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Potatoes as wheat flour substitute in gluten-free pastry cream

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Abstract. Pastry cream contains wheat flour, which is not suitable for celiac patients who require a gluten-free diet. Potatoes are known as a good source of starch, minerals and vitamins. They also contain protein, dietary fibre and various phytochemicals. Their addition to pastry cream can both serve as a texturising agent and enrich the nutritional value of the final product. This study aimed to evaluate the suitability of potatoes as a replacement for wheat flour in pastry cream. For study purposes, the physicochemical attributes of eleven potato varieties were evaluated. Among other varieties, the boiled potato variety Gala exhibited higher fibre, fat, phosphorus and potassium content; however, significantly higher protein (12.48 ± 0.08 g 100 g^{-1} DW) and iron (3.12 ± 0.02 g 100 g^{-1} DW) content. Higher antiradical activity (18.72 ± 0.74 mM TE 100^{-1} g DW) was detected in potatoes of the variety Blue Congo. After preliminary investigation, wheat flour was replaced with mashed potatoes, making up 30% of the cream weight, and its impact on the pastry cream was studied. It was established that potatoes had a significant effect on pastry cream colour and texture. American Rose, Imanta, Rigonda and Viviana were selected as the most suitable from the eleven varieties tested. The addition of potatoes in pastry cream doubled its fibre and potassium content, whereas, other changes in nutritional value of the creams were variety dependent.

Key words: potato variety, cream textural properties, nutritional value, phenolic compounds, antioxidant activity.

Introduction

Potatoes (*Solanum tuberosum* L.) were introduced to Europe in the 16th century, and since then they have been bred to produce heat- and cold-tolerant potatoes and increase the content of biologically active compounds (Skrabule & Bebre, 2013). Nowadays, the potato is the fourth most widely consumed crop in the world after rice, wheat and maize, with a biodiversity of around 5,000 varieties (Burlingame *et al.*, 2009; Zhou *et al.*, 2019). It has been reported that potatoes are an important source of various nutrients, such as starch, proteins, dietary fibre, minerals and vitamins. After cooking, the starch becomes more rapidly digestible and is quickly absorbed in the human body, which can be explained by its hydrolyses (Singh *et al.*, 2020). In addition, potatoes contain phenolic compounds and other phytochemicals possessing antioxidant activity. According to Yang *et al.* (2016), the total content of phenols, including pigments, may decrease, remain the same or even increase in potatoes upon processing. Some phenolic compounds may be degraded by heating or extracted into cooking water (Fang *et al.*, 2022a).

Potato components have been reported to have various health benefits (Tian *et al.*, 2016). Therefore, potatoes are used in preparation of various dishes through boiling and frying (Dong *et al.*, 2021), used as colorants in the drinks industry (Sampaio *et al.*, 2021), for food packaging (Wang *et al.*, 2022), and as an additive to enrich other foods such as steamed bread (Cao *et al.*, 2020). Nevertheless, some adverse effects should be noted. Rapidly digested starch of cooked potatoes may cause increased glucose levels, presence of glycoalkaloids and allergy causing proteins that are deemed unfavourable for human health (Tian *et al.*, 2016).

Traditionally, pastry cream is an oil-in-water emulsion. Liquids (water, milk) form the continuous phase. Sweeteners (sugar), fats, gelling agents and other ingredients are also used in the formulation of

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pastry cream (Schutte & Heuvelman, 2008; Rønholt *et al.*, 2013). Wheat flour (typically not more than 15% from cream mass) is often used as a gelling agent (Horincar *et al.*, 2020), which is not suitable for celiac patients. Celiac disease is characterised by chronic immune-mediated enteropathy, usually caused by the ingestion of gluten (Lionetti *et al.*, 2023) which is especially present in cereals (Kliewer *et al.*, 2016).

