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Development and Characterisation of Fortified Yogurt with the Addition of Carrot Peel and Celery Peel as By-Products from the Vegetable Industry

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Abstract

Developing products that meet consumer expectations can be a challenge for researchers. Yogurt is a palpable dairy product because it is versatile and can be eaten as a dessert and snack. The present work aims to develop a yogurt with the addition of carrot peel and celery peel to satisfy the current market requirements by reintegrating some vegetable by-products in the technological process of making yogurt but also to replace protein additives, which have the role of improving the rheological characteristics and sensory properties of yogurt. In this sense, a comparative analysis was made between yogurt with addition, classic yogurt, and yogurt with powdered milk. A non-numerical multi-criteria multi-personal agreement method described by Fadhil and collaborators was used to perform the sensory analysis (Fadhil et al., 2021). Physicochemical analysis of the samples was performed during a storage period of 18 days on the first day, the ninth day and the eighteenth day. The pH, titratable acidity, syneresis, water holding capacity and lactose content of the samples were measured. The results indicate an improvement in the degree of syneresis and the water retention capacity, especially in the second part of the storage time, of the yogurt with the addition of celery and carrot peels, compared to the other two samples. The evaluated sensory characteristics obtained better scores because the carrot and celery peels brought a unique flavor to the product.

Keywords: Circular economy; By-products recovery; Carrot peel; Celery peel; Fortified yogurt

1 Introduction

Food production involves a complex chain that inevitably results in many by-products and waste that cause environmental problems through the need to remove them.
Studies show that one-third of annual global food production is lost as food loss and waste (FLW), generating the equivalent of approximately 3.6 gigatons of CO_2 (FAO, 2019).

The awareness of the environmental problems caused by the excessive production of food and food waste leads research towards the search for environmentally friendly solutions that reduce food losses as much as possible. Where this is not possible, the solution is to reintroduce the residues into other technological flows to solve specific shortages for industry (e.g., food additives).
The circular food economy prevents food loss and

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waste, improves food safety, food security and biodiversity conservation, manages perishability, and uses regenerative agriculture by reusing, recycling, recovering and reprocessing edible food and inedible parts in circular loops and alliances (Lugo et al., 2022). Yogurt is an acidic dairy product usually made from milk and lactic cultures. It is a fermented dairy product obtained by fermentation of lactose under the action of two microorganisms, *Lactobacillus delbrueckii* sp. *Bulgaricus and Streptococcus thermophilus* (Sumarmono et al., 2015). The addition of other ingredients in yogurt production is due mainly to the need to prevent defects, such as eliminating whey, and to diversify the product's assortment range.

To improve the texture of yogurt, milk powder, skimmed milk powder, milk proteins and hydrocolloids are added (Tamime & Robinson, 2007). Also, many fruit and vegetable preparations or fruit and vegetable by-products can be used as ingredients to enhance the physicochemical and sensory characteristics of the product or to give the product the status of a functional food.

Adding powdered milk to yogurt production can significantly improve yogurt's nutritional quality and textural and sensory characteristics. The fermentation process of concentrated Greek-style yogurt was affected by the addition of skim milk powder and dairy cream, resulting in a high protein content (6.38–6.61%) and low-fat content (1.37–1.38%) compared to the control sample (5.96% protein content and 1.59% fat content) and also improving the sensory attributes (Cândido De Souza et al., 2021).

Different by-products can be used to fortify yogurts. For example, for health promotion, wheat bran is used as a source of fiber in yogurts, grape extract and grape skin flour are good sources of polyphenols in yogurts, and grape seeds are a source of antioxidants (Chouchouli et al., 2013; Ersöz et al., 2011; Hashim et al., 2009; Karnopp et al., 2017; Marchiani et al., 2016; Sandoval-Castilla et al., 2004).

Extracts from many by-products of the agro-industry can be added to fortify yogurts. For example, chestnut shells, grapeseed and pomegranate peel can replace preservatives and functional ingredients (Ferreira & Santos, 2023). β-carotene from carrots encapsulated by the extrusion technique can be added as an active ingredient to fortified yogurt. The stability and microbiological profile of tested fortified yogurts did not change until the end of the examination period. Using carrot waste beads in yogurt provides bioactive potential and gives consumers a potential functional food product that can be introduced into the daily diet (Šeregelj et al., 2021).

