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Original Research

Development of cooking method for senior-friendly food using fruits suitable for older adults with masticatory dysfunction

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ABSTRACT

BACKGROUND/OBJECTIVES: The purpose of this study was to establish a fruit-cooking method suitable for older adults with masticatory dysfunction.
MATERIALS/METHODS: Five types of fruits were selected to make fruit jelly and puree: apple, sweet persimmon, mandarin, Korean melon, and watermelon. Recipes were selected based on the Korean Industrial Standard (KS) for senior-friendly foods (KS H 4897), which classifies foods into 3 levels (L1–L3) based on their hardness and viscosity.
RESULTS: In South Korea, senior-friendly foods are classified into 3 stages based on their hardness. Stage 1 is for foods that are able to eat with teeth (hardness greater than 50,000 N and less than 500,000 N), Stage 2 is for foods that are able to eat with gums (hardness greater than 20,000 N and less than 50,000 N), and Stage 3 is for foods that are able to eat with the tongue (hardness less than 20,000 N). As a result of measuring the hardness by varying the shape of the fruit, it was found that nearly all fruits could be eaten fresh by chewing with the teeth (L1) but did not meet the KS for mastication using the gums (L2) or tongue (L3), so the cooking method was selected as fruit jelly and fruit puree. Only sweet persimmon, which had a hardness of 61,624–496,393 N, was not suitable for consumption in fresh fruit, unprocessed form. Based on their hardness measurements, fruit jellies (27,869 to 36,343 N) and fruit purees (315 to 1,156 N) met the L2 and L3 requirements, respectively. The viscosity results of all fruit purees met the L3 requirement.
CONCLUSION: These results offer a simple cooking method to prepare texture-modified fruits suitable for safe consumption by older adults living with masticatory difficulties in general households and nursing facilities.

Keywords: Aged; mastication; fruit; chewing; hardness tests

INTRODUCTION

Statistics Korea predicts that South Korea will become a super-aged society by 2025 due to its rapidly aging population. By 2050, the proportion of persons aged 6 yrs and older is expected to exceed 40% [1]. Accordingly, health challenges of older adults have emerged as one of the social problems. Several physical changes occur with aging, the most prominent of which is a

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Conflict of Interest
The authors declare no potential conflicts of interests.

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decline in chewing, swallowing, and digestive functions [2]. In addition, as aging progresses, teeth weaken and are lost due to periodontal disease and caries, leading to difficulty chewing hard or tough foods (e.g., fruits, meat, and nuts). This is regarded as a particularly serious problem as the decrease in the types of foods that can be voluntarily eaten reduces the enjoyment of eating and quality of life (QoL) and can lead to nutritional imbalances [3,4].

Japan, the United States, and Europe, which were early entrants into the aging society, are developing foods that consider the needs of older adults. In 2002, the Japan Care Food Association established the Universal Design Foods (UDF) concept [5], which was later borrowed and unified by the Japanese government in 2016 to create the Smile Care Foods standard [6]. Since the Korean Industrial Standard (KS) was enacted, it has been amended 4 times, most recently in 2022, to stipulate the legal basis for senior-friendly foods. The KS for senior-friendly food (KS H 4897) classifies food into 3 levels (L1–L3) based on hardness and viscosity characteristics, similar to the Japanese UDF standard (**Table 1**), According to KS H 4897, L1 food (hardness, 50,000–500,000 N) can be chewed using the teeth, L2 food (hardness, 20,000–50,000 N) can be ingested using the gums, and L3 food (hardness, < 20,000 N; viscosity ≥ 1,00 mPa·s) can be consumed using only the tongue. However, unlike Korea, Japan classifies foods that can be crushed with the tongue as L3 and foods that can be swallowed without chewing as L4. In this study, foods were developed to satisfy each of the 3 levels specified by the KS H 4897. Different test methods were used depending on the product's properties.

Previous research on senior-friendly foods in Korea has included the development of a soft diet for patients with dysphagia [7], mackerel with controlled physical properties [8], enzyme-treated and reconstituted foods [9], and hamburger steak, cooked rice with vegetables, and white anchovy stew as senior-friendly foods [10]. Whereas food development and research for older adults are actively progressing, the development of senior-friendly food that meets the hardness and viscosity standards of KS is insufficient. In addition, most of the foods being developed fall into specific food groups, such as grains and meat, and many of them are semi-cooked or fully-cooked processed products. At present, senior-friendly foods available in South Korea primarily consist of porridge, softened meat, and softened fish. As of March 2023, only 4 out of the 145 senior-friendly foods designated in South Korea were made with fruits or vegetables [11]. Therefore, it is essential to keep developing food options for older adults, especially those with masticatory dysfunction, to ensure they can consume an adequate amount of plant-based foods, including fruits and vegetables.

Fruits are rich in antioxidants and minerals like vitamin C, carotenoids, dietary fiber, and phenolic compounds, and studies on their benefits are continuously being reported [12-14].

Table 1. Standards for senior-friendly foods in Korea and Japan

Classifications	Stage	Description	Hardness (N)	Viscosity (mPa·s)
Korea KS 고령친화식품	1	Able to eat with teeth	≤ 5×10^5	-
	2	Able to eat with gum	≤ 5×10^4	-
	3	Able to eat with tongue	≤ 2×10^4	≥ 1,500
Japan UDF ユニバーサルデザインフード	1	Able to chew easily	≤ 5×10^5	-
	2	Able to crush with gum	≤ 5×10^4	-
	3	Able to crush with tongue	≤ 1×10^4 (sol) ≤ 2×10^4 (gel)	≥ 1,500 (sol)
	4	No chew	≤ 3×10^3 (sol) ≤ 5×10^3 (gel)	≥ 1,500 (sol)

KS, Korean Industrial Standards, KS H 4897; UDF, Japan Care Food Conference, Universal Design Food.