Some researchers have proposed to use enzymatically modified starches, sago or tapioca starch to form the gel structure in pastry cream (Hirao *et al.*, 2021). Potatoes can also be considered as an alternative for wheat flour due to their high starch content. Potatoes are naturally gluten-free, and they are already widely used in the production of gluten-free bread in combination with other raw materials (Kim *et al.*, 2015). Besides, potatoes are also a source of non-allergic high-quality proteins as they are low in calories and fat (Hussain *et al.*, 2021) and are used as a source of lysine in the human diet (Ansari & Mu, 2018). However, the appropriate cooking method, especially domestic cooking, helps to retain potatoes' nutritional value, to destroy phytochemicals and help to influence its glycaemic response significantly (Tian *et al.*, 2016). Potato pulp in wheat bread, 30–50%, reduced the content of rapidly digestible starch and also the glycaemic index of steamed bread resulting in a new product for a healthy dietary choice (Cao *et al*., 2019). Thereby, the addition of potatoes in pastry cream could serve as a gelling agent and enrich its nutritional value. Potato starch typically contains 20–27% amylose (W/W) of total starch and 80–73% amylopectin (W/W), depending on the type and measurement technique; their ratio plays a very important role in any technological process. However, both the recrystallisation and gelatinisation of starch are influenced by the amylose/amylopectin ratios (Karlsson *et al*., 2007). By dissolving the micelle structure in starch granules and rupturing the intermolecular hydrogen bond, potato starch can be gelatinised in hot water and leach out of the granule (Xu *et al.*, 2021).

After summarising the theoretical data available within scientific literature, the research hypothesis was established: it is possible to obtain gluten free pastry cream with increased nutritional value and acceptable textural properties by substituting wheat flour with boiled potatoes in the pastry cream formulation.

This study aimed to evaluate the suitability of potatoes as a replacement for wheat flour in pastry cream.

Materials and Methods

Materials

In the present research, eleven potato varieties – Agrie Dzeltenie, American Rose, Blue Congo, Gala, Imanta, Jelly, Lenora, Monta, Prelma, Rigonda and Viviana (Table 1) – harvested in Latvia in 2020 in a farm in the Kuldiga region, Latvia (56°50′57′′N 22°22′24′′E) were used. Other pastry cream ingredients – butter (82.5% fat content), milk (2.5% fat content), sugar, raw eggs and wheat flour (proteins 11.0 g 100 g^{-1}, fats 1.1 g 100 g^{-1}, carbohydrates 72.6 g 100 g^{-1}) – were purchased from a local supermarket.

Table 1

Characteristics of the fresh potatoes*

Potato variety	Maturity	Cooking quality	Starch content, %	Amylose content, %
Agrie Dzeltenie	Early	Very mealy	14.70	17.10
American Rose	Early	Medium mealy	12.80	29.11
Blue Congo	Late	Medium mealy	13.10	29.57
Gala	Medium early	Medium mealy	13.10	27.65
Imanta	Medium late	Very mealy	20.80	18.60
Jelly	Medium to late	Mealy	15.40	26.01
Lenora	Medium early	Mealy	19.90	26.46
Monta	Early	Medium to little mealy	18.40	24.13
Prelma	Medium early	Medium to little mealy	15.00	22.78
Rigonda	Early	Little mealy	15.00	25.91
Viviana	Very early	Little mealy	12.20	18.31

* Producer's information.

Experimental design

Research was done at the Food Institute in Latvia University of Life Sciences and Technologies.

Step 1. Peeled potatoes of each of the eleven varieties were boiled in water until their pulp was soft (15–20 min). After boiling, the water was drained and the potatoes were left to cool down to room temperature. The physicochemical characteristics (chemical composition, total phenol content, antiradical activity and pH) of the prepared potatoes were evaluated.

Step 2. Pastry cream (control sample) was prepared using the following ingredients: 55% pasteurised milk, 23% sugar, 12% raw eggs, and 10% cream butter. In the control sample, 3% wheