

## QUALITATIVE CHARACTERISTICS OF SELECTED LIQUID FRUIT PRODUCTS AVAILABLE ON THE POLISH MARKET

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### ABSTRACT

The current study aimed to assess the quality of selected liquid food products made from apple juice and available on the domestic market. The study determined the extract content, pH and density of twenty products, i.e., juices, nectars, soft drinks and smoothies from different producers. The study shows that the apple juice-based liquid products tested differ in terms of quality. The analyses also show that there is a greater variation in the apple juice-based liquid products tested in terms of extract content, to a lesser extent in terms of acidity, whereas in terms of density, it is small but statistically significant. The highest extract content, density and pH values were noted for the smoothies and apple juices, whereas the lowest values were noted for soft fruit drinks and nectars.

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## Introduction

Poland is the European Union's largest producer of apples (*Malus domestica*) and apple juice concentrate. The production of apples in Poland in 2023 amounted to 3.89 million tonnes, whereas the production of concentrated apple juice from domestic raw materials in the 2023/24 season is estimated at 265,000 tonnes (Raport Rynkowy SKUPS, 2024). According to the AIJN (European Fruit Juice Association) Report (2018), the consumption of juices and nectars in Poland remains above the EU average. The consumption of juices and nectars is 21.3 L per person per year (the EU average is 17.9 L). The most popular flavour of juices and nectars in Poland is apple (27.2%), followed by orange (24.7%). The less popular flavours include multifruit (12.7%) and grapefruit (6.4%) (AIJN, 2018). According to a 2023 survey by the National Union of Juice Producers (KUPS) Association, Poles prefer orange

juice, with apple juice in second place (<https://agronomist.pl/artykuly/poland-what-kind-of-juices-do-oles-drink>). Apple juices are available as juices from concentrate, clear and cloudy juices, juices with added pulp, juices pressed directly from the fruit, i.e., not from concentrate (nfc), as well as pasteurised or unpasteurised juices (Włodarska et al., 2023).

Apart from juices and nectars, soft fruit drinks are important in the Polish market. In recent years, there has also been an increase in consumers' interest in fruit cocktails of the 'smoothy' type. Depending on the juice content, smoothies can be classified as juices, nectars or soft drinks. Juices, nectars, soft drinks and smoothies contain a high concentration of compounds with health-promoting properties and can, therefore, be classified as high biological value foods (Michalak-Majewska et al., 2009; Markowski and Mieszczakowska-Frać, 2009; Lietzov, 2022). Apples (*Malus domestica*) are made up of water (85%), carbohydrates (12-14%), proteins (approximately 0.3%), a small amount of lipids (<0.1%), minerals and vitamins (Savatović et al., 2009). Apples and juices obtained from them contain phenolic compounds with documented anti-oxidant, anti-microbial, anti-viral, anti-inflammatory, anti-allergic, and even anti-neoplastic properties (Hyson, 2011; Markowski et al., 2015).

According to a study by Włodarska et al. (2016), Polish consumers prefer freshly pressed apple juices, whereas cloudy juices not prepared from concentrate, and clear juices prepared from a concentrate are less favoured. Due to the production volumes and flavour preferences in Poland, many liquid food products are produced from apple juice. Concentrated apple juice, freshly pressed fruit juice, and even fruit purée are used for these products.

The increased production and the variety of liquid food products made from apple juice necessitate their quality assessment. Detailed guidelines for juices and nectars are provided in the Polish Standards and the AIJN (European Fruit Juice Association) Code of Practice. Juices and nectars have to be produced in accordance with the current legislation (Neves et al., 2011). Consumers demand high-quality food. However, many consumers are unaware of the differences between the individual groups of liquid food products.

The extensive range of liquid food products available on the market requires constant quality monitoring. In this regard, research is carried out into the physico-chemical properties and sensory characteristics of individual products juices, nectars, soft drinks and smoothies (Okayasu and Naito (2001; Baryłko-Pikielna et al., 2002; Michalak-Majewska et al., 2009; Czarnowska et al., 2015; Szwedziak et al., 2015; Lietzov, 2022).