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Previous studies have shown that consuming more fruit lowers blood lipid levels and oxidative damage and reduces mortality from cancer and cardiovascular diseases [15-17]. Furthermore, Kantorowicz *et al.* [18] and Koo *et al.* [19] reported that an increase in fruit intake, a major source of vitamin C, was linked to a decrease in the prevalence of cavities and periodontal diseases, such as periodontitis. In this way, fruit consumption not only lowers the risk of developing various diseases but also supplements trace nutrients, such as vitamins and minerals, which are often lacking in older adults. However, fruits contain high levels of sugars, including fructose, which can lead to health problems, such as obesity and diabetes, if consumed excessively [20,21]. In the utilization of Dietary Reference Intakes for Koreans (KDRIs) 2020 [22], it was reported that older adults recommend consuming one to 2 servings of fresh fruit per day. Based on the calorie content per serving (50 kcal), the amount of fruit varies depending on the variety, so this should be taken into account when consuming the actual fruit.

Due to the age-related decline in masticatory ability, older adults have more restrictions on fresh fruit intake than other age groups, but there has been very little development of senior-friendly foods using fruits. Therefore, this study was conducted to develop fruit-cooking methods that meet Korea's senior-friendly food standards and specifications. Through this, we wanted to make fruit consumption by older adults with chewing difficulties easier and safer.

MATERIALS AND METHODS

Criteria for selection of fruit type

Five types of fruits (apple, sweet persimmon, mandarin, Korean melon, and watermelon) were selected for the manufacture of senior-friendly foods based on the results of the 2016–2018 Korea National Health and Nutrition Examination Survey (KNHANES) and a survey on fruit provision (data not shown). Survey on fruit provision was conducted by surveying dietitians in older adult care facilities and conducting an online survey on a nutritionist network site. According to the 2016–2018 KNHANES (n = 4,498), older adults commonly consumed apples, persimmons, mandarins, Korean melons, watermelons, peaches, pears, grapes, bananas, and oranges as their top 10 fruit choices. Apples accounted for 31.80%, persimmons 15.06%, and mandarins, Korean melons, and watermelons 6.94–7.73%. In order to understand the current state of fruit provision in older adult care facilities, questionnaires were mailed to older adult care facilities and hospitals, and an online survey was conducted through a nutritionist network site [23]. A total of 300 responses were collected through this survey, the results of which were analyzed and used to select the fruit sample for this study. According to the survey results, 73.8% of health care institutions provided fruit, with bananas (19.1%), watermelons (15.1%), apples (12.1%), mandarins (11.6%), and strawberries (6.5%) being the most frequently provided. In addition, bananas (28.5%) were the most preferred fruit by older adults, followed by watermelons (22.1%) and apples (9.2%). Hence, apples, persimmons, mandarins, Korean melons, and watermelons were selected as the fruits for the production of senior-friendly foods, as they are the fruits most consumed by this population and have a high preference and frequency of provision in older adult care facilities.

Ingredients

The senior-friendly foods were made using apples (var. Fuji, *Malus domestica* Borkh.), sweet persimmons (var. Fuyu, *Diospyrus kaki* Thunb.), mandarins (*Citrus unshiu*), Korean melons (var. Geumsaragieuncheon, *Cucumis melo* L.), and watermelons (var. Sambok Honey, *Citrullus vulgaris*). The fruits were purchased from a local food market in Wanju-gun (South Korea)

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between July and November 2022, based on their availability (apples: October–November, sweet persimmons, mandarins: October–November, Korean melons, watermelons: July–August). The fruits were refrigerated and, if necessary, crushed or juiced immediately before cooking. The sugar (CJ CheilJedang, Seoul, Korea), powdered agar (Woorigastory, Yangju, Korea), vitamin C powder (esFood, Gunpo, Korea), and viscosity enhancer (Daesang Wellife, Seoul, Korea) are all commercially available ingredients used in cooking fruit jelly and puree. Vitamin C powder was used to prevent fruit browning that occurs when cutting or crushing fruit. **Table 2** shows the amount of ingredients needed to prepare the fruit jelly and puree according to the KS H 4897 levels.

Cooking method

According to the KS H 4897 for hardness and viscosity, it was first determined whether fresh fruit could be provided. The pre-treatment methods (slicing, mincing, crushing, and juicing) were different for the 5 types of fruits based on the characteristics of the fruits.

Slicing

Apples, sweet persimmons, and Korean melons with hard flesh were sliced into various thicknesses (1, 3, 4, 5, 7, 8, and 10 mm) using a knife. Mandarins with endocarp (inner rind) were prepared by removing the outer rind and then cutting into 4 equal parts or horizontally into 2 equal parts in the shape of a cross. Watermelon was prepared by dicing into 2 thicknesses (10 and 20 mm) because the flesh has a lot of moisture, and the seeds are not evenly distributed in the flesh.

Mincing

After removing the peel and seeds, 4 fruits, except mandarins, were sliced thinly to a thickness of 2 mm using a knife. Mandarins were divided into mincing with the endocarp and mincing only granules after removing the endocarp.

Crushing

When crushing apples, sweet persimmons, and Korean melons, the peel and seeds of fruits were removed, and the fruits were cut into small sizes, placed in a grinder (SMX-P4000LOT; Shinil Co., Ltd., Yongin, Korea), and ground for 1 min.

Juicing

When juicing mandarins and watermelons, the outer skin was removed before putting the fruit in a juicer (HE-DBF04; Hurom Co., Ltd., Seoul, Korea). Afterward, the fruit was strained with a sieve. When fresh fruit could not be produced by the above methods, the fruit was cooked to a jelly or puree.