Carrots and celery are products consumed all over the world. After their preparation, they can often be used to produce various food products (meals, soups, juices, salads). Preparing carrots and celery involves washing and peeling a thin layer from their surface, resulting in waste and by-products. These peels can be processed and reused in food production due to their composition.

Carrot (*Daucus carota*) is a good source of nutrients like carbohydrates, minerals and vitamin A (Sharma et al., 2012).

Carrot waste contain dietary fiber (cellulose, hemicellulose, lignin and pectin) and carotenoids, especially β-carotene (Sharma & Kumar, 2017). Carrot peel has a higher level of β-carotene (204.5 μg/g) as compared to carrot pomace (19.81 μg/g) and carrot pulp waste (39.2 μg/g) (Hiranvarachat & Devahastin, 2014).

Celery (*Apium graveolens* L.) is a vegetable used in the food, medical, cosmetic and chemical industries. It has a lot of fiber, carotene, vitamin A, minerals, amino acids and phenolic compounds. It also has antioxidant activity (Kooti & Daraei, 2017).

This research aims to develop an acid dairy product fortified with vegetable by-products (carrot peel and celery peel) to improve the physicochemical and sensory characteristics and prevent the appearance of technological defects (removal of whey).

2 Materials and Methods

2.1 Materials

Preparation of carrot peel and celery peel samples

Carrots and celery were washed and peeled using a vegetable and fruit peeler. The peels removed

Table 1: Yogurt Sample Description

Sample code	Sample description				
	Cow milk	Starter culture	Powdered milk	Carrot peel	Celery peel
YCS	100%	0.2 %	-	-	-
YPM	98%	0.2 %	2%	-	-
YCCP	98%	0.2 %	-	1%	1%
YCCPH	99%	0.2%	-	0.5%	0.5%

were dried at 50 ^{o}C for 36 hours. These were ground using a coffee grinder to get the finest grain size and sieved on a <600 μm mesh screen (Frumento et al., 2013). The powders thus prepared were used in the manufacture of yogurts.

Preparation of yogurt samples

The samples were prepared in the laboratory by the following steps and using the ingredients shown in Table 1

- milk pasteurization was done at 90-95 ^{o}C for 20 minutes
- the samples were cooled to 42 ^{o}C and inoculated with 0.2% (w/v) yogurt starter culture
- the other ingredients were added according to Table 1
- the yogurt was packed in 250 ml jars
- the jars were placed in a thermostatically controlled system at 42-45 ^{o}C for 4 hours
- the samples were precooled at 20 ^{o}C for 3 hours
- the samples were cooled at 2-4 ^{o}C until the next day when they were analyzed

2.2 Methods

Sensory analyses

The samples were analysed from a sensory point of view on the first day of storage, the 9th day, and the 18th day by a team of 5 amateur tasters and yogurt consumers.
A non-numerical multi-criteria multi-personal agreement method described by Fadhil and collaborators was used to perform the sensory analysis (Fadhil et al., 2021).
The observed characteristics were consistency, colour, stickiness, taste and odour. Table 2 shows the linguistic scale used to evaluate the yogurt, and Table 3 shows the criteria of importance level based on the scale.
Formula 1 was used to calculate the negation of the importance level of the criteria.

Table 2: Linguistic assessment scale

Scale	**Description**	**Abbreviation**
1	Like very much	LV
2	Like moderately	LM
3	Like Slightly	LS
4	I neither like nor dislike	NT
5	Dislike slightly	DS
6	Dislike moderately	DM
7	Dislike very much	DV

Table 3: Criteria importance level

Scale	**Description**	**Abbreviation**
1	Very high	LV
2	High	LM
3	I neither like nor dislike	NT
4	Low	DM
5	Very low	DV

$$Neg(W_k) = (W_{q-k+1}) \quad (1)$$

Where:
Neg (W_k) – score negation of criteria k;
k – index;
q – scale amount.

The process of aggregation on the criteria relied on formula 2:

$$V_{ij} = min[Neg(W_{ak}) \vee V_{ij}(a_k)] \quad (2)$$

Where:
V_{ij} – the score of alternative i by person j;
V_{ij} (a_k) – the score of alternative i by person j on criteria k;
k – 1, 2, …., m.

The score was determined using formula 3:

$$Q_k = Int[1 + (k \times (q-1)/r)] \quad (3)$$

Where:
Q_k – the score k;
Int – integer;
R – the number of assessors.

