Consumer properties of biodegradable edible cups for hot drinks

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Abstract

Introduction. Determining the biodegradable edible cup consumer properties will allow finding an ecological alternative to disposable cups for hot drinks.

Materials and methods. Butter cookies were made in the shape of a cup, followed by the application of a waterproof layer, the basis of which was pectin or polyvinyl alcohol. A 10-point scale for evaluating cups by individual indicators was developed, and the Harrington`s function was used.

Results and discussion. Biodegradable edible cups in terms of organoleptic, ergonomic and geometric parameters fully correspond to disposable cups that are currently used. Due to the thicker walls and the material (biscuits) properties, the edible cup allows you to hold a cup with a hot drink in your hands without an additional layer. The absence of an additional layer is important from an economic and environmental point of view. The edible cup could keep the drink inside from 20 minutes to 1 hour. The cup appearance did not change under the influence of drinks at different temperatures: 10–15 °C (Glaze, Frappe, Cold Americano, Ice Cream), warm, 60–65 °C (Latte, Cappuccino, Mochaccino, Macchiato, Flat White, Raff) and hot, 85–90 °C (Americano, Espresso and their varieties). The biodegradable edible cup is resistant to acetic acid and ethyl alcohol that is important because some types of coffee-based drinks require the addition of alcoholic beverages, in particular, Irish coffee, Farisei, Karsk, Coffee punch. The cups can be used for a wide drinks range with a temperature from 10 to 90 °C. It has excellent ergonomic performance and is environmentally friendly, as it can be decomposed like any other confectionery product.

Conclusions. The biodegradable edible cup has excellent ergonomic indicators, is environmentally friendly because it can be easily decomposed like any other confectionery.

Introduction

The problem of the accumulation of plastic materials in the environment requires society to reconsider its habits, including the refusal of using polymer disposable cups when consuming hot drinks. A possible solution for utilization of disposable non-biodegradable coffee cups could be replacement them with (a) reusable cups; (b) biodegradable non-edible cups and (c) biodegradable edible cups. Reusable cups are the most optimal way, but the least convenient in practice, since in this case you need to carry the cup with you, have enough space for it in your bag, protect the cup from breakage, and follow sanitary rules (Allison et al., 2021). To follow this way, Starbucks, the largest coffeehouse chain in the world, offers a discount to consumers, who bring a reusable coffee cup (Ziada, 2009). Some coffee shops propose discount for use the ceramic mugs available in store instead of using paper cups (Jung et al., 2011). Additional motivating factors include environmental commitments, financial support, corporate initiatives, customer demand, and public pressure (Ma, 2014).

There is a worldwide increase in coffee consumption in disposable cups-to-go. For example, about 3 billion disposable coffee to-go-cups are used each year in Germany (Loschelder et al., 2019). However, encouraging café customers to become part of the 'choose a reusable mug' movement in a 14-week intervention trial in which 23,946 hot drinks were sold resulted in a reduction in the use of disposable cups and an increase in the use of reusable cups by 17.3% (Loschelder et al., 2019)

Different approaches to the classification of disposable cups such as by purpose, by the number of uses, by the presence of a barrier coating, and by the type of main raw material for cup making were proposed (Bidiuk et al., 2020). Paper cups are coated with a thin layer of plastic, usually petro-plastic, to prevent liquid to intrude into the cup. Particularly petro-plastic cups are frequently associated with an unnecessary use of limited resources and superfluous production of waste (Van der Harst et al., 2013). However, polyethylene can be replaced with a biodegradable material, for example, natural polymers (Mahinpei, 2020). Waste paper cups can be pyrolyzed at temperatures ranging from 325 to 425°C to produce commercial fuel (Biswal et al., 2013) or used for production of the bio-eco-based cellulose nanomaterials by citric acid hydrolysis (Nagarajan et al., 2020).

Another type of disposable cups are foam cups, which are cheaper compared to paper ones. However, Styrofoam cups are also not biodegradable and should be landfill or incinerated (Jung et al., 2011).

Sazeli et al. (2021) proposed to make disposable tableware and cutlery from organic material such as corn and barley to develop fully biodegradable tableware.