Table 2. Formulas for jelly and purees with various kinds of fruits

Commodity	Apple	Sweet persimmon		Mandarin	Korean melon	Watermelon
Senior-friendly foods stage	2	1	2	2	2	2
Jelly ingredients (g)						
Fruits puree or juice	300.0	300.0		300.0	300.0	300.0
Sugar	32.0	32.0		32.0	32.0	32.0
Agar	2.2	2.2	1.4	2.2	2.2	2.2
Water	100.0	100.0		100.0	100.0	100.0
Puree ingredients (g)						
Fruits puree or juice	100.0	100.0		120.0	150.0	150.0
Thickener	-	-		2.4	-	3.0

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The main priority was to produce senior-friendly foods using raw fruits without any processing procedure. However, depending on the characteristics of the fruits, when their texture was too hard, or they posed a risk of aspiration when consumed in the raw, unprocessed state, they were cooked according to the following 4 cooking rules established from the perspective of the researcher: (1) simple cooking methods, such as grinding or boiling, were selected; (2) the mixing ratio of the ingredients was set so that the fruit content was greater than 50%; (3) a recipe for food that can be consumed by older adults using their chewing organs, such as the teeth and gums, was selected; (4) if heat cooking was necessary, a short cooking method (≤ 10 min) was selected to minimize the destruction of the nutritional components of the fruit.

As mentioned above, in addition to preparing raw fruits, fruits were processed as jelly and puree. Regarding the method for processing, easier cooking methods were used with expert consultation so that they were appropriate for use at home and in welfare centers and older adult care facilities. Second, through previous studies [24-26], the most commonly used cooking method was selected among the various recipes for fruits. Third, agar was selected as the gelling agent for the preparation of fruit jelly in this study. Agar was chosen because it is easy to use, economical, and can be easily used by the elderly, caregivers, guardians, and dietary managers at home or in nursing facilities, as mentioned in previous studies [27]. In addition, viscosity enhancers were applied to some fruits (mandarine and watermelon) that could not be served as juice-type puree because their viscosity was lower than the standard (L3 standard of KS H 4897) for elderly meals, and commercially available xanthan gum-based viscosity enhancers commonly used in nursing facilities in Korea were used [28].

L1 (able to eat using the teeth)

Apples, mandarins, Korean melons, and watermelons could be served raw as L1 foods (hardness, 50,000–500,000 N) (**Table 3**). The fruits were washed and peeled, and the seeds were removed. Afterward, the fruit was cut to a thickness (apples: 1 mm, mandarins: horizontally into 2 equal parts, Korean melons: 1 mm, watermelons: 20 mm) and used as a material.

Table 3. Fruit recipes by the mastication stage of the elderly

Stage	Corresponding fruits	Cooking process
1	Apple, Mandarin, Korean melon, Watermelon	1. Wash the fruit thoroughly and remove the peel. For fruits with seeds, remove the seeds. 2. Depending on the type of fruit, cut it into the thickness corresponding to Stage 1 (apples: 1 mm, mandarins: horizontally into 2 equal parts, Korean melons: 1 mm, watermelons: 20 mm). (To prevent apple browning, soak briefly in water with some vitamin C powder or a little lemon juice before slicing.) 3. Serve one serving size per person.
2	Apple, Sweet persimmon, Mandarin, Korean melon, Watermelon	1. Measure the ingredients according to the quantity (Table 2). (At this time, pulverize apples, sweet persimmons, and Korean melons thoroughly for 3 min with a grinder, and squeeze juice from mandarins and watermelons with a juicer, and strain one time through a sieve.) 2. Macerate agar powder in water for 15 min. 3. Put the agar, sugar, and water in the pot, and boil for 5 min at medium temperature (80–90°C). 4. Add the prepared fruit puree or fruit juice and boil for an additional 5 min to mix well with the agar. 5. Put one serving size in a bowl and cool at room temperature for 30 min and refrigerate.
3	Apple, Sweet persimmon, Korean melon	1. Wash the fruit thoroughly, remove the peel, and cut it into appropriate sizes that could be crushing with a grinder. Remove the seeds inside. 2. Pulverize the fruits thoroughly for 3 min using a grinder. (To prevent apple browning, add 0.15% vitamin C powder to the weight of apples or a little lemon juice, and grind them.) 3. Serve one serving size per person.
	Mandarin, Watermelon	1. Wash the fruit thoroughly, peel the husk, and cut it into appropriate sizes that could be crushing with a grinder. For fruits with seeds, remove the seeds. 2. After extracting the juice from the fruit using a juicer, strain it one time through a sieve. 3. Put one serving size in a bowl, add a thickener and mix evenly. 4. One minute after adding a thickener, eat it when viscosity that meets the Stage 3 standard (1,500 mPa·s or more) is formed.

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L2 (able to eat using the gums)

Because raw fruit did not satisfy the L2 requirement specified in KS H 4897, all 5 types of fruits were made into jelly (**Table 3**). **Table 2** shows the mixing ratio of the jelly used, which was prepared using the methods detailed by Cha *et al.* [24], Hwang and Moon [25], and Jeong *et al.* [26]. Preliminary experiments with powdered agar were performed by varying the addition ratio from 0.3% to 0.8%, and the addition ratio that controlled the hardness corresponding to L2 was finally selected. Depending on the type of fruit, different pre-treatment methods were used for the fruit puree or fruit juice used in the production of jelly.

Apples, sweet persimmons, and Korean melons with difficult-to-extract flesh were finely ground for 1 to 2 min in a grinder (SMX-P4000LOT; Shinil Co., Ltd.). Mandarins and watermelons were squeezed with a juicer (HE-DBF04; Hurom Co., Ltd.) and then filtered through a sieve to remove the fibers and remaining flesh. The materials used in jelly production were weighed, and the powdered agar was soaked in water for 15 min. The soaked agar, sugar, and water were combined in a pot and boiled at 80°C for 5 min. The prepared fruit puree or juice was placed in a pot and boiled for an additional 5 min to mix thoroughly with the agar. Finally, the samples were placed in a transparent polypropylene container (50 mm × 20 mm), allowed to cool at room temperature for 30 min, and then refrigerated for 2 h before use in the experiment.