The aggregation process for a person (assessor) used formula 4:

$$V_i = f(V_i)max[Q_j \wedge b_j] \quad (4)$$

Where:
V_i – the total value for alternative i;
Q_j – score j;
J – 1, 2, …, m;
b_j – order from the biggest alternative score i from alternative score j.

Physicochemical analyses

pH

The ORION 2 STAR digital pH meter was used to determine the samples' pH during storage. (Thermo Scientific)

Titratable acidity

The Thorner method was used to analyse the titratable acidity of the samples. For that, 10 g of yogurt were mixed with 20 mL of warm distilled water and then titrated with 0.1 N sodium hydroxide in the presence of phenolphthalein until the color turned pale pink, which persisted for 30 seconds (Horwitz, 2005). The acidity is measured in degrees Thorner and is calculated by formula 5:

$$Acidity^oT = (V \times 10)/m \quad (5)$$

Where:
V = volume of 0.1 N sodium hydroxide solution, used for titration, in ml;
10 = volume of sample taken in progress;
m = mass of the analysed sample, in g.

Lactose content

After deproteinizing the sample, the filtrate was polarized and the percentage of lactose present in the analysed sample was calculated from the measured rotation according to formula 6 (Tita, 2002)

$$Lactose\% = \frac{\alpha \times 100}{[\alpha]_n^{20} \times 2} \quad (6)$$

Where :
a= the angle read at the polarimeter
$\alpha\ {}_n^{20}$= lactose specific rotation equal to +52.53
2= wavelength of the polarimetric tube, dm

Syneresis

100 ml of each sample was placed on a funnel lined with a number 1 filter paper to measure the volume of drained whey in 6 hours. Formula 7 was used to calculate the sensitivity to syneresis of the yogurt samples (Barkallah et al., 2017):

$$Syneresis, \% = V_1/V_2 \times 100 \quad (7)$$

Where:
V1 = volume of whey collected after draining;
V2 = volume of the yogurt sample;

Water holding capacity (WHC)

5 g of yogurt was weighed into a test tube (Mi) and centrifuged at 4500 x g for 30 minutes at 10 ^oC. The resulting supernatant was removed, and the ejected precipitate was collected and weighed (Pt) (Barkallah et al., 2017) WHC was calculated using formula 8:

$$WHC(\%) = (1 - W_1/W_2) \times 100 \quad (8)$$

Where:
W_1 = weight of whey after centrifugation;
W_2 = yogurt weight;

3 Results and Discussion

3.1 Sensory analyses

The first step was to calculate the negation of the importance of the levels using formula 1. The results of the calculation of the denial of the criteria are presented in Table 4.
All the sensory assessments for each person are tabulated in Table 5.

Criteria of aggregation

The aggregation criteria for each alternative were calculated using formula 2. The approval criteria for each alternative on each day of storage are shown in Table 6.

Person aggregation

The value weights were calculated using formula 3. The following results were obtained: Q1=DM, Q2=NT, Q3=LM, Q4=LV, Q5=LV.
Formula 4 was used to calculate the person aggregation for each alternative. The results are shown in Table 7.
The classic yogurt (control sample) obtained "Like slightly" throughout the storage period.
Yogurt with added milk powder achieved "Like moderately" throughout storage. Similar results were obtained for the samples in which carrot peel and celery peel were added. From this, it follows that yogurts with vegetable by-products are comparable to yogurt with powdered milk, especially in terms of consistency and viscosity.
Although carrot peel and celery peel change the taste of yogurt, this does not negatively influence the tasters' perception of the product.
However, the consumption of these types of products that use food by-products to capitalize and bring sustainable technological benefits to the finished product may have some limitations. The consumer's acceptability of these products is closely related to the knowledge they have about the circular economy, food safety and food production. Less well-known processes such as extraction, isolation or ultrafiltration can lead consumers to high levels of neophobia towards food technology, as consumers increasingly demand less processed and more natural products (Coderoni & Perito, 2020; Sousa et al., 2021).

3.2 Phisicochemical analyses

pH

As shown in Figure 1, during the fermentation process, the pH decreases and continues to decline slightly throughout the storage period due to the slow continuation of the fermentation process. The highest values for pH were obtained for the control sample.