Kaya et al. (2016) proposed the production of chitin and chitosan cups from the abdominal exoskeleton of the insect *Pimelia sp.* as an alternative to synthetic materials in the food industry. Both chitin and chitosan cups exhibited antimicrobial activity against two common food pathogens *Candida albicans* and *Listeria monocytogenes.* Liu et al. (2020) developed an all-natural biodegradable, hygienic, water- and oil-resistant, mechanically strong, and low-cost tableware using environmentally friendly sugarcane fiber and bamboo fiber using a scalable molding method cellulose. Choeybundit et al. (2022) propose the production of cutlery from soy protein isolate with the addition of 5-20 % crude fiber from morning glory stems. The production of these biodegradable cutlery involves hydraulic hot pressing at a temperature of 160 °C for 5 min. Production of environmentally friendly, biodegradable plates made of areca leaves were proposed (Nayak et al., 2021). The technology of a new disposable cups type made from bioplastics based on spent coffee grounds and using natural binding food components has been developed (Bidiuk et al., 2020).

Currently, there are already developments of alternatives to disposable cups that have been implemented into production. The Inferra Pack Company produces biodegradable tableware from various natural raw materials: sugar cane cake, corn starch, and coffee waste. Using the innovative secondary processing technology of cellulose, kraft tableware contains 30 % more recycled raw materials than ordinary paper tableware. The uniqueness of this ecological product is that the term of its complete disposal in the soil is about 180 days. The advantage of using environmentally friendly single-use bioplastic packaging is its computability. Manufacturers who are already engaged in the production of such disposable tableware most often position them as a confectionery product and offer coffee in such cookies in the shape of a cup/glass.

Although a straw is not a mandatory attribute for drinking coffee, many consumers prefer to drink it by this way. For example, only in Taiwan three billion non-degradable plastic straws are consumed annually (Cheng et al., 2022). Currently many countries are already planning to increase strict legislation of plastic straws.

The literature analysis showed that scientists all over the world are actively engaged in the replacing non-biodegradable tableware with biodegradable ones. Because currently quite a limited number of developments have been put into production, the development and research of edible cups is still relevant.

Therefore, the development of technology for ecological biodegradable disposable tableware for widespread use is currently an extremely important task to ensure sustainable development and environmental protection.

Materials and methods

Materials

Wheat flour (40–60%); native potato starch or native corn starch (10–25 %); white sugar (5–20 %); margarine (5–20%); leavening agents (0.5–2 %); drinking water (10–30 %) were used as raw materials for the biodegradable edible cup production.

Pectin (E440) or polyvinyl alcohol (E1203), and drinking water served as raw materials for making a waterproof layer.

Production of experimental cups

From the specified raw materials, dough for butter cookies having shape of cups was prepared. The shape of the cup could be changed according to the customer's requirements. The formed cup was baked, after which a waterproof layer was applied to the inner surface of the baked product by praying, glazing or brushing on the surface, and the cup was kept for 10±2 h until the waterproof coating is dry. The variants of the developed biodegradable cups is shown (Figure 1).