L3 (able to eat using the tongue)

To satisfy the L3 requirement, all 5 types of fruits were prepared as puree (**Table 3**). To meet the viscosity requirement for KS H 4897, the viscosity of fruit puree was adjusted by adding a viscosity enhancer based on the characteristics of the fruit. The flesh of apples, sweet persimmons, and Korean melons, which are hard, remained in the form of lumps after grinding, and no viscosity enhancers were added because they met the viscosity standard. The fruit was washed and peeled, and any seeds were removed before cutting the flesh to an appropriate size and finely grinding for 1 to 2 min using a grinder. The apple was severely brown at this point; hence, vitamin C powder weighing 0.15% of the apple's weight was added and ground with the apple.

A commercially available viscosity enhancer was added to mandarins and watermelons when they were juiced using a juicer because they did not meet the viscosity standard. The viscosity enhancer was tested at addition rates of 1.0%, 2.0%, and 3.0% in relation to the specified systematic addition amount, and the minimum addition rate that provided a viscosity corresponding to the L3 specification was finally selected. After extracting the juice, the fruit was sieved to remove the fibers and remaining pulp. Then, the fruit juice was placed in a bowl suitable for one person, a viscosity enhancer was added and stirred quickly, and when the viscosity formed after 1 to 2 min, the modified fruit juice was immediately used in the experiment.

Hardness

Hardness, also known as firmness, refers to the peak force at first compression, which is the force required to chew food after it has been placed in the mouth. Hardness was measured according to the KS Senior-friendly Food Test Method [29]. This method has 3 sub-methods classified according to the level of the senior-friendly food sample, and hardness was measured using a texture analyzer (TA.XTplusC; Stable Micro Systems, Godalming, UK). Methods 1 and 3 measure L1 samples and mainly correspond to solid samples. The result obtained according to Method 3 shall be used for the hardness value, but it shall not exceed 500,000 N when measured according to Method 1. Method 2 measures L2 and L3 samples

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and mainly corresponds to semi-solid or liquid samples. However, solid samples that are hard or broken when placed in a probe, such as fruit jelly, are measured in accordance with Methods 1 and 3.

Methods 1 and 3 were used to test fresh fruits and fruit jellies in solid form, corresponding to L1 and L2. Fresh fruit was cut to the appropriate thickness and used to cover a wider area than the probe area. Immediately after preparation, 25 g of fruit jelly was placed in a transparent container (50 mm × 20 mm), cooled at room temperature for 30 min, and then refrigerated for 2 h. When the temperature of the jelly reached 20 ± 2°C, it was used in the experiment. Method 1 began with a puncture test using a circular probe with a diameter of 5 mm. The probe test speed was set to 100 mm/min, and the clearance was set to 130% of the sample thickness. Method 3 involved a compression test using a circular probe with a diameter of 3 mm. The probe test speed was set to 600 mm/min, and the clearance was set to 30% of the sample thickness. In principle, the hardness of the sample was tested using Method 3, and it was confirmed that it did not exceed 500,000 N based on Method 1.

Because chopped fruit and fruit puree or juice corresponding to L3 could not be specified or are fluid-like liquids, they were placed in a round container (40 mm × 15 mm), and Method 2 was used with the probe test speed set to 600 mm/min and the measurement height set to 5 mm from the bottom of the container. The hardness value of all samples was measured as stress (N/m^2) divided by the area (m^2) of the probe used for measurement at the highest peak height (N) when compressed or penetrated by the probe. When compared to solid foods, such as cookies and bread, the fresh fruits and processed fruit products used in this experiment varied in shape and were fluids, so samples of uniform size were prepared and repeated 10 times to obtain reliable results.

Viscosity

Viscosity was measured using a rotational viscometer (DV-II+ Pro; Brookfield Engineering Laboratories, Inc., Middleboro, MA, USA) according to the KS Senior-Friendly Food Viscosity Test Method [29]. After putting approximately 500 mL of the sample in a glass beaker (600 mL, ø = 90), a spindle (No. 62) was placed in the center of the glass beaker, and measurements were taken at 20 ± 2°C and 12 rpm for 2 min. The measured value was multiplied by the corresponding coefficient and converted into viscosity units (mPa·s).

Fork and spoon tests

In this study, the fork drip, fork pressure test, and spoon tilt test were used to confirm the degree of cohesiveness and adhesion of the fruit by observing the shape and flow of the foods on a fork or spoon. In addition to the mechanical results, we tested the hardness and viscosity using the International Dysphagia Diet Standardization Initiative (IDDSI) test [30] and the National Institute of Agricultural Sciences method [31], which are easy to use at home or in care facilities. We also checked the levels of fruits according to the KS criteria with the IDDSI levels.

Nutrition facts

The results of the analysis of the nutritional components of senior-friendly foods made from fruits are presented in **Supplementary Table 1**. Calories, carbohydrates, total sugars, dietary fiber, proteins, fats, and vitamin C were among the nutrients labeled. Total sugars were included among the nutrients in consideration of simple sugars, which account for most of the carbohydrates in fruits, and the level of simple sugar intake of older adults.

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When analyzing nutritional components, each component was converted and labeled according to the amount per serving per person with reference to the National Standard Food Composition Table [32]. The amount per serving was calculated based on the KDRIs developed by the Korean Nutrition Society and the Korean Diabetes Association (KDA) [22,33]. The fruits used in this study had a serving size of 100 g for apples and sweet persimmons and 150 g for Korean melons and watermelons. However, mandarins did not meet the calorie per exchange unit (50 kcal) recommended by the Korean Nutrient Intake Standard; hence, one exchange unit (120 g) from the KDA's food exchange table was used. One portion (120 g) of fruit jelly was calculated to contain 50 kcal of energy.