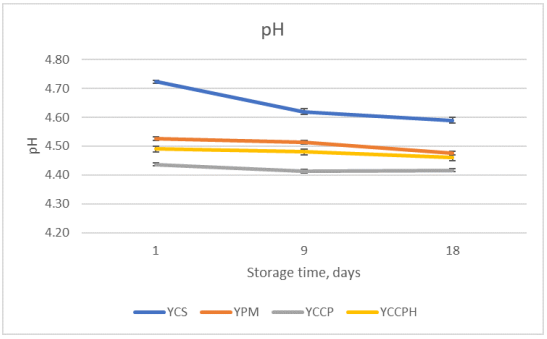

Figure 1: Evolution of pH during the storage time

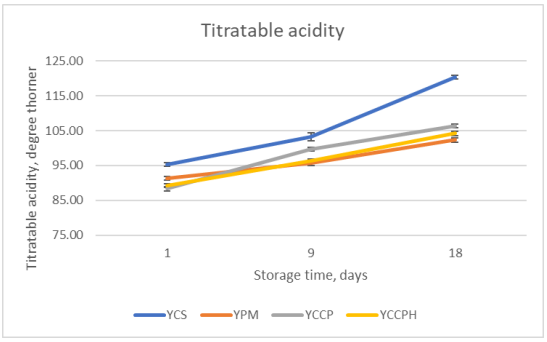

Figure 2: Evolution of titratable acidity during the storage time

Table 4: Negating the importance level of the criteria

The importance level of the criteria		**Negating the importance level of the criteria**	
Criterion 1 =	Very high	**Criterion 1 =**	Very low
Criterion 2 =	High	**Criterion 2 =**	Low
Criterion 3 =	I neither like nor dislike	**Criterion 3 =**	I neither like nor dislike
Criterion 4 =	Low	**Criterion 4 =**	High
Criterion 5 =	Very low	**Criterion 5 =**	Very high

Table 5: The sensory assessment for each person

Persons	**Alternative**	**Evaluation criteria**														
		Consistency uniformity			**Viscosity**			**Colour**			**Taste**			**Odour**		
		Day 1	Day 9	Day 18	Day 1	Day 9	Day 18	Day 1	Day 9	Day 18	Day 1	Day 9	Day 18	Day 1	Day 9	Day 18
P1	A1	LS	LS	LS	LS	LM	LS	LM	LM	LM	LV	LM	LM	LV	LV	LV
	A2	LM	LM	LV	LM	LV	LV	LM	LM	LV	LS	LM	LM	LV	LM	LV
	A3	LM	LV	LV	LM	LV	LV	LV	LV	LV	LM	LV	LM	LM	LV	LV
	A4	LM	LV	LV	LV	LM	LV	LM	LV	LV	LM	LM	LV	LV	LV	LV
P2	A1	LS	LS	LS	LS	LM	LM	NT	LS	LM	NT	LS	LM	LV	LV	LV
	A2	LM	LM	LM	LM	LM	LV	LM	LM	LV	LS	LS	LS	LV	LM	LV
	A3	LM	LV	LV	LM	LV	LV	LV	LV	LV	NT	LV	LM	NT	LV	LV
	A4	LM	LV	LV	LM	LV	LV	LV	LV	LV	LM	LV	LV	LM	LV	LV
P3	A1	LS	LS	LS	LS	LM	LS	LM	LM	LM	LS	LM	LM	LV	LM	LV
	A2	LM	LM	LV	LM	LV	LV	LM	LM	LV	LS	NT	LM	LV	LM	LV
	A3	LM	LV	LV	LM	LV	LV	LV	LM	LV	LM	LS	LM	LM	LV	LV
	A4	LV	LV	LV	LV	LV	LV	LV	LV	LM	LM	LV	LV	LM	LV	LV
P4	A1	LS	LS	LS	LS	LS	LS	LM	LM	LM	LV	LM	LM	LV	LM	LV
	A2	LM	LM	LV	LM	LV	LV	LS	LM	LM	NT	NT	LS	LV	LV	LV
	A3	LM	LV	LV	LM	LM	LV	LV	LM	LV	LM	LM	LV	LM	LV	LV
	A4	LV	LM	LV	LM	LV	LV	LV	LV	LM	LM	LV	LV	LM	LV	LV
P5	A1	LS	LS	LS	LS	LS	LS	LM	LM	LM	LV	LM	LV	LV	LV	LV
	A2	LM	LV	LV	LM	LV	LV	LM	LM	LV	LS	LS	LM	LV	LV	LV
	A3	LM	LV	LV	LM	LV	LV	LV	LM	LV	LM	LM	LV	LM	LM	LV
	A4	LV	LV	LV	LM	LV	LV	LV	LM	LV	LM	LV	LM	LV	LV	LV