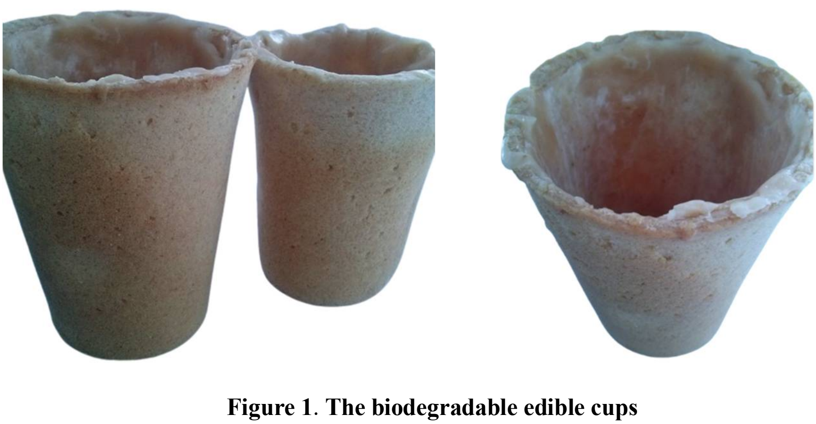


Figure 1. The biodegradable edible cups

Research methods

The properties of the developed biodegradable tableware were studied according to Bidiuk et al. (2020): *organoleptic* (color, appearance, physical condition, presence of smell) according to the technical specifications for the corresponding disposable cups; *the sound when struck with a wooden stick* was determined by hitting the edge of the cup, indirectly this method indicates the presence of voids inside the material); *defects* (heterogeneity of the surface, uneven and visible loose seam for a paper cup, color heterogeneity for an edible cup, indistinct pattern for paper and polymer tableware); *ease of use* was determined by the subjective perception of holding and consuming the drink; *actual capacity*, ml, distilled water was poured into the cup under study, after which it was poured into a measuring cylinder and the volume was determined; *height*, mm, was measured with a caliper; *the diameter in the upper part*, mm, was measured with a caliper; *the diameter in the lower part*, mm, was measured with a caliper; *wall thickness*, mm, was measured with a caliper; *the thickness of the bottom*, mm, was measured with a caliper; *mass fraction of moisture*, %, method of drying to constant mass; *short-term exposure to hot water*: for this, the tested product is immersed in distilled water with 85–90 °C, the water should not change color or a sediment should appear, the tableware were removed from the water, wiped dry and compared with a similar sample that was not immersed in water; *short-term exposure to an alcohol solution*: for this, the tested product is immersed in a 30 % solution of ethyl alcohol at 60–65 °C, the alcohol solution should not change color or a sediment should appear, the tableware were removed from the water, wiped dry and compared with a similar sample that did not was immersed in an alcohol solution; *short-term exposure to an acetic acid solution*: for this, the product under investigation is immersed in a 9% acetic acid solution at 85–90 °C, the acetic acid solution should not change color or a sediment should appear, the dishes were removed from the water, wiped dry and compared with a similar sample, which was not immersed in an acid solution; the method of *temperature influence* on disposable cups.

The waterproofness of the developed biodegradable cups was checked according to the method, which involves dense placement of filter paper on the outer surface. After that, a liquid (distilled water or a drink of the appropriate temperature) is poured into the cup. The duration of aging is determined by the usual drink consumption duration. The minimum acceptable duration is 40±5 min, which is due to the coffee consumption traditions. The spots appearance on the filter paper indicates cup water penetration. The waterproofing performance was tested empirically by placing a beverage in a designed cup and placing the cup in filter paper and visually observing the appearance of spots on the filter paper surface. The biodegradable edible cup does not pass liquid, because not a single plume appeared on the filter paper during the entire research duration. The research duration was determined by the keeping expediency the liquid inside the drink – the time until the drink is consumed. A hot drink is consumed on average within 20-30 min according to personal observations. If the drink is consumed in the consumer company, the duration may increase to 1 hour.

Processing of research results

The degree of expert opinions consistency regarding product quality indicators was assessed using the average determining sum ranks method and the squared sum ranks deviations from the average sum (Koretska et al., 2018).

The grades variance was calculated using the formula:

$$\sigma_j = 1/(n_j - 1) \cdot \sum_{i=1}^{n} (C_{ij} - N_j)^2 \ , \tag{1}$$

where $N_j = \sum_{i=1}^{n} C_{ij} / n_j$ – average value in points; $C_{i,j}$ – evaluation of the i expert in the j direction; $n_j = 5$

The grades variation coefficient in the j direction was calculated using the formula:

$$\gamma_j = \sqrt{\sigma_j / N_j} \cdot 100\% \tag{2}$$

Melnik et al. (2020) and Chen et al. (2012), which allows universalizing the general approach regarding the expediency of using and/or replacing paper and polymer disposable cups with biodegradable edible ones. One of E. K. Harrington's logistic functions was taken as a basis – the «desirability curve», which is the geometric mean of individual desirability functions:

$$D = \sqrt[q]{d_1 \cdot d_2 \cdot ... d_q} \tag{3}$$

where d_1, d_2...d_q – desired level (separate desirability function) of the 1-st, 2-nd, etc. optimization parameter (changes from 0 to 1); q – the parameters number.

Harington's scale

To construct a significance scale, was used a well-known table of ratings correspondence in empirical or numerical systems. Standard correspondences of the significance scale (Harington's scale) are given in Table 1.

Table 1

Harrington's scale desirability for individual assessments

Grade	Value intervals
Very good	0.80–1.00
Good	0.63–0.80
Satisfactory	0.37–0.63
Poor	0.20–0.37
Very bad	0.00–0.20

The values choice 0.63 and 0.37 is partially explained by the calculation convenience:

$$e \approx 2.7; \quad 0.37 \approx 1/e; \quad 0.63 \approx 1\text{-}1/e$$

For further research, the scale was presented in the form of a graph.