Statistical analysis

All experiments, except hardness measurements, were performed 3 times, and the data were presented as mean and SD. Data analysis for hardness and viscosity was performed using SPSS (IBM SPSS Statistics 27.0; IBM Corp., Armonk, NY, USA). The analysis of variance and Duncan's multiple range test were performed appropriately to analyze the data. The level of significance was set at $\alpha = 0.05$.

RESULTS

Hardness of fruit according to the pre-treatment method

In this study, we assessed the hardness level corresponding to the physical property standards for senior-friendly foods in Korea and Japan based on the shape of the fruit. The hardness of fresh fruit with different pre-treatment methods is shown in **Table 4**.

Slicing

When sliced into 1 mm thickness, the hardness values of apples and Korean melons were 496,393 and 385,253 N, respectively, and satisfied L1. Sweet persimmons showed a hardness of 623,477 N even at a thickness of 1 mm, indicating that the raw fruit could not be classified as a senior-friendly food. Mandarins and watermelons, depending on the cutting method, met the L1 requirement.

Mincing

The hardness values of apples and sweet persimmons were 39,041 and 36,736 N, respectively, which met the L2 requirement. Korean melons, mandarins, and watermelons had hardness values between 9,584 and 15,550 N and thus were classified as L3.

Crushing

Crushed apples, Korean melons, and sweet persimmons corresponded to L3 foods. Among them, sweet persimmons showed a particularly high hardness of 1,156 N.

Juicing

When mandarins and watermelons were juiced, they resembled a water-like liquid state, so the hardness could not be measured.

The relative standard deviation (RSD) of hardness was less than 15% for most fruit samples. However, chopped fruit had a value as high as 20% or more, and for sweet persimmons and mandarins, the RSD exceeded 20% in more than 3 cases. It was found that all the samples tested had identical hardness levels for senior-friendly foods, whether categorized within

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Table 4. Hardness of raw fruits according to pretreatment methods

Commodity[1)]	Pretreatment method	Hardness (n)		KS	UDF stage
		Mean ± SD[2)]	RSD (%)	stage	
Apple	Cut into 8 pieces	813,458.60 ± 66,420.29^{a***}	8.17	-	-
	Cut into 10 mm	832,797.69 ± 1.12^{a}	13.49	-	-
	Cut into 7 mm	801,815.53 ± 58,491.89^{a}	7.29	-	-
	Cut into 5 mm	784,612.65 ± 26,246.89^{a}	3.35	-	-
	Cut into 3 mm	770,891.37 ± 30,468.30^{a}	3.95	-	-
	Cut into 1 mm	496,393.66 ± 52,369.34^{b}	10.55	Stage 1	Stage 1
	Mincing	39,041.34 ± 12,719.40^{c}	32.58	Stage 2	Stage 2
	Pulverizing	669.72 ± 46.05^{c}	6.88	Stage 3	Stage 4
Sweet persimmon	Cut into 8 pieces	1,192,300.00 ± 151,981.00^{a***}	12.75	-	-
	Cut into 10 mm	1,195,500.00 ± 138,004.00^{a}	11.54	-	-
	Cut into 7 mm	995,008.41 ± 226,695.00^{b}	22.78	-	-
	Cut into 5 mm	952,369.03 ± 247,315.00^{b}	25.97	-	-
	Cut into 3 mm	882,241.83 ± 110,895.00^{b}	12.57	-	-
	Cut into 1 mm	623,477.11 ± 46,641.20^{c}	7.48	-	-
	Mincing	36,736.78 ± 8,755.64^{d}	23.83	Stage 2	Stage 2
	Pulverizing	1,156.74 ± 69.25^{d}	5.99	Stage 3	Stage 4
Mandarin	One segment with inner peel	66,420.80 ± 16,302.35^{b***}	24.54	Stage 1	Stage 1
	One segment without inner peel	72,900.00 ± 19,694.44^{b}	27.02	Stage 1	Stage 1
	Cut into 4 pieces	138,132.30 ± 49,313.81^{a}	35.70	Stage 1	Stage 1
	Cut into 2 pieces	123,858.00 ± 19,729.15^{a}	15.93	Stage 1	Stage 1
	Minced with inner peel	3,417.40 ± 440.75^{c}	12.90	Stage 3	Stage 4
	Minced without inner peel	3,418.40 ± 440.75^{c}	12.89	Stage 3	Stage 4
	Squeezing	-	-	-	-
Korean melon	Cut into 4 pieces	1,138,800.00 ± 171,520.00^{a***}	15.06	-	-
	Cut into 10 mm	1,051,400.00 ± 192,254.00^{ab}	18.29	-	-
	Cut into 7 mm	989,299.63 ± 149,599.00^{b}	15.12	-	-
	Cut into 5 mm	950,132.37 ± 131,544.00^{b}	13.84	-	-
	Cut into 3 mm	807,877.56 ± 118,932.00^{c}	14.72	-	-
	Cut into 1 mm	385,253.99 ± 36,954.49^{d}	9.59	Stage 1	Stage 1
	Mincing	15,550.77 ± 2,155.36^{e}	13.86	Stage 3	Stage 3
	Pulverizing	339.32 ± 7.67^{e}	2.26	Stage 3	Stage 4
Watermelon	20 mm cubed	179,357.01 ± 25,623.91^{a***}	14.29	Stage 1	Stage 1
	10 mm cubed	145,432.25 ± 9,749.54^{b}	6.70	Stage 1	Stage 1
	Mincing	9,584.31 ± 1,939.65^{c}	20.24	Stage 3	Stage 3
	Squeezing	-	-	-	-

RSD, relative standard deviation; KS, Korean Industrial Standards, 2020 (KS H 4897); UDF, Japan Care Food Conference, 2020, Universal Design Foods; -, not determined.