Where:
A1 – classic yogurt
A2 – yogurt with the addition of powdered milk
A3 – yogurt with addition of 1% carrot peel powder and 1% celery peel powder
A4= yogurt with addition of 0.5% carrot peel powder and 0.5% celery powder
P1...5 = persons

Table 6: The approval criteria for each alternative

Day of storage	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Day 1	LS, NT, LS, LS, LS	LM, LM, LM, LS, LM	LM, LM, LM, LM, LM	LM, LM, LM, LM, LM
Day 9	LS, LS, LS, LS, LS	LS, LM, LM, LM, LM	LV, LV, LM, LM, LM	LM, LV, LV, LM, LM
Day 18	LS, LS, LS, LS, LS	LM, LS, LM, LM, LM	LM, LM, LM, LV, LV	LV, LV, LM, LM, LM

Table 7: The person aggregation for each alternative

The outcome of the person aggregation for the alternatives				
Day of storage	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**
Day 1	LS (Like slightly)	LM (Like moderately)	LM (Like moderately)	LM (Like moderately)
Day 9	LS (Like slightly)	LM (Like moderately)	LM (Like moderately)	LM (Like moderately)
Day 18	LS (Like slightly)	LM (Like moderately)	LM (Like moderately)	LM (Like moderately)

Titratable acidity

The titratable acidity of the samples increases during the storage period. This is due to the slow action of lactic acid bacteria on lactose that continues during the storage period (continuation of the process of lactose decomposition into lactic acid).
The lowest value was obtained for the sample with carrot peel powder and celery peel powder on the first day of storage.
The lowest values for the control sample were obtained on days 9 and 18. During this period, the sample fortified with the addition received median values compared to the other samples.

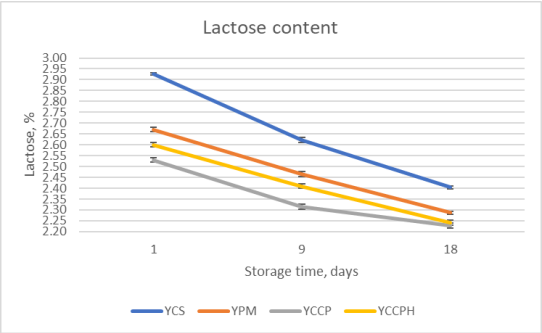

Figure 3: Evolution of lactose content during the storage time

Lactose content

As shown in Figure 3, the lactose content continues to decrease during the storage period due to the slow continuation of fermentation under the action of the yogurt bacteria. The YCCP sample recorded the lowest values, followed by YCCPH and YPM. The control sample obtained the highest values.
A decrease in pH and lactose and an increase in acidity are normal phenomena in sour dairy products due to the action of microorganisms on lactose leading to the accumulation of lactic acid. Similar results were also observed by other authors in dairy products with added apple pomace at 1, 2 or 3% in the manufacture of set-type yogurt (Wang et al., 2020). This also happened in the yogurts produced with the addition of lyophilized red grape pomace and raised with forced air (1, 3 or 5%), where increasing the percentage of pomace did not greatly affect the pH and acidity values but higher values were observed for samples produced with forced air-dried pomace compared to lyophilized pomace. The highest acidity value at the end of the storage period was observed for the control sample (plain yogurt) (Demirkol & Tarakci, 2018).