The primary quality determinants of liquid food products include, e.g., the extract content, density and acidity.

The current study aimed to assess the quality of selected liquid food products made from apple juice and available on the domestic market. The study determined the extract content, pH and density of twenty products, i.e., juices, nectars, soft drinks and smoothies from different producers.

The novelty of the present study is to conduct tests on different groups of liquid fruit products and compare them in terms of selected quality parameters.

## Materials and Methods

The study focused on liquid food products made from apple juice by eleven producers purchased in retail shops. The samples selected for the study came from the leading beverage

producers on the Polish market. The study was carried out on five types of apple juices, five types of soft drinks, five types of nectars, and five types of smoothies.

The study used three clarified apple juices and two unclarified juices (Table 1). The unclarified juices were produced by direct pressing, whereas the clarified juices were reconstituted from a concentrate. All the juices were pasteurised.

Table 1.  
*Characteristics of the product tested – an apple juice*

Sample code	Composition	Comments
S1	100% apple juice from a concentrated juice	Pasteurised, with vitamin C added
S2	100% apple juice from a concentrated juice	Pasteurised, with vitamin C added
S3	100% apple juice from a concentrated juice	Pasteurised, with vitamin C added
S4	Pressed apple juice 100%	Unclarified, pasteurised
S5	Pressed apple juice 100%	Cloudy, pasteurised

As for the soft drinks, all of them were produced from concentrated apple juice, and, in one case, pear juice was added (Table 2). Except for one product, the apple juice from a concentrated juice content was 20%. In two cases, soft drinks contained sweetening agents added. All of the soft drinks were pasteurised.

Table 2.  
*Characteristics of the product tested – a fruit soft drink*

Sample code	Composition	Comments
N1	20% apple juice from a concentrated juice, water	Pasteurised
N2	20% apple juice from a concentrated juice, water	Pasteurised
N3	20% apple juice from a concentrated juice, water	Pasteurised
N4	20% apple juice from a concentrated juice, water	Pasteurised, contains sugar and a sweetening agent
N5	15% apple juice from a concentrated juice, 5% pear juice from a concentrated juice, water	Pasteurised, contains sugar and a sweetening agent

The nectars involved in the study contained at least 50% of fruit juice-based pulp (Table 3). Three nectars were produced from concentrated fruit (apple) juice, whereas two were produced without using concentrated juices. Two nectars contained ingredients other than apple juice, i.e., a juice or purée from other fruits. All the nectars were thermally preserved by pasteurisation. Regarding smoothies, the primary recipe ingredient was apple juice and/or purée (Table 4). The smoothies tested were produced using fruit purées from apples, pears, sour cherries, strawberries, gooseberries, aronias, bananas, oranges, bee honey, and oat flakes. All of the smoothies were pasteurised.

Table 3.  
*Characteristics of the product tested – a fruit nectar*

Sample code	Composition	Comments
Nk1	50% apple juice from a concentrated juice; water	Pasteurised, contains a sweetening agent
Nk2	50% apple juice from a concentrated juice; water	Pasteurised, contains sugar
Nk3	50% apple juice from a concentrated juice; water	Pasteurised, contains sugar
Nk4	Apple juice 30%; banana purée 18%; carrot purée 12%; water	Pasteurised, prepared without the use of concentrated juices.
Nk5	Apple juice 41%; banana purée 10%; raspberry purée 8%; bilberry purée 1%; water	Pasteurised, prepared without the use of concentrated juices.

Table 4.  
*Characteristics of the product tested – a fruit smoothie*

Sample code	Composition	Comments
Sm1	Pressed apple juice 33%; apple purée 36%; banana purée 18%; pressed orange juice 16%; spinach purée, moringa 0.5%	Pasteurised
Sm2	Apple juice 56%; banana purée 15%; pear purée 5%; apple purée 12%; oat flakes 1%; bee honey 1%	Pasteurised, enriched with vitamin C
Sm3	Apple purée 60%; 18% apple juice from a concentrated juice; sour cherry purée 16%; concentrated aronia juice 6%	Pasteurised
Sm4	Banana purée 30%; 29% apple juice from a concentrated juice; apple purée 20%; strawberry puree 15%; 6% sour cherry juice from a concentrated juice	Pasteurised, enriched with vitamin C
Sm5	Apple purée 55%; 19% apple juice from a concentrated juice; pear purée 14%; gooseberry purée 12%	Pasteurised

Before measurements, the samples were transferred into plastic containers and then stored in a refrigerator at approximately 4°C. The measurements were carried out in the laboratory of the Department of Food Engineering and Machines. The laboratory temperature was 20±1°C.