[1)]Top 5 most frequently consumed fruits by the elderly over 65 yrs of age (n = 4,498) according to the results of the Korean National Health and Nutrition Examination Survey ('16–'18).

[2)]Average of hardness (n = 10) ± SD.

[a,b,c,d,e]Different superscripts indicate there are significant differences between values in a same column according to Duncan's multiple range test ($P < 0.05$).

[***]$P < 0.001$.

the KS H 4897 framework or the Japanese UDF standards framework, except for the minced or pulverized form. Based on their hardness values, pulverized apples, pulverized Korean melons, pulverized sweet persimmons, and minced mandarins are classified as L3 by the KS but L4 by the UDF standard, thus differing by one level.

Hardness and viscosity of the final recipe of fruits

The final serving method for the 5 different types of fruits was determined based on the results of the hardness analysis of the fruits prepared using different pre-treatment methods. For L1, apples and Korean melons were cut into 1 mm thickness, and sweet persimmons were cooked in jelly because they could not be cut. Mandarins and watermelons were cut into halves and diced into 20 mm thickness, respectively. Except for apples and sweet persimmons, no other fruits showed hardness corresponding to L2. Furthermore, apples and sweet persimmons were excluded from the final sample selection of L2 foods due to the

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risk of aspiration in older adults when served in chopped form; hence, fruit jelly was selected as the final serving method. For L3, apples, sweet persimmons, and Korean melons were cooked as fruit purees in their crushed form, whereas mandarins and watermelons, for which hardness measurement was not possible, were selected after they were modified into purees by adding viscosity enhancers.

Table 5 shows the hardness and viscosity results for the selected fruit recipe. Among the modified fruits confirmed to have L1 classification for hardness, sweet persimmon jelly had the lowest value, and apple had the highest value. The L2 fruit jelly had a hardness value of 27,869–36,343 N, and the L3 fruit puree was in the range of 315–1,156 N, with all fruits meeting the corresponding standard. The RSD of hardness was within 15% at all levels (L1–L3). However, when the KS H 4897 and the UDF standard were compared, there was a one-level difference between the 2 standards during crushing, as in the case of fruit samples according to the pre-treatment method. Products that can be consumed with the tongue are likely to be classified as L3 according to KS H 4897 or L4 according to the UDF standard.

Fruit samples corresponding to KS L3 and UDF L3 and L4 were tested for viscosity. All fruit purees met both criteria (> 1,500 mPa·s). Apples, sweet persimmons, and Korean melons were closer to the gel form than the mean solid, so the torque value was high, and the upper limit for low viscosity that could be measured with a rotational viscometer was exceeded. Because mandarins and watermelons did not meet the viscosity standards when juiced, a commercially available viscosity enhancer was mixed in a specified amount (1, 2, or 3 g/100 mL). As a result, the viscosity of 1 g/100 mL (mandarin: 386.57 mPa·s, watermelon: 1,034.10 mPa·s) and 2 g/100 mL (mandarin: 2,122.33 mPa·s, watermelon: 2,069.00 mPa·s) did not meet the standard. The 3 g/100 mL viscosity was outside the upper limit of the measurable value and met the criteria. Overall, the viscosity RSD was generally low, at less than 10%.

Table 5. Hardness and viscosity according to the final selected fruit recipes

Commodity[1)]	Cooking method	KS stage	UDF stage	Hardness (n)		Viscosity (mPa·s)	
				Mean ± SD[2)]	RSD (%)	Mean ± SD	RSD (%)
Apple	Cut into 1 mm	1	1	496,393.66 ± 52,369.34^{a***}	10.55	-	-
	Jelly	2	2	28,209.33 ± 1,246.23^{b}	4.42	-	-
	Puree	3	4	669.72 ± 46.05^{b}	6.88	Overload[3)]	-
Sweet persimmon	Jelly	1	1	61,624.79 ± 7,908.67^{a***}	12.83	-	-
	Jelly	2	2	35,056.53 ± 1,810.24^{b}	5.16	-	-
	Puree	3	4	1,156.74 ± 69.25^{c}	5.99	Overload	-
Mandarin	Cut into 2 pieces	1	1	123,857.92 ± 19,729.14^{a***}	15.93	-	-
	Jelly	2	2	34,462.35 ± 2,471.31^{b}	7.17	-	-
	Puree	3	4	322.13 ± 4.72^{c}	1.47	2,122.33 ± 132.39	6.24
Korean melon	Cut into 1 mm	1	1	385,253.99 ± 36,954.49^{a***}	9.59	-	-
	Jelly	2	2	27,869.80 ± 2,390.63^{b}	8.58	-	-
	Puree	3	4	339.32 ± 7.67^{c}	2.26	Overload	-
Watermelon	20 mm cubed	1	1	179,357.01 ± 25,623.91^{a***}	14.29	-	-
	Jelly	2	2	36,343.92 ± 1,444.96^{b}	3.98	-	-
	Puree	3	4	315.13 ± 0.00^{c}	0.00	2,069.00 ± 102.83	4.97

RSD, relative standard deviation; KS, Korean Industrial Standards, 2020 (KS H 4897); UDF, Japan Care Food Conference, 2020, Universal Design Foods.
[1)]Top 5 most frequently consumed fruits by the elderly over 65 yrs of age (n = 4,498) according to the results of the Korean National Health and Nutrition Examination Survey ('16–'18).
[2)]Average of hardness (n = 10) and viscosity (n = 3) ± SD.
[3)]Products that exceed the upper limit that can be measured with a viscometer for low-viscosity applications are considered to meet the standard.
[a,b,c]Different superscripts indicate there are significant differences between values in a same column according to Duncan's multiple range test ($P < 0.05$).
[***]$P < 0.001$.