Syneresis

The stability of the curd is one of the leading quality parameters of set yogurts, which should be monitored during storage (Srisuvor et al., 2013).
As shown in Figure 4, the highest values for syneresis were obtained for the control sample. It is known that milk powder has good effects on yogurts' resistance to syneresis.
The carrot and celery peel powder sample obtained slightly lower results than the yogurt with added milk powder. This is due to the increase in dry substance content, which benefits the yogurt's resistance to syneresis.
During the storage period, the syneresis of the samples increased slightly which may be due to the ability of the samples to retain water.
Raising the dry matter content of yogurt samples can have a beneficial effect on whey removal (Mahdian & Tehrani, 2007).
Similar results were obtained by other authors. A study looking at the effect of pumpkin peel powder added to yogurt reported that yogurt syneresis was reduced by the addition of pumpkin powder compared to the control, and yogurt syneresis increased over the 14-day storage period (Gavril et al., 2024).
Other authors have observed that the addition of apple pomace powder to yogurt leads to a reduction in syneresis, and 3% powder added to yogurt can reduce syneresis by half compared to yogurt without addition (Wang et al., 2020).
Demirkol and Tarakci (2018) reported that yogurt produced with freeze-dried grape pomace and dried grape pomace using forced air drying (1, 3 or 5%) showed a decrease in synergism over the 21-day storage period. This was less for

samples with 3% and 5% dry pomace that obtained approximately constant values for syneresis. This could be because dry powders have a lower water-holding capacity than lyophilized powders (Demirkol & Tarakci, 2018).

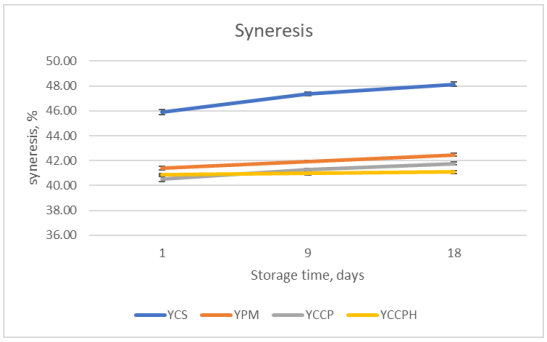

Figure 4: Evolution of syneresis during the storage time

Also, an improvement in WHC was seen in yogurts with added pumpkin seed flour where the water holding capacity was reduced by 13.7% compared to the control sample, without addition (2018).

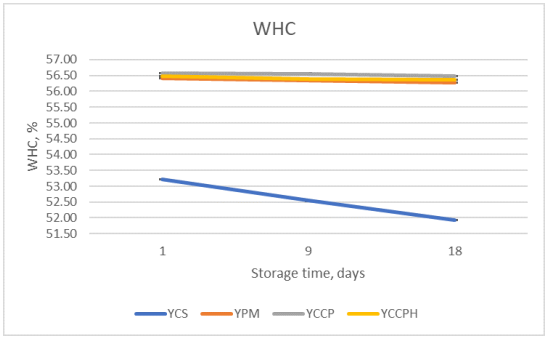

Figure 5: Evolution of WHC during the storage time

Water holding capacity

Water holding capacity means the ability of yogurt to retain its whey, which directly affects the product's acceptability and shelf life and is a vital physical property of yogurt (Almusallam et al., 2021; Balpetek Külcü et al., 2021).
A significant difference between the samples with addition and the control sample regarding WHC is shown in Figure 5. The water holding capacity is improved by adding powdered milk or carrot peel powder (0.5% & 1%) and celery peel powder (0.5% & 1%), with the results being almost similar for all 3 samples.
During the storage period, the WHC increased significantly for the control sample, which may be related to decreased entrapment of solids in the protein matrix and the reduction of the stability of the yogurt matrix due to the rearrangement of the gel network (Bakry et al., 2019).
Other authors obtained an improvement in WHC for yogurts with 1% grape pomace and 1% flaxseed oil, encapsulated and in free form. They observed higher results during the storage period in yogurts with grape pomace and flaxseed oil in free form due to the presence of dietary fibers (Saberi et al., 2023).

4 Conclusions

Yogurts with the addition of 1% carrot peel and 1% celery peel, and 0.5% carrot peel and 0.5% celery peel, were as well accepted as yogurts with the addition of powdered milk and compared better to classic yogurt in terms of the evaluated sensory attributes (consistency uniformity, viscosity, colour, taste and odour).
Adding carrot peel and celery peel to manufacture yogurts can improve the consistency and viscosity of yogurts. Whilst these by-products change the taste, colour and odour of yogurt, the tasters accepted the yogurts with added by-products and the yogurt with added powdered milk. All three yogurts with additions obtained lower values for pH and acidity during the storage period compared to the control sample.
Carrot peel and celery peel powders improve the resistance to syneresis and the water holding capacity of yogurts. The results obtained are comparable to those for yogurt with added powdered milk.

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