Color shade scale (white-yellow)
Green color of leaves	Intensity of greenness of leaves	Color shade scale (white-green)
Shiny/waxy	Degree to which surface looks shinny/waxy	-
Stem diameter	Average diameter of stem (small-big)	-
Stem shape	Degree to which stem looks straight in shape (curve-straight)	-
Stem length	Average length of stem (short-long)	-
Leaf size	Average size of leaf (small-big)	-
Leaf thickness	Average thickness of leaf (thin-thick)	-

Note: * All panelists were asked to chew 3 sprouts for 5 times for “Crunchiness”,” Juiciness” and 10 times for “Fibrousness”, Astringent”, and “Hard to swallow” as tasting procedure.

Table 2 Definitions and reference samples of the sensory descriptive attributes of sunflower sprout and mung bean sprout samples (Continue)

Sensory attributes	Definitions	Reference samples
Aroma		
Raw vegetable	Aromatics associated with Cruciferous vegetables	Chopped Chinese cabbage
Green	Aromatics associated with green aroma in pea	Chopped pea
Bean sprout identity	Aromatics associated with bean sprout	Raw bean sprouts
Cool/fresh	Aromatics associated with cool/fresh feeling	Fresh mint
Beany	Aromatics associated with soaked beans	Soaked soy beans for 6–8 h.
Yam bean-like	Aromatics associated with yam bean	Chopped yam bean
Flavor		
Sunflower oil	Flavor associated with sunflower oil	Sunflower oil
Sunflower identity	Flavor associated with identify of sunflower	Unroasted sunflower seeds
Taste		
Sweet	Fundamental taste sensation of sucrose	2% sucrose solution
Salty	Fundamental taste sensation of salt	1% salt solution
Texture		
Crunchiness	Amount of sprout crunchiness felt on first bite	-
Juiciness	Amount of liquid released when chewing	-
Fibrousness	The presence of tough strands of vascular tissue due to fiber content	-
After taste/ after feel		
Sweet aftertaste	Fundamental taste sensation of sucrose after swallowing	2% sucrose solution
Astringent	The shrinking or puckering of the tongue surface caused by substances	-
Hard to swallow	A sticky sensation after swallowing	-
Overall flavor intensity	The overall intensity of product's flavor	-

Note: *All panelists were asked to chew 3 sprouts for 5 times for "Crunchiness"," Juiciness" and 10 times for "Fibrousness", Astringent", and "Hard to swallow" as tasting procedure.

2.5 Data analysis

SAS version 9.3 (Statistical Analysis System, Cary, NC) was used for all analysis of variance. The Type I error confidence level was set at alpha=0.05. To describe the differences among sprout samples and to assess panel performance, 2-way analysis of variance, multiple mean comparisons (Duncan's multiple range test), and principal component analysis (PCA) (XLSTAT version 2012, Addinsoft, Paris, France) were used to evaluate panel ratings.

PCA was conducted from significant attributes by using the covariance matrix extraction method with no rotation. PCA was selected because it can be used to generate a simplified view of a multi-dimensional data set (Lawless and Heymann, 2010). Two main PCAs were presented by significant attributes. The interrelationships among sprout samples, sensory attributes, and between sets of sprout samples and sensory were illustrated by PCA as correlation bi-plot which confirmed by the results of mean intensity of significant attributes.

3. Results and Discussion

The ANOVA of all 10 sprout samples revealed that all sensory attributes except "raw vegetable aroma" and "sweet aftertaste" attributes were significant difference (data not show). Thus, the total 25 significant sensory attributes were averaged to perform the PCA. The PCA indicated that principal components (PCs) 1 and 2 explained 79.60% and 14.09 % of the total variance, respectively (Figure 1).