To determine the reliability of such a replacement, was proposed the restrictions introduction on the main quality indicators of experimental samples and the restrictions formation on the values of individual indicators (Kim et al., 2002; Marinković, 2021; Sharma et al., 2022). To do this, Harington's scale was transformed into a ten-point scale and superimposed it on the ordinate scale (Figure 2).

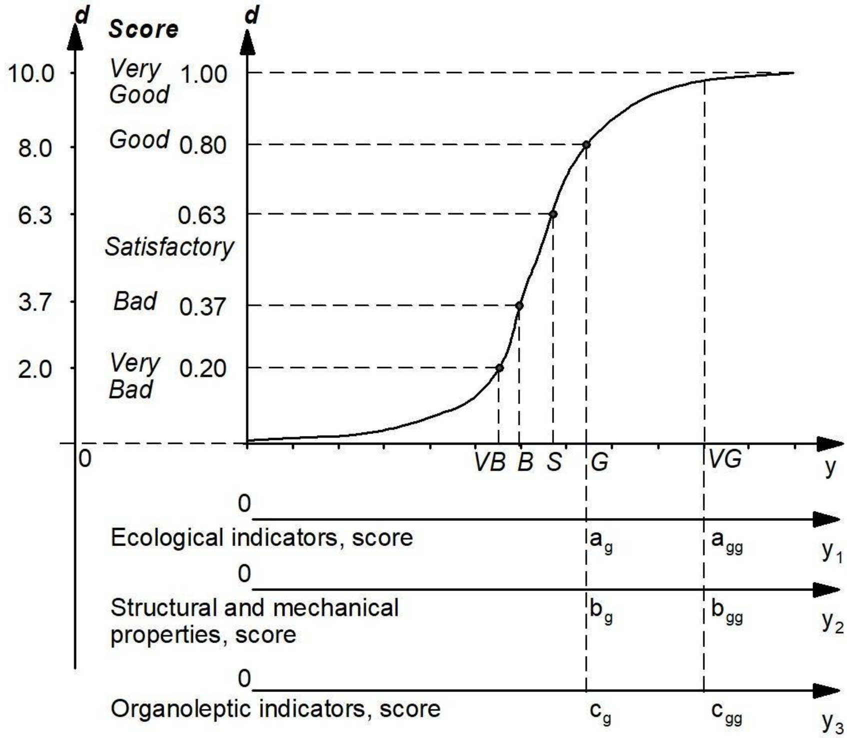


Figure 2. The quality indicators generalized analysis of the researched tableware for drinks samples

On this scale, five intervals were used in the general scale interval from 10 to 0: very good (VG), 10.0- 8.0; good (G), 8.0–6.3; satisfactory (S), 6.3–3.7; bad (B), 3.7–2.0; very bad (VB), 2.0–0.0. The Figure 2 shows the desired indicators limits, according to which the samples quality will be within the range of «good – very good». The estimate arrival at the point d_l will indicate the submission to the minimum value point of the given critical limit.

A 10-point scale to evaluate cups was developed. Groups of main indicators P_i were used for evaluation: 1, temperature of the cup surface with a drink; 2, environmental friendliness; 3, organoleptic indicators; 4, structural and mechanical properties and their descriptors (P_{ij}) (Table 2).

The obtained objective indicators were transformed into objective values by converting them into points.

The profilograms area (S) (quality criterion) is equal to the areas sum of the triangles formed by the corresponding rays of individual (partial) quality indicators:

$$S=\sum_{j=1}^{n}(\frac{1}{2}f_1 f_{j+1}\cdot\sin\frac{2\pi}{n})=\frac{1}{2}\sin\frac{2\pi}{n}\sum_{j=1}^{n}(f_1 f_{j+1}), f_{n+1}=f_1 \quad (4)$$

Instead of the function S, the function F was used, which differs from S only by a constant factor that does not affect the choice of the largest value. To choose the most successful option with the largest value of the complex criterion, it is enough to use the criterion definition formula:

$$F=f_1 f_2+f_2\cdot f_3+...+f_{n-1}f_n+f_n f_1 \quad (5)$$

Table 2
General scoring scale for evaluation the quality of polymer, paper and biodegradable cups taking into account the weighting factors of the main indicators