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Fork and spoon tests

Table 6 shows the results of using a fork and spoon to describe the texture of the fruits. Except for sweet persimmons, all fruits in L1 were in the form of fresh fruits, which were easily cut when pressed with a fork and did not return to their original shape when it was removed. In comparison to the levels outlined in the IDDSI, fruits at L1, according to KS H 4897, were found to be equivalent to IDDSI L6 or L7. The L2 fruit jelly (IDDSI L6) was easily crushed and spread uniformly distributed between the prongs. Furthermore, the agar particles were evenly distributed throughout the reticular structure of the gel, resulting in a uniform jelly consistency. The L3 fruit puree corresponded to IDDSI L3 or L4. Apples and sweet persimmons, which corresponded to L4, remained lumpy on the fork during the fork drip test and did not continuously flow down the fork prongs, whereas Korean melons, mandarins, and watermelons, corresponding to L3, showed a slow drop in the form of long lumps through the fork prongs. During the spoon tilt test, whereas apples and sweet persimmons maintained their shape on the spoon, slipped easily when tilted, and were not sticky, the pureed Korean melons, mandarins, and watermelons fell off without residue.

Nutrition facts

Supplementary Table 1 shows the nutritional component analysis results of older-adult-friendly foods prepared using fruits. After analyzing the nutritional content of apples, it was found that they contained approximately 56.00–106.01 kcal of energy, 13.58–26.70 g of carbohydrates, 11.13–23.44 g of total sugars, 2.70–2.91 g of dietary fiber, 0.20–0.23 g of protein, 0.77–0.83 g of fat, and 1.41–1.52 mg of vitamin C. Compared to the other fruits, apples showed higher calories, fat, and total sugar content at all levels (L1–L3). Regarding sweet persimmons, the L1 and L2 jellies were higher in calories (100.42–100.62 kcal), carbohydrates (26.64–26.79 g), total sugars (22.79–22.84 g), and dietary fiber (6.89–6.91 g) than other fruit jellies but the fat content was the lowest at 0.04–0.05 g. The nutrient ranges of the L1–L3 mandarins provided 46.80–87.69 kcal of energy, 12.05–22.89 g of carbohydrates, and 9.59 to 20.06 g of total sugars. Additionally, they had a high vitamin C content ranging from 33.06 to 36.83 mg. Korean melons had the lowest content of calories (40.50–74.77 g), carbohydrates (7.50–17.46 g), and total sugars (0.00–11.46 g) compared to other fruits at all levels. In particular, the L1 (raw fruit) and L3 (puree) Korean melons were found to be sugar-free, and the L2 (jelly) Korean melons showed significantly lower sugar content than other fruit jelly. However, the total fiber content was found to be extremely low. The L1–L3 watermelons provided 46.50–79.08 kcal of energy, 11.75–20.51 g of carbohydrates, 7.59–16.91 g of total sugars, 0.22–1.47 g of dietary fiber, 0.87–1.19 g of protein, and 0.06–0.08 g of fat. While the fat and total sugar contents were found to be relatively low, watermelon was deficient in vitamin C compared to other fruits.

DISCUSSION

The purpose of this study was to produce and evaluate fruit-cooking methods based on senior-friendly food standards in order to increase fruit intake by older adults with masticatory dysfunction.

Five fruits that are commonly consumed by older adults and frequently served in older adult care facilities were selected. The fruits varied in hardness and viscosity due to their characteristics and shape. For L1, all fruits, except for the sweet persimmon, could be consumed raw. However, for L2 and L3, the fruits had to be cooked into fruit jelly and puree.

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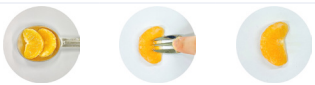
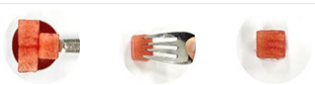
Table 6. IDDSI food testing methods according to the mastication stage of the elderly

Commodity[1)]	Cooking method	Picture	KS stage	UDF stage	IDDSI		Expression of texture[2)]	Description
					Level	Test		
Apple	Cut into 1 mm		1	1	7 (EC)	Fork Pressure test		It doesn't break off completely with a fork, leaving only a pressure mark
	Jelly		2	2	6 (SB)	Fork Pressure test		It can be pressed gently with a fork and leaves a mark.
	Puree		3	4	4 (PU)	Spoon Tilt test;		It falls in the form of a lump and flows, and the form remains.
Sweet persimmon	Jelly		1	1	6 (SB)	Fork Pressure test		It can be pressed with a little force and leaves a mark.
	Jelly		2	2	6 (SB)	Fork Pressure test		It can be pressed gently with a fork and leaves a mark.
	Puree		3	4	4 (PU)	Spoon Tilt test;		It falls heavily in the form of lumps, and after flowing, the shape remains clear.
Mandarin	Cut into		1	1	7 (EC)	Fork Pressure test		It can be pressed with a little force, leaving a mark and not cutting completely.
	Jelly		2	2	6 (SB)	Fork Pressure test		It can be pressed gently with a fork and leaves a mark.
	Puree		3	4	3 (MO)	Spoon Tilt test;		It is slightly viscous and remains in shape after flowing.
Korean melon	Cut into 1 mm		1	1	7 (EC)	Fork Pressure test		It doesn't break off completely with a fork, leaving only a pressure mark
	Jelly		2	2	6 (SB)	Fork Pressure test		It can be pressed gently with a fork and leaves a mark.
	Puree		3	4	3 (LQ)	Spoon Tilt test;		It falls in the form of a lump and flows, and the form remains.
Watermelon	20 mm cubed		1	1	7 (EC)	Fork Pressure test		It can be pressed with a little force and leaves a mark.
	Jelly		2	2	6 (SB)	Fork Pressure test		It can be pressed gently with a fork and leaves a mark.
	Puree		3	4	3 (MO)	Spoon Tilt test;		It has a slightly viscous and slowly flowing consistency.