Testing the quality characteristics of liquid food products based on apple juice involved the determination of the extract content (°Bx), density and pH. The extract content was determined in accordance with PN-90/A-75101/02, whereas the acidity (pH) was measured according to PN-EN 1132:1999. The extract content was measured using a Pal-3 refractometer (Atago, Japan), the pH measurements used a CPC-411 pH meter (Elmetron, Poland), and the density was measured using a pycnometer. As regards the pH measurement, the measurement time was 90 s, i.e., until the value on the pH-meter display stabilised. The density was determined by the pycnometric method by measuring the weight of the determined volume of the

sample at  $20\pm 0.5^{\circ}\text{C}$  and comparing it to the weight of the same volume of the reference liquid (distilled water) at  $20\pm 0.5^{\circ}\text{C}$  (PN-EN 1131:1999). The density was expressed in  $\text{kg}\cdot\text{m}^{-3}$ . Each measurement was made in 3 replicates.

Statistical analysis of the study results was carried out using Statistica software (Statistica 12.0, StatSoft Inc., Tulsa, OK, USA), with an analysis of variance for factorial systems. The significance of differences was tested with the help of Tukey's LSD test at significance level of  $p<0.05$ .

## Results and Discussion

### Qualitative characteristics of apple juice-based liquid food products, depending on the product type

Figure 1 shows the average extract content of the tested apple juice-based liquid products. An analysis shows that the tested products differ in terms of the extract content, with the exception of juices and smoothies.

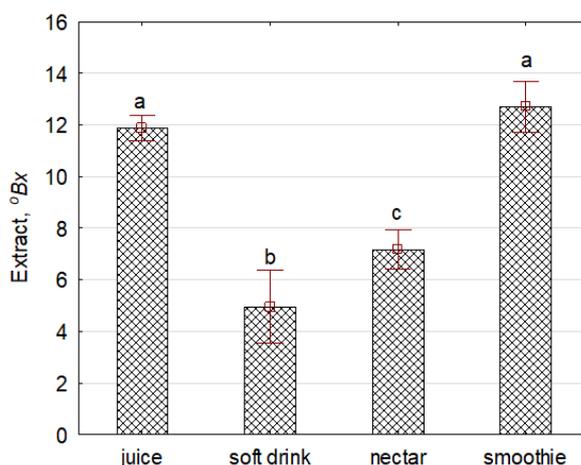


Figure 1. The average extract content ( $^{\circ}\text{Bx}$ ) depending on the product type

The average extract content of the tested products ranged from  $5.1$  to  $12.7^{\circ}\text{Bx}$ . According to the Codex Alimentarius (2005), the minimum Brix level for reconstituted apple juice should be  $11.5^{\circ}\text{Bx}$ , while the Brix value may vary from country to country. The highest average extract content was noted for the smoothies and juices, and the lowest was for the soft drinks. For the smoothies and juices, the average extract content was over 2.5 times higher than the average extract content of the soft drinks. From a consumer's perspective, due to their high extract contents, smoothies and juices are characterised by the highest quality.

Figure 2 provides the characteristics of the liquid fruit products tested in terms of the pH value. The pH value of the products tested ranged from 3.1 to 3.7. The difference between the products tested did not exceed 20%. The highest pH value was noted for smoothies and

juices, whereas the lowest was for soft drinks. No statistically significant differences were noted in the pH value between the juices and nectars or between the nectars and smoothies. According to consumers, the acidic taste is considered a favourable characteristic of fruit products. However, a low pH value for soft drinks may be indicative of over-acidification of products.