Indicators (notation)	Test method	Weighting factor	Evaluation, points		Assessment, points	
			min	max	min	max
The temperature of the cup surface with a drink (P_1)	objective	1.5	6	10	9	15
Environmental friendliness (P_2)	objective or organoleptic	2.5	6	10	15	25
Organoleptic properties (P_3)	organoleptic or objective	3.5	6	10	21	35
Sensation when touching the cup surface	organoleptic	4.0	6	10	24	40
Color (P_{32})	organoleptic or objective	2.0	6	10	12	20
Odor (P_{33})	organoleptic	1.0	6	10	6	10
Taste (P_{34})	organoleptic	1.0	6	10	18	30
Structural and mechanical properties (P_4)	organoleptic or objective	2.5	6	10	15	25
The structure (P_{41})	organoleptic	2.0	6	10	12	20
Deformation under the temperature influence 85-90 °C (P_{42})	organoleptic	5.0	6	10	30	50
Waterproof (P_{43})	objective	3.0	6	10	18	30
Product quality based on the sum of all indicators	calculated	10.0	24	40	60	100

Notes: The deformation index was determined for two temperatures, which are typical for cold and hot drinks. The temperature of 60-65 °C (Table 2) was not used, because if the cup does not deform at 85-90 °C, then at a lower temperature (60-65 °C) there will be no deformation.

In the case of a one-sided restriction on the optimization parameters, a separate desirability function d_i takes the known form (Fig. 2):

$$d_i = exp[-exp(-y_i')] \quad (6)$$

y_i' – some dimensionless quantity related to the optimization parameter y_i by a linear law:

$$y_i = b_0 + b_1 y_i \quad (7)$$

b_0, b_1 – coefficients that can be determined if two values of the optimization $F = f_1 f_2 + f_2 f_3 + f_{n-1} f_n + f_n f_1$ parameter y_i are given corresponding values of a separate desirability function.

The indicator average value was calculated for the series of each experiment:

$$Y = \frac{\sum_{n-1}^{n} Y_1}{n} \tag{8}$$

Y – the indicator average value; Y_I – the indicator value in each experiment; N – the parallel number experiments.

Next, was evaluated the variance of the arithmetic mean S^2 for each series of experiments:

$$S^2 = \frac{\sum_{n-1}^{n} (y_1 - \overline{y}_2)^2}{n-1} \tag{9}$$

The repeating experiments frequency was 3–5 times.

Results and discussion

Consumer properties of experimental samples

The disposable cup is represented by edible and non-edible samples. Biodegradable edible tableware should also have similar mechanical, ergonomic and operational indicators as non-edible tableware. The most daring idea is the complete replacement of paper, polymer (polystyrene and polypropylene) cups by edible tableware. Authors of this research have opinion that replacing non-edible tableware by edible ones is not an equivalent replacement, therefore, non-edible tableware should be replaced with biodegradable ones, in particular, the polyethylene layer in paper cups should be replaced with ecological ones, and polypropylene and polystyrene should be replaced with natural polymers. An edible cup also serves as a snack and a sweet for a drink.

Quality indicators are determined by the technical specifications of the market operator. Characteristic of disposable tableware was provided according to the following indicators: (1) organoleptic (color, appearance, physical condition, smell); (2) sound when struck with a wooden stick; (3) the presence of defects; (4) ease of use; (5) the actual capacity, ml; (6) the height, mm; (7) the diameter of the upper part, mm; (8) the diameter of the bottom part, mm; (9) the wall thickness, mm; (10) the bottom thickness, mm;(11) the moisture mass fraction, %; (12) short-term hot water influence (60–65 °C and 85–90 °C); (13) short-term cold water influence (10–15 °C); (14) short-term alcohol solution influence; (15) short-term influence of acetic acid solution.

Organoleptic, ergonomic and geometric properties of biodegradable edible cups

Organoleptic, ergonomic and geometric properties of biodegradable edible cups were compared with properties of disposable paper and polymer cups (Table 3).