KS, Korean Industrial Standards, 2020 (KS H 4897); UDF, Japan Care Food Conference, 2020, Universal Design Foods; IDDSI, International Dysphagia Diet Standardization Initiative, 2019; EC, easy to chew (Level 7); SB: soft & bite-sized (Level 6); PU: pureed (Level 4); MO, moderately thick (Level 3); LQ: liquidized (Level 3).
[1)]Top 5 most frequently consumed fruits by the elderly over 65 yrs of age (n = 4,498) according to the results of the Korean National Health and Nutrition Examination Survey ('16–'18).
[2)]Texture expression using IDDSI food testing methods (Fork Pressure test, Spoon Tilt test and Fork Drip test).

The agar, added as a gelling agent in the jelly, was mixed with the jelly's reticular structure to ensure even distribution in the mouth. The puree formulation of apples, sweet persimmons, and Korean melons, depending on their characteristics, does not have the crumbly texture of agar jelly. Instead, it gently mixes with saliva in the mouth to form a proper bolus. Apples,

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sweet persimmons, and Korean melons with firm textures met the viscosity standards in their crushed form, but mandarins and watermelons did not until viscosity enhancers were added.

This study proposed a straightforward test method for older adults to check food properties using a fork and spoon. The IDDSI test method differs from the KS and UDF methods in that it allows for the visual measurement of both the hardness and viscosity of foods. Although internationally recognized standards should be prioritized, the IDDSI framework is highly fragmented with 8 levels and thus may have limited practical use. Therefore, we compared the levels of fruits according to the KS criteria with the IDDSI levels and found that the characteristics of each stage of the IDDSI framework were relatively well aligned. These results are expected to assist professionals in the field, such as nutritionists and chefs, in implementing the fruit recipes presented in this study more efficiently.

The amount of fruit per serving was determined using the KDA's nutrient intake standards and one exchange unit of the fruit group. According to the 2020 Korea National Health Statistics [2], older men consumed 159.7 g of fruit per day in 2010, 188.9 g in 2015, and 162.5 g in 2020, whereas older women consumed 168.9, 191.3, and 167.1 g, respectively. The serving sizes for fruits in this study were 100–150 g for fresh fruit and puree and 120 g for fruit jelly, based on the KDRIs [22]. For people aged 65 yrs and older, one to 2 servings of fruit per day are recommended, with a caloric value of 50 kcal per serving [22]. The energy value per portion of fruit, depending on the mastication level, ranged from 40.50 to 106.01 kcal, which was in line with the recommended intake. However, the calorific value of fruit jelly ranged from 74.77 to 106.01 kcal per serving, which is higher than the recommended calorific value, and it is suggested that it be consumed once or twice a day as a snack to supplement the calorie deficit of older adults. According to IDDSI guidelines [30], the food pieces corresponding to L6 or L7 foods for adults should be no larger than the size of a thumbnail (1.5 cm × 1.5 cm). Purees do not have a set size recommendation, but it is suggested that they should be no more than 10–15 mL per cutlery, considering typical serving sizes and swallowing comfort.

There are some limitations in this study. Firstly, the 1 mm slices of fruits (apple and Korean melon) that meet the L1 requirements are thin, so there were difficulties such as time-consuming cooking and browning (only apple). Secondly, fruit jelly has the inconvenience of having to be constantly stirred during the heating process to prevent it from sticking or hardening. It also contains added sugar, so older adults on a diet should consult their doctor before consuming it. Furthermore, although the fruit jelly developed in this study was made with agar, the agar was added at a low percentage, resulting in a texture that is softer than the typical agar jelly texture or slightly firmer than puree. However, the use of agar as a gelling agent can cause it to crumble and disperse in the mouth, posing a risk of inhalation. Therefore, older adults on strict diets should still consult a doctor. Thirdly, some fruit purees require the use of commercially available viscosity enhancers, which are expensive and have different characteristics depending on the manufacturer and product characteristics, such as increased viscosity over time [34, 35]. Therefore, careful selection of viscosity enhancers during cooking, and guidance and education for older adults and their caregivers on the physical characteristics of the food served is needed to maintain the nutritional content of the fruit and reduce the risk of aspiration. Fourth, the physical property (hardness, viscosity) criteria for L3 foods (able to be crushed with the tongue or swallowed as is) in the Korean Standard for Industrialization of Senior-friendly Foods (KS H 4897) used in this study are not a more detailed classification system (L3: able to be crushed with the tongue, L4: no chewing

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required) than the Japanese UDF [5]. Therefore, a detailed classification system should be prepared so that the elderly can choose foods according to the condition of their teeth, oral cavity, and jaw joints. Additionally, more in-depth food development research that considers dysphagia other than chewing difficulties is also needed.

Nevertheless, this study is thought to be meaningful in that it provides appropriate guidelines for adjusting the hardness and viscosity of fruits in the elderly with the mastication difficulties of using the Korean Standard for Industrialization of Senior-Friendly Foods (KS H 4897).

Furthermore, the development of food for the elderly with chewing difficulties is considered a necessary field of research to improve the quality of life and provide balanced nutrition. The results of this study are expected to serve as a guideline for providing fruit according to the chewing stage at homes and nursing facilities that care for the elderly with chewing difficulties. It is expected that it can be used as basic data for the development of various foods for the elderly with chewing difficulties in the future.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Nutritional components of fruits by the mastication stage of the elderly

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