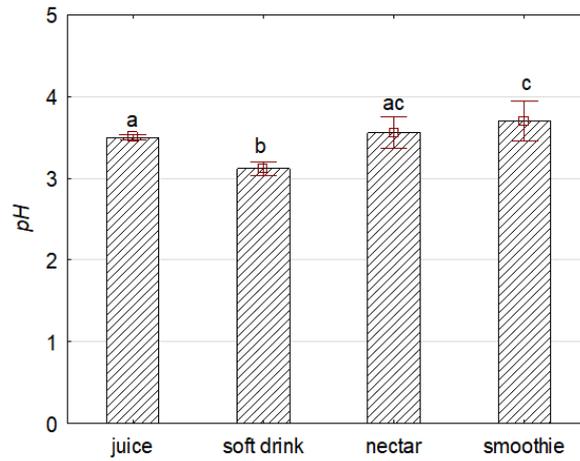


Figure 2. The average acidity (pH) depending on the product type

Figure 3 shows the density of the apple juice-based liquid food products tested. The testing results indicated the average density values ranged from 1.013 to 1.046 kg·L<sup>-1</sup>.

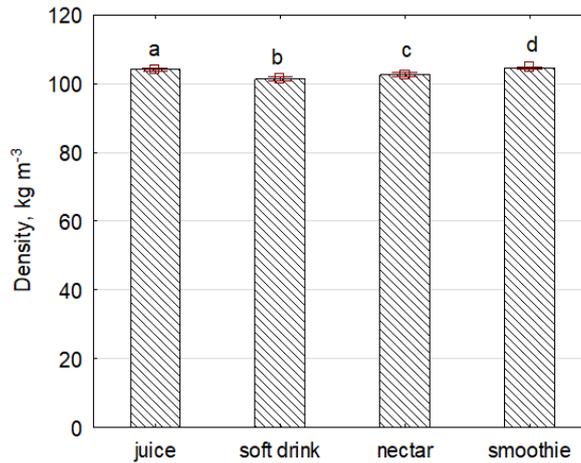


Figure 3. The average density (kg·L<sup>-1</sup>) depending on the product type

The differences in the density of the products tested were minor, although statistically significant. The lowest density was noted for the soft drinks and the highest for the smoothies. It can be assumed that liquid products with a higher density are favoured more by consumers, as they are not considered to be diluted or watered down.

### Qualitative characteristics of apple juice-based liquid products, depending on the producer

Table 5 shows the extract content of the individual products, depending on the producer. The average extract content of the juices tested varied and ranged from 11.37 to 12.67°Bx. The differences in the extract content were statistically significant. The highest average extract content was noted for the juice from producer S5, whereas the lowest was for the juice from producer S3. A study by Al-Farsi et al. (2024), conducted on apple juice, found a similar extract content ranging from 10.8 to 13.4°Bx. Szwedziak et al. (2015) also found a slight variation between apple juices from different producers in terms of the extract content. According to Okayasu & Naito (2001), the extract content of apple juices, both clarified and unclarified, ranged from 11.0 to 14.3°Bx. According to Polish regulations, the minimum extract content (Bx) of apple juice reconstituted from juice concentrate must be 11.2°Bx (Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi, 2021).

Table 5.

*The extract content (°Bx) of the individual products, depending on the producer*

Product	Producer (probe)				
	S1	S2	S3	S4	S5
Juice	11.57±0.06ab	11.62±0.11b	11.37±0.06a	12.13±0.11c	12.67±0.07d
Soft drink	N1	N2	N3	N4	N5
	5.17±0.06a	2.51±0.11b	6.77±0.06c	5.11±0.11a	5.27±0.06a
Nectar	Nk1	Nk2	Nk3	Nk4	Nk5
	5.73±0.06a	7.73±0.07b	7.72±0.06b	7.33±0.06c	7.31±0.11c
Smoothie	Sm1	Sm2	Sm3	Sm4	Sm5
	12.97±0.21a	13.43±0.07b	12.63±0.06c	13.51±0.11b	10.93±0.06d

\* a, b, and c—average values in a row marked with the same letter are not statistically significantly different ( $p < 0.05$ ).