The developed cup fully corresponds in terms of organoleptic, ergonomic and geometric parameters to the disposable cups that are currently in use. In addition, the developed edible cup also has an advantage over paper and polymer analogues, because due to the greater thickness of the walls and the material properties (cookies), it is possible to hold a cup with a hot drink in your hands without an additional layer. From the outside, the designed cup can be coated with edible polymer, which can be consumed or thrown away without negative impact on the environment.

Table 3

Properties of various disposable cups for hot drinks

Indicators	Paper cup	Polymer cup	Biodegradable edible cup
Organoleptic (color, appearance, physical condition, smell, taste*)	White, opaque, no smell, soft, visible side seam of gluing, there is a border on top	Transparent, polypropylene glass is soft in the hands, deforms with a slight effort; polystyrene cup is hard in the hands, does not deform. There is a border on top	The color inherent in baked butter cookies, the pleasant smell of cookies, there is a border on top, it is firm in the hands and does not deform, the pleasant taste, characteristic of butter cookies
Sound when struck with a wooden stick	Unvoiced		
Presence of defects	Absent in the studied samples		
Ergonomic indicators	It is comfortable to hold in the hand, but needs an additional intermediate layer to hold a hot drink	It is convenient to hold in the hand, polystyrene cups do not need an additional thermal insulation layer, unlike polypropylene	The shape is similar to a paper or polymer cup
Actual capacity, ml	In accordance with the standard size and consumer needs		
Height, mm	90±0.1	90±0.1	90±0.1
Diameter of the upper part, mm	70±0.1	70±0.1	70±0.1
Diameter of the bottom part, mm	40±0.1	42±0.1	40±0.1
Wall thickness, mm	1±0.1	0.5±0.1	5±0.1
Bottom thickness, mm	1±0.1	0.5±0.1	8±0.1
Moisture mass fraction, %	5.5±0.5	5.0±0.5	14±0.5
Short-term hot water influence	The shape and appearance of the cups remained unchanged		
Short-term cold water influence			
Short-term alcohol and acetic acid solution influence			

* the taste was determined only for edible cups

Coffee contains organic acids, and some types of coffee-based drinks, such as Irish coffee, Dumas, Karsk, Espresso Martini, and Coffee punch, are prepared with the addition of alcohol. Therefore, the effect of alcohol and acetic acid on the developed biodegradable cup was studied.

The key characteristic of the biodegradable edible cups is their waterproofness, which allows to completely replace disposable cups. As mentioned above, the cup waterproofness was created due to the inner natural polymer layer. The manufactured biodegradable cup with a drink was kept for 2 hours and no place of liquid leakage was found.

Effect of temperature on the biodegradable edible cup properties

Bidiuk et al. (2020) recommend to test tableware at temperatures for typical drinks offered by restaurants: 10-15 °C (Glaze, Frappe, Cold Americano, Ice Cream); 60-65°C (Latte, Cappuccino, Mochacino, Macchiato, Flat White, Raff), and 85-90°C (Americano, Espresso and their varieties). The effect of different temperatures on the change in appearance on disposable cups are present in Table 4.

Table 4

Temperature influence on disposable cups

Experimental conditions	Paper cup	Polymer cup	Biodegradable edible cup
Drink with a temperature of 10-15 °C	No changes in appearance		
Drink with a temperature of 60-65°C	No changes in the appearance for holding in hand	No changes in appearance, the polypropylene cup needs an additional heat-insulating layer to hold in the hand	No changes in appearance, it is possible to hold without an additional insulating layer to hold in the hand
Drink with a temperature of 85-90°C	No changes in the appearance of the cup, but it is impossible to hold it in your hands without an additional layer	A beverage with a temperature above 70 °C cannot be placed in a polypropylene cup (manufacturer's recommendation on the label); polystyrene cup unchanged	No changes in appearance, it is possible to hold without an additional insulating layer for holding in the hand

The results are quite acceptable since the polymers used are insoluble in water and the water drink will not dissolve the inner waterproof layer of the biodegradable edible cup. Naik et al. (2019) substantiated the importance of possible burn depending on the drinkware type. That is why in the Table 4 presents the sensations characteristics when holding a cup with a drink in your hands. The results agree with Bidiuk et al. (2020): the developed cups do not show any changes at 85-90 °C, therefore a lower temperature does not change the cups appearance.

Quality assessment of test samples

The quality criterion determination of test samples was carried out in several stages: (1) determination of characterize indicators, conversion of measurement units into dimensionless units (if necessary); (2) mathematical model development and calculation of product quality criteria.