As indicated in Figure 1 and Table 3, the PC 1 dimension was mostly defined by the attributes of "green color of stem", "green color of leaves", "stem length", "leaf size", "leaf thickness", "cool/fresh aroma", "sunflower oil aroma", "sunflower flavor identity", "astringent", "hard to swallow", "fibrousness", "stem shape", and "overall flavor intensity" (negative PC 1 dimension), and "yellow color of leaves", "stem diameter", "bean sprout identity aroma", "beany aroma", "yam bean-like aroma", and "sweet taste" (positive PC 1 dimension). The sprout samples were grouped into two big groups and separated mainly on the PC 1 dimension by the type of sprout samples. All sunflower sprout samples were placed on the negative side of PC 1 dimension whereas all mung bean sprout samples were located on the positive side of PC 1 dimension. The major sensory attributes described PC 2 dimensions showed contrast between "shinny/waxy appearance", "salty taste", and "white color of stem" (positive PC 2 dimension) and "green aroma" (negative PC 2 dimension). "Crunchiness" and "juiciness" were in the middle of the first quadrant and the fourth quadrant of PC 1 and PC 2 dimensions, respectively. These two attributes were well explained by both dimensions. According to the pattern and the location of samples on PC 2 dimension, it was found that all fresh sprout samples were located on the positive side of PC 2 dimension while all cooked (blanched) sprout samples were placed on the negative part of PC 2 dimension. Thus, PC 2 dimension mostly described the effect of heat treatment (blanching) on the sensory characteristics of sprout samples.

According to principal component loadings and scores (Figure 1) and the mean intensity of significant attributes (Table 3), it was clear that the sprout samples were grouped into two sets of samples based on the type of sprouts. Two sets of sprout samples were separated on PC 1 dimension. Sunflower sprouts samples were on the negative PC 1 dimension whereas mung bean sprouts were on the positive PC 1 dimension. The set of sunflower sprout samples had a significantly higher intensity of “leaf size”, “leaf thickness”, “green color of leaves and stem”, “stem shape (curvy)”, “overall flavor intensity”, “cool/fresh aroma”, “sunflower oil flavor”, “sunflower identity flavor”, “hard to swallow”, “astringent”, and “fibrousness” than those attributes in the set of mung bean sprout samples. On the other hand, the set of mung bean sprout samples had a significantly higher intensity of “yellow color of leaves”, “stem diameter”, “yam bean-like aroma”, “beany aroma”, “bean sprout identity aroma”, and “sweet taste” than those attributes in the set of sunflower sprout samples. The PC 2 dimension was described by the effect of heat treatment (blanching) to sensory characteristics of the samples. All sprout samples on the positive PC 2 dimension were all fresh sprout samples while all cooked sprout samples were on the negative PC 2 dimension. The fresh sprout samples showed a significantly stronger intensity of “shinny/waxy”,” “crunchiness”, and “white color of stem” than those attributes in the cooked sprout samples. In contrast, the cooked sprout samples had a significantly higher intensity of “green aroma” than that characteristic in the fresh sprout samples. The “juiciness” attribute that was placed in the middle of the positive PC 1 dimension and the negative PC 2 dimension showed that this attribute was dominant for both mung bean sprout samples and cooked sprout samples. Like “juiciness”, “crunchiness” attribute was in the middle between the positive PC 1 dimension and the positive PC 2 dimension. Thus, mung bean sprout samples and fresh sprout samples would have high intensity of “crunchiness”.

As shown in the principal component score (Figure 1 (b)), the samples of sunflower sprouts were grouped but expansion along the PC 2 dimension was observed. To confirm the differences found in the sunflower sprout samples, the PCA for all 6 sunflower sprout samples was rerun. After running ANOVA of all 6 sunflower sprout samples, the results showed that 16 of 27 sensory attributes were significant difference (data not show). Then, the total 16 significant sensory attributes were averaged to perform the PCA. The PCA showed that principal components (PCs) 1 and 2 explained 77.21% and 19.48 % of the total variance, respectively (Figure 2).