The apple juice-based soft drinks tested vary considerably in terms of the average extract content. The extract content of the tested soft drinks ranged from 2.51 to 6.77°Bx and was significantly lower compared to the extract contents of juices and smoothies. The average extract content of the soft drink from producer N2 was 2.7 times lower than that of the soft drink from producer N3. No statistically significant differences were noted in the extract content of the soft drinks from producers N1, N4 and N5. Czarnowska et al. (2015) found that the extract content of soft drinks varied widely and could be up to several times lower

than the extract contents of juices and smoothies. According to the study by Muntean & Muntean (2010), the extract content of soft drinks ranged from 8.26 to 12.10°Bx. As for the nectars, there is also variation in terms of the average extract content, with these differences being statistically significant. The average extract content of the nectars tested ranged from 5.73 to 7.73°Bx and was lower than that in juices and smoothies. Nectars from producers Nk2, Nk3, Nk4 and Nk5 were characterised by a higher extract content than that of the nectars from producer Nk1. The average extract content for smoothies ranged from 10.93 to 13.51°Bx, and the differences were statistically significant, with the exception of smoothies from producers Sm2 and Sm4. The lowest extract content was noted for the smoothie from producer Sm5, and the highest was noted for the smoothie from producers Sm2 and Sm4. The difference between these values amounted to approximately 24%.

Table 6 shows the average pH values of the liquid food products tested. The average pH value of the tested juices was at a similar level and amounted to approximately 3.5 pH.

Table 6.

*The pH values of the individual products, depending on the producer*

Product	Producer (probe)				
	S1	S2	S3	S4	S5
Juice	3.53±0.04a	3.52±0.02a	3.48±0.02a	3.49±0.01a	3.47±0.01a
Soft drink	N1	N2	N3	N4	N5
	3.09±0.01a	3.22±0.01b	3.09±0.01a	3.01±0.01c	3.18±0.01b
Nectar	Nk1	Nk2	Nk3	Nk4	Nk5
	3.48±0.01a	3.39±0.01ab	3.46±0.01ab	3.91±0.09c	3.56±0.01b
Smoothie	Sm1	Sm2	Sm3	Sm4	Sm5
	4.01±0.01a	3.87±0.01b	3.55±0.01c	3.73±0.01d	3.34±0.01e

\* a, b, and c—average values in a row marked with the same letter are not statistically significantly different ( $p < 0.05$ ).

The differences in the pH between the juices were statistically insignificant. However, Włodarska et al. (2016) noted that the pH of fruit juices ranged from 3.33 to 3.63. A study by Al-Farsi et al. (2024) indicated that the pH value of the apple juices they tested was higher and ranged from 3.73 to 3.96. However, Okayasu & Naito (2001) reported that the pH values for clarified and unclarified apple juices ranged from 3.32 to 3.84. A study by Halagarda and Suwała (2018) showed that the apple juice preferred by consumers should be characterised by a balanced, sweet-and-sour flavour. The average pH values of the soft drinks tested ranged from 3.01 to 3.22 and were noticeably lower than the pH values for the juices, nectars and smoothies tested. The differences between the pH values of soft drinks were statistically significant, with the exception of soft drinks N1 and N3. The low pH value may be indicative of significant additional acidification of the product. Czarnowska et al. (2015) found that the pH value of soft drinks can range from 3.29 to 3.83. However, Muntean & Muntean (2010) indicated that the pH value of soft drinks ranged from 2.71 to 2.95. This is because soft drinks can be sweetened and acidified, which affects their acidity level. The pH of nectars ranges

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from 3.39 to 3.91, with the differences being statistically significant. Nectars from producers Nk1, Nk2, Nk3 and Nk5 were characterised by similar pH levels. The nectar from producer Nk4 had a markedly higher pH compared to the four other nectars. As for the smoothies, greater variation was observed in terms of the average pH value compared to other types of products. The average pH value for the smoothies tested ranged from 3.34 to 4.01. The highest pH value was noted for the smoothies from producer Sm1, whereas the lowest was for smoothies from producer Sm5. All of the tested smoothies differed statistically significantly in terms of pH value.