A critical limit was set for a specific indicator for 0.6 points during the determinations. If the absolute value of the property indicator corresponds to the limit provided for in the regulatory documentation for the product, then a score of K_{ij} = 0.37 is an unacceptable indicator quality for the sample.

An important issue for the scientific substantiation of expert evaluation is the degree consistency assessment of expert opinions using the indicator system (Koretska et al., 2003). To assess the generalized agreement opinions measure from all directions, it was calculated the expert opinions agreement degree. The calculations results are given in the Table 5.

Table 5

Assessment results of the consistency experts' opinions degree

The samples	The indicator	The average value (rank)
Biodegradable edible cup	The variance	0.0236
	Rate of variation, %	2.657
Paper cup	The variance	0.0187
	Rate of variation, %	2.784
Polymer cup	The variance	0.0192
	Rate of variation, %	2.852

It can be seen that the variance value the estimates is close to zero from the obtained data (Table 5), and the variation estimates coefficient is no more than 3%. Such a result indicates a high assessment by experts of the finished product quality and shows consistency in the samples assessment between experts. This is explained by the fact that the group of experts was selected correctly. For the first time was calculated the conformity assessment results of experts' opinions for disposable cups.

Quality assessment of disposable cups using Harington's scale

Table 6 presents the results of s disposable polymer, paper and biodegradable edible cups evaluation.

The edible cup is completely biodegradable compared to other ecological cups, because it is a food. Tableware made of polylactide can completely decompose into water and carbon in 3 months (Ziada, 2009). There is an indicator environmental friendliness (P_2) in Table 6 that is why decomposition requires temperatures of at least from 55 to 70 °C and humidity, which can only be provided by commercial composting plants (Changwichan et al., 2020). In addition, much less carbon dioxide and other greenhouse gases are released during biopolymer production. Switching from conventional plastic to bioplastic would reduce greenhouse gas emissions by up to 25% (Ziada, 2009). The use of polylactide will reduce dependence on petroleum-based polymer materials, which, in turn, will reduce demand for it.

Table 6
Score evaluation quality of disposable cups taking into account the importance of the main indicators

Indicators (notation)	Biodegradable edible cup	Disposable cups	
		polymer	paper
The temperature of the cup surface with a drink (P_1)	13.5	9	10.5
Environmental friendliness (P_2)	25	15	15
The organoleptic properties (P_3)	31.9	24.5	25.0
Sensation when touching the cup surface (P_{31})	36	28	30.4
Color (P_{32})	18	18	18
Odor (P_{33})	8.9	6*	6*
Taste (P_{34})	28.8	18	18
Structural and mechanical properties (P_4)	22.1	25.0	24.8
The structure (P_{41})	17	20	20
Deformation under the temperature influence 85-90 °C (P_{42})	45	50	50
Waterproof (P_{43})	27	30	29.4
Criterion of product quality, point	92.52	73.50	75.36

* to avoid the exclusion of the indicator, its value was taken as the critical limit

Polygon of the quality assessment of disposable cups

The quality criterion were used to construct diagrams, according to the planar principle, that is, the value of the complex quality criterion corresponds to the area of a polygon in which the distances from its center to the vertices are equal to the normalized values of individual quality indicators (Koretska et al., 2003) (Figure 3).

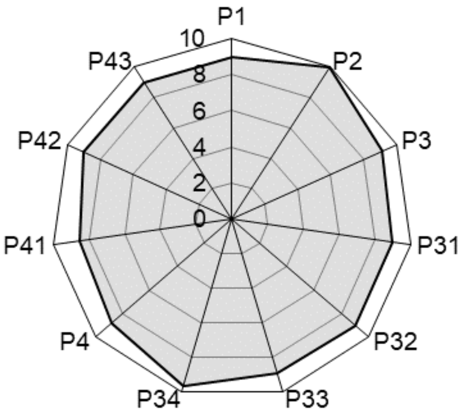
This is because the biodegradable edible cup has the advantage of being environmentally friendly. Other researchers have obtained the similar results (Liu et al., 2020).

The generalized quality criterion determined by the desirability function is calculated and presented in Table 7.