As presented in Figure 2 and Table 4, the PC 1 dimension was mostly defined by the attributes of “green color of leaves”, “green aroma”, and “juiciness” (negative PC 1 dimension) and “cool/fresh aroma”, “stem shape”, “shinny/waxy”, “crunchiness”, “hard to swallow”, “overall flavor intensity”, “white color of stem”, “yellow color of leaves”, and “salty taste” (positive PC 1 dimension). The 6 sunflower sprout samples were divided into two groups and separated mainly on the PC 1 dimension by the effect of heat treatment. All 3 cooked sunflower sprout samples were placed on the negative side of PC 1 dimension while 2 fresh sunflower sprout samples from oilseed variety were located on the positive side of PC 1 dimension. Only sunflower sprout sample that had the position on positive PC 2 dimension was fresh sunflower sprouts from non-oilseed variety (Fresh Sun Snack). This result was consistent with the previous PCA of all 10 sprout samples that heat treatment played an important role on the differences of sensory characteristics. The major sensory attributes described on PC 2 dimensions were “stem diameter”, “leaf size”, and “leaf thickness” (positive PC 2 dimension).

Based on principal component loadings and scores (Figure 2) and the mean intensity of significant attributes of sunflower sprout samples (Table 4), the group of cooked sunflower sprout samples (negative PC 1 dimension) had a significantly higher intensity of “green color of leaves”, “green aroma”, and “juiciness” than those attributes in fresh sunflower sprout samples. However, both fresh sunflower samples from oilseed variety showed a significantly higher intensity of “cool/fresh aroma”, “stem shape (curvy)”, “shinny/waxy”, “crunchiness”, “hard to swallow”, “overall flavor intensity”, “white color of stem”, “yellow color of leaves”, and “salty taste” than those attribute in cooked sunflower sprout samples.

According to the result presented in Table 4, both fresh sunflower sprout samples from oilseed variety had a significantly higher intensity of “salty taste” than other sunflower sprout samples. So, “salty taste” was the unique characteristic found in fresh sunflower sprouts from oilseed variety. The fresh sunflower sprouts form non-oilseed variety (positive PC 2) was only sunflower sprout sample that had a significantly stronger intensity of “leaf size” and “leaf thickness” than those in other sunflower sprout samples.

From PCA results (Figure 1 and 2), there were two main factors that affected to the sensory characteristics of all sprout samples. The first factor was the type of sprout samples and the second factor was the effect of heat treatment. Type of sprout samples showed a significant effect by separating the sprout samples into two big sets as shown in Figure 1. However, the real main factors influencing the differences in the sensory characteristics was the cultivation process used for producing sprout samples and the consumption behavior. The process of making mung bean sprouts and sunflower sprout are completely different. Consumers prefer to consume mung bean sprouts that their stems and leaves are not fully developed to green color. The good mung bean sprouts should have straight white stem and some yellow tiny leaves while consumers would like to consume sunflower sprouts in the form of fully developed to green plants. So, the sprout producers need to let the yellow sunflower sprouts explode to sunlight to start photosynthesis in order to make them have green stems and green leaves, and then their stems start elongation and develop the structural fiber. In case of shinny/waxy appearance, it was found that sunflower sprouts had a significantly higher intensity of "shinny/waxy" attribute than mung bean sprouts. Different cutin content which is naturally waxy layer found on the surface of fruit and vegetable should be responsible for the shiny/waxy appearance (Xue *et al*., 2017).