Table 7 shows the average density of the products tested. The average density of the juices tested was at a similar level, ranging from 1.038 to 1.043 kg/L, and shows no statistically significant differences depending on the juice producer.

Table 7.  
*The density (kg·L<sup>-1</sup>) of the individual products, depending on the producer*

Product	Producer (probe)				
	S1	S2	S3	S4	S5
Juice	1.041±0.004a	1.038±0.003a	1.042±0.004a	1.039±0.003a	1.043±0.004a
Soft drink	N1	N2	N3	N4	N5
	1.012±0.002a	1.007±0.002a	1.023±0.004b	1.009±0.001a	1.014±0.004a
Nectar	Nk1	Nk2	Nk3	Nk4	Nk5
	1.018±0.002a	1.023±0.002a	1.030±0.003bc	1.033±0.003c	1.024±0.003ab
Smoothie	Sm1	Sm2	Sm3	Sm4	Sm5
	1.044±0.003a	1.078±0.003a	1.045±0.004a	1.040±0.003a	1.042±0.002a

\* a, b, and c—average values in a row marked with the same letter are not statistically significantly different ( $p < 0.05$ ).

Slightly higher juice density values, ranging from 1.046 to 1.053 kg·L<sup>-1</sup>, were noted by Szwedziak et al. (2015). In their study, it was the naturally cloudy apple juice that had the highest density. However, Halagarda & Suwała (2018) found that from a consumer's perspective, the optimal density of juices should be 1.043 kg·L<sup>-1</sup>. The soft drinks tested differ slightly in terms of the average density. The average density of the soft drinks tested ranges from 1.007 to 1.023 kg·L<sup>-1</sup>. No statistically significant differences were noted in the density of the soft drinks from producers N1, N2, N4 and N5. The average density of the nectars tested ranged from 1.018 to 1.033 kg·L<sup>-1</sup>. A statistical analysis showed a slight but statistically significant variation between nectars in terms of density. The density of the smoothies tested ranged from 1.042 to 1.078 kg·L<sup>-1</sup>. No statistically significant differences were noted in the density of smoothies from different producers.

## Conclusions

The study shows that the apple juice-based liquid products tested differ in terms of quality. The analyses also show that there is a greater variation in the apple juice-based liquid products tested in terms of extract content, to a lesser extent in terms of acidity, whereas in terms of density, it is negligible. The highest extract content, density and pH values were noted for the smoothies and apple juices, whereas the lowest values were noted for soft fruit drinks and nectars. It is worth noting that nectars showed a similar pH value to that of fruit juices. The study demonstrates that the individual products, i.e., juices, soft drinks, nectars and smoothies, vary from producer to producer. This is particularly evident with regard to the extract content. In this regard, the smoothies are the most differentiated. A further line of research should be an organoleptic evaluation of apple juice-based liquid products, allowing consumer preferences to be identified and instrumental research to be combined with sensory testing.

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## CHARAKTERYSTYKA JAKOŚCIOWA WYBRANYCH PŁYNNYCH PRODUKTÓW OWOCOWYCH DOSTĘPNYCH NA RYNKU POLSKIM

**Streszczenie.** Celem niniejszej pracy była ocena jakości wybranych płynnych produktów spożywczych wytwarzanych z soku jabłkowego i dostępnych na rynku krajowym. W badaniu określono zawartość ekstraktu, pH i gęstość dwudziestu produktów, tj. soków, nektarów, napojów bezalkoholowych i smoothie różnych producentów. Badanie wykazało, że testowane płynne produkty na bazie soku jabłkowego różnią się pod względem jakości. Analizy wykazały również, że w testowanych płynnych produktach na bazie soku jabłkowego występuje większe zróżnicowanie pod względem zawartości ekstraktu, w mniejszym stopniu pod względem kwasowości, natomiast pod względem gęstości jest ono niewielkie, ale statystycznie istotne. Najwyższe wartości zawartości ekstraktu, gęstości i pH odnotowano dla smoothie i soków jabłkowych, natomiast najniższe wartości odnotowano dla napojów owocowych i nektarów.

**Słowa kluczowe:** sok, napój bezalkoholowy, nektar, smoothie, jakość