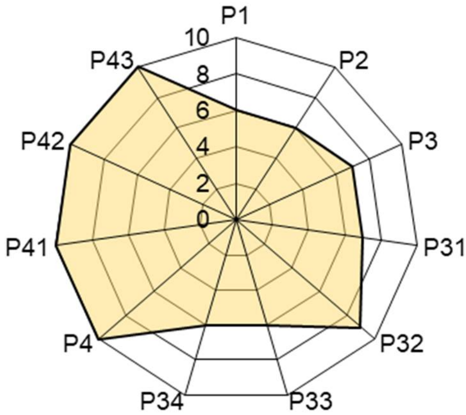
Table 7
Ranking of disposable cups according to the generalized desirability function

Type of cup	Biodegradable cup	Polymer cup	Paper cup
Quality criterion	92.52	73.50	75.36

When rating the tested samples, the quality criterion of a paper cup, 75.36 points, was accepted as 100%. The quality criterion of the developed biodegradable edible cup was higher, 122.8% = 92.50 points, compared to the polymer cup, 97.53% = 73.5 points.



a



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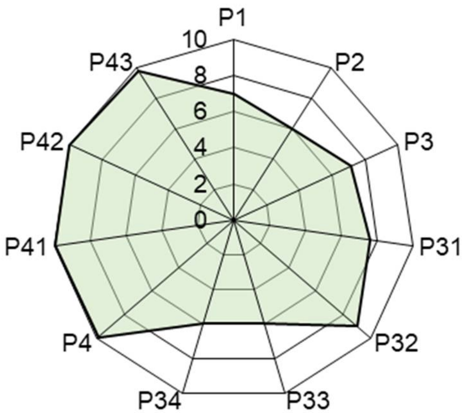

c

Figure 3. The quality profilograms of the researched cups
biodegradable edible cup (a); polymer cup (b); paper cup (c).
P_1 is the temperature of the cup surface with a drink;
P_2 is environmental friendliness;
P_3 is the organoleptic indicators:
P_{31} is sensation when touching the cup surface,
P_{32} is color,
P_{33} is odor,
P_{34} is taste;
P_4 is structural and mechanical properties;
P_{41} is the structure,
P_{42} is deformation under the temperature 85-90 °C, P_{43} is waterproof.

Environmental benefits

The expediency of replacing the existing disposable cups with a biodegradable edible cup is evident because nowadays environmental friendliness is a priority compared to other characteristics of the cups. In addition, do not forget about the capital investment required for the collection and processing of used paper and polymer cups. The biodegradable edible cup does not need to be recycled, because it is edible and is consumed completely with a drink or could be completely decomposed like any other confectionery product.

Environmental initiatives will have a positive effect only under the condition of a comprehensive approach and the population's awareness of the need for such initiatives. It is more difficult to convince the adult population to change their preferences and habits, and that is why ecological products are becoming the subject of sociological research in the field of marketing (Ivanov et al., 2021; Kim et al., 2019; Lee et al., 2023; Marinova et al., 2022). Today, consumers are becoming more aware of the importance of caring for the environment, which will be reflected in their attitude towards quality disposable edible new cups (Bertossi et al., 2023). Environmentalism must be brought up in children, so that in adulthood it is already perceived as a norm, a habit and a necessity of everyday life.

A separate segment that also needs to be provided with eco-friendly tableware is hotels (Subbiah et al., 2011). Such dishes keep their shape well when hot dishes are packed into them and can be used to store liquid dishes and sauces for 24 h without getting wet or softening. Biodegradable tableware is an ideal solution for catering and is suitable for heating in microwave ovens of different power. Bioware can be easily disposed of together with other food scraps, which will greatly facilitate the work of the restaurant by reducing the amount of waste and will allow to completely abandon the sorting of plastic.

Conclusions

1. The biodegradable edible cup is a full-fledged replacement of currently used polymer and paper cups. It has been confirmed using the Harrington`s function.
2. The biodegradable edible cup is a cookie formed in the form of a cup. It is possible to change the shape of the cup according to the consumer requirements. The cup’s waterproofness is provided due to the waterproof layer inside it.
3. The developed cup can be used for a wide range of drinks with a temperature from 10 to 90 °C.
4. The biodegradable edible cup is resistant to the action of acetic acid and ethyl alcohol.
5. The biodegradable edible cup has excellent ergonomic indicators, is environmentally friendly and can be easily decomposed like any other confectionery.

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