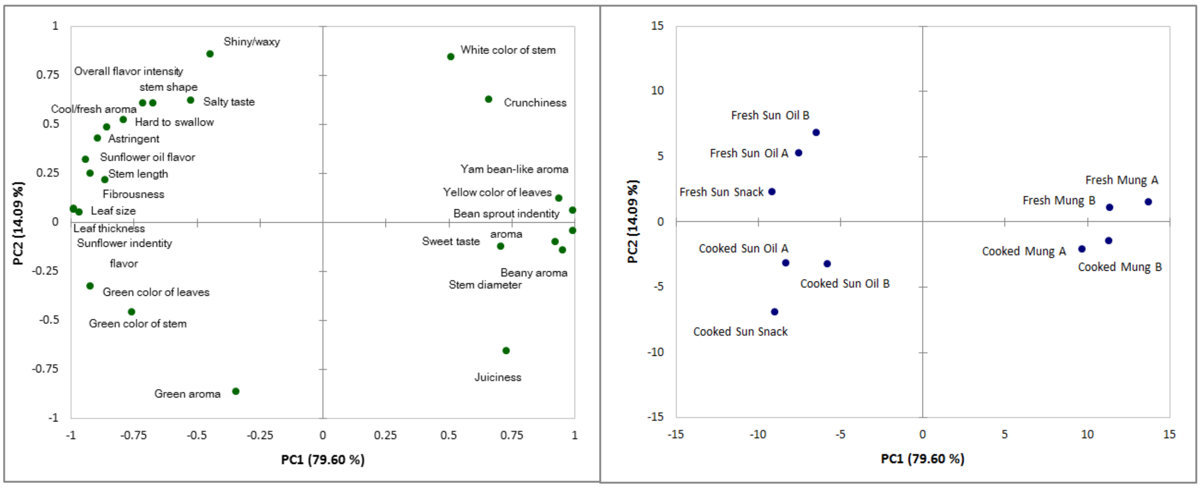
For aroma and flavor, mung bean sprout samples were detected the unique aroma and flavor including "bean sprout identity aroma", "yam bean-like aroma", and "beany aroma". These aromas could be related to the study by Chow *et al.* (2007). They stated that aromas found in beans or product form beans caused by changes of polyunsaturated fatty acids to aldehydes and alcohol by lipoxygenase. According to the result of this study, sunflower sprouts samples were rated as high intensity of "sunflower identity flavor", "sunflower oil flavor", and "cool/fresh aroma". This result was similar to the previous sensory study on virgin sunflower seed oil by Raß *et al.,* (2008). They reported that "sunflower seed like" was the dominant characteristic found in all virgin sunflower seed oil. So, sunflower aroma and flavor are the superior characteristics found in sunflower related product. Chambers and Koppel (2013) stated that sunflower like aroma could be related with some chemicals such as 3-methyl-1-butanol, α-pinene, and (E)-2-heptenal.

In case of cool/fresh aroma, essential oil containing menthol was found in sunflower seed (Downum *et al.,* 2013; Rowe *et al.,* 2012). Thus, when panelists squeezed the sunflower sprout samples gently, they could smell cool/fresh aroma.

In terms of basic taste, mung bean sprouts were found that they had a higher intensity of "sweet taste" than sunflower sprouts. The reason to support this finding was the chemical changes during germination process. As mentioned before, mung bean sprouts are not fully developed to green shoots like sunflower sprouts. During germination, β-amylase is still working to digest the starch molecule stored in the cotyledons, or seed leaves to simple carbohydrates such as glucose and fructose to provide energy for cell division (Nonogaki *et al*., 2010) making mung bean sprouts are perceived a sweet taste.

For textural properties, mung bean sprouts had a higher intensity of "crunchiness" and "juiciness" than sunflower sprouts while sunflower sprouts had a higher intensity of "fibrousness". The plant structure is the reason for these findings. Sunflower sprouts are the sprouts under the development of inner structure from the synthesis of cellulose and hemicelluloses (Carpita and Gibeaut, 1993) which make sunflower sprouts have more fibers than mung bean sprouts, whereas mung bean sprouts are not fully developed making they have more “crunchiness” and “juiciness”. Astringency was perceived in sunflower sprout samples. This perception might be due to the presence of phenolic compounds that make the bitter taste and astringency in many fruits and vegetables (Sang-Uk, 2013). Hard to swallow was one of the attributes that was rated as high in sunflower sprouts. Higher content of oil in sunflower seed (23.98–24.86 %) (Akande, 2011) than in mung bean (2.10–2.70 %) (Zia-Ul-Haq *et al*., 2008) would make sunflower sprouts have a higher intensity of “ hard to swallow”.

Besides the type of sprouts that caused the differences in sensory characteristics, effect of heat treatment was also major issue affecting the differences. In case of color, proteins in cell membrane denature and coagulate during heating causing loss of osmotic pressure. Air, water, and soluble compounds expose from inner side of cell to outer side of cell leading chlorophyll is clearly seen (Panda, 2013). Moreover, when blanching, Magnesium molecule in chlorophyll would be replaced by hydrogen molecule which make chlorophyll a and b change to pheophytin a and b. These reactions create more green color in the blanched samples (Steinka *et al.,* 2017). Cutin on the surface might be dissolve to boiling water making the sample had a lower intensity of “shinny/waxy”. Heat treatment also has some impacts to the structure of the samples. Heat destroys the plant cell wall leading the soft texture.



(a) (b)

Figure 1 Principal component loadings and score of (a) significant sensory attributes and (b) the sprouts samples (n=10) for principal component 1 and 2 (PC1 vs PC2)

Table 3 The mean intensity of all significant sensory attributes of sprout samples

Sensory attributes	Fresh Mung A	Fresh Mung B	Cooked Mung A	Cooked Mung B	Fresh Sun Snack	Fresh Sun Oil A	Fresh Sun Oil B	Cooked Sun Snack	Cooked Sun Oil A	Cooked Sun Oil B
White color of stem	8.22^{ab}	8.77^{a}	5.23^{d}	6.32^{cd}	5.56^{d}	7.14^{bc}	8.76^{a}	1.43^{f}	3.39^{e}	3.19^{e}
Yellow color of leaves	8.75^{a}	9.72^{a}	8.70^{a}	9.80^{a}	1.11^{cd}	2.74^{b}	2.82^{b}	1.19^{cd}	0.91^{d}	2.25^{bc}
Green color of stem	0.76^{ef}	0.05^{f}	0.58^{ef}	0.09^{f}	4.57^{b}	1.89^{d}	1.44^{de}	7.18^{a}	3.50^{c}	2.30^{d}
Green color of leaves	0.93^{e}	0.10^{e}	0.65^{e}	0.12^{e}	7.96^{b}	4.82^{d}	4.28^{d}	10.08^{a}	8.13^{b}	6.75^{c}
Shiny/waxy	3.31^{c}	2.79^{c}	1.84^{e}	2.10^{de}	7.50^{ab}	6.92^{b}	8.00^{a}	1.66^{e}	2.38^{de}	2.28^{de}
Stem diameter	7.14^{ab}	7.62^{a}	6.37^{c}	6.67^{bc}	4.37^{d}	2.94^{e}	2.55^{e}	4.18^{d}	2.63^{e}	2.85^{e}
Stem shape	2.76^{c}	3.11^{c}	3.53^{bc}	2.89^{c}	7.10^{a}	7.11^{a}	6.42^{a}	4.09^{b}	4.30^{b}	3.54^{bc}
Stem length	2.62^{d}	2.78^{d}	2.82^{d}	2.48^{d}	7.15^{bc}	8.75^{abc}	10.14^{a}	6.68^{c}	8.99^{ab}	7.51^{bc}
Leaf size	1.44^{f}	0.82^{f}	1.12^{f}	0.82^{f}	7.69^{a}	6.17^{bc}	5.03^{de}	6.58^{b}	5.47^{cd}	4.49^{e}
Leaf thickness	1.10^{e}	0.75^{e}	1.23^{e}	0.84^{e}	7.04^{a}	5.93^{bc}	5.72^{bcd}	6.38^{ab}	5.37^{cd}	5.08^{d}
Green aroma	1.58^{d}	1.72^{cd}	1.90^{cd}	2.06^{cd}	1.64^{d}	1.57^{d}	1.44^{d}	4.03^{a}	2.43^{b}	3.00^{b}
Bean sprout identity aroma	9.28^{b}	10.83^{a}	7.76^{c}	8.26^{c}	0.09^{d}	0.50^{d}	0.06^{d}	0.57^{d}	0.09^{d}	0.74^{d}
Cool/fresh aroma	0.39^{de}	0.56^{cde}	0.17^{e}	0.12^{e}	1.63^{a}	1.36^{ab}	1.51^{a}	0.92^{bc}	0.75^{cd}	0.75^{cd}
Beany aroma	2.52^{bc}	2.33^{c}	3.27^{a}	3.15^{ab}	0.40^{d}	0.41^{d}	0.35^{d}	0.38^{d}	0.55^{d}	0.79^{d}
Yam bean-like aroma	5.87^{a}	5.98^{a}	2.78^{c}	3.68^{b}	0.53^{d}	0.73^{d}	0.88^{d}	0.27^{d}	0.42^{d}	0.45^{d}
Sunflower oil flavor	1.61^{d}	1.51^{d}	1.47^{d}	1.11^{d}	4.15^{abc}	4.64^{a}	4.34^{ab}	3.41^{c}	3.63^{bc}	3.37^{c}
Sunflower identity flavor	0.10^{b}	0.06^{b}	0.10^{b}	0.06^{b}	4.70^{a}	4.68^{a}	4.31^{a}	4.37^{a}	4.21^{a}	4.53^{a}
Sweet taste	4.26^{ab}	4.83^{a}	2.60^{ed}	3.69^{bc}	2.77^{ecd}	2.35^{e}	2.44^{e}	2.77^{ecd}	2.92^{ecd}	3.57^{bcd}
Salty taste	0.33^{cd}	0.16^{cd}	0.25^{cd}	0.23^{cd}	0.30^{cd}	1.14^{ab}	1.38^{a}	0.31^{cd}	0.45^{cd}	0.73^{bc}
Crunchiness	7.64^{b}	8.65^{a}	5.34^{c}	5.087^{c}	5.80^{c}	5.33^{c}	6.03^{c}	2.77^{d}	3.22^{d}	3.22^{d}
Juiciness	7.02^{bcd}	7.67^{abc}	8.03^{ab}	8.14^{a}	5.17^{e}	4.75^{e}	4.47^{e}	6.71^{cd}	6.51^{d}	7.20^{abcd}
Fibrousness	3.80^{cd}	3.12^{d}	3.08^{d}	3.50^{d}	5.88^{bc}	9.01^{a}	5.99^{bc}	5.82^{bc}	6.84^{b}	6.42^{b}
Overall flavor intensity	3.60^{bc}	3.41^{c}	2.53^{d}	2.87^{cd}	4.30^{ab}	4.57^{a}	4.88^{a}	3.58^{bc}	3.45^{c}	4.21^{ab}
Astringent	0.45^{c}	0.39^{c}	0.21^{c}	0.25^{c}	2.27^{a}	2.48^{a}	2.15^{a}	1.37^{b}	1.54^{b}	1.38^{b}
Hard to Swallow	0.52^{d}	0.55^{d}	0.60^{d}	0.41^{d}	2.72^{b}	3.53^{a}	3.08^{ab}	1.75^{c}	1.84^{c}	1.87^{c}

Note: * Means within a row not sharing a superscript letter are significantly difference (*p*<0.05, Duncan's multiple range test).

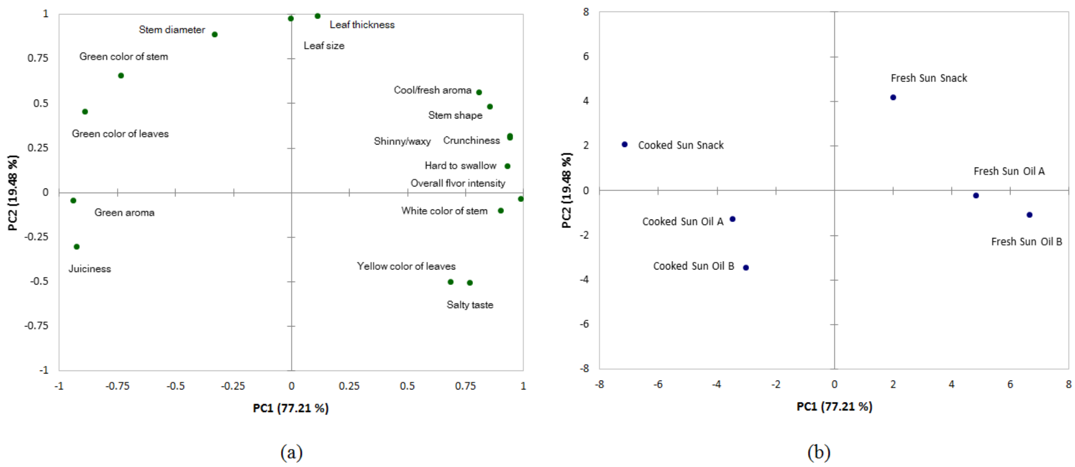


Figure 2 Principal component loadings and score of (a) significant sensory attributes and (b) the sunflower sprouts samples (n=6) for principal component 1 and 2 (PC1 vs PC2)

Table 4 The mean intensity of all significant sensory attributes of sunflower sprout samples

Sensory attributes	Fresh Sun Snack	Fresh Sun Oil A	Fresh Sun Oil B	Cooked Sun Snack	Cooked Sun Oil A	Cooked Sun Oil B
White color of stem	5.56[c]	7.14[b]	8.76[a]	1.43[e]	3.39[d]	3.19[d]
Yellow color of leaves	1.11[b]	2.74[a]	2.82[a]	1.19[b]	0.91[b]	2.25[a]
Green color of stem	4.57[b]	1.89[d]	1.44[d]	7.18[a]	3.50[c]	2.30[d]
Green color of leaves	7.96[bc]	4.82[d]	4.28[d]	10.08[a]	8.13[b]	6.75[c]
Shiny/waxy	7.50[ab]	6.92[b]	8.00[a]	1.66[c]	2.38[c]	2.28[c]
Stem diameter	4.37[a]	2.94[b]	2.55[b]	4.18[a]	2.63[b]	2.85[b]
Stem shape	7.10[a]	7.11[a]	6.42[a]	4.09[b]	4.30[b]	3.54[b]
Leaf size	7.69[a]	6.17[bc]	5.03[de]	6.58[b]	5.47[cd]	4.49[e]
Leaf thickness	7.04[a]	5.93[bc]	5.72[bcd]	6.38[b]	5.37[cd]	5.08[d]
Green aroma	1.64[c]	1.57[c]	1.44[c]	4.03[a]	2.43[b]	3.00[b]
Cool/fresh aroma	1.63[a]	1.36[ab]	1.51[a]	0.92[bc]	0.75[c]	0.75[c]
Salty taste	0.30[c]	1.14[ab]	1.38[a]	0.31[c]	0.45[c]	0.73[bc]
Crunchiness	5.80[a]	5.33[a]	6.03[a]	2.77[b]	3.22[b]	3.22[b]
Juiciness	5.17[b]	4.75[b]	4.47[b]	6.71[a]	6.51[a]	7.20[a]
Overall flavor intensity	4.30[a]	4.57[a]	4.88[a]	3.58[bc]	3.45[c]	4.21[ab]
Hard to swallow	2.72[a]	3.53[a]	3.08[a]	1.75[b]	1.84[b]	1.87[b]

Note: * Means within a row not sharing a superscript letter are significantly difference (*p*<0.05, Duncan's multiple range test).

4. Conclusion

The major factors that affected sensory characteristics of the samples were type of sprout (cultivation process and consumption behavior) and effect of heat treatment. Mung bean sprouts had a stronger intensity of yellow color of leaves, stem diameter, yam-like aroma, beany aroma, bean sprout aroma identity, sweetness, and juiciness than those characteristics in sunflower sprouts. In contrast, sunflower sprouts were characterized by having a higher intensity of green color of leaves and stem, leaf thickness, stem length, curvy shape of stem, sunflower oil flavor, sunflower flavor identity, fresh/cool aroma, astringent, overall flavor intensity, fibrous texture, and hard to swallow than those attributes in bean sprouts. After blanching, sunflower sprouts tended to have a lower intensity of white color of stem, waxy appearance, curvy shape of stem, fresh/cool aroma, crunchiness, overall flavor intensity, hard to swallow whereas green color of leaves and stem, green aroma, and juiciness increased. The results provide initial findings of sensory characteristics for both types of sprouts. Researchers and marketers can correlate sensory descriptive data with consumer data in order to find the important sensory attributes leading to consumer acceptability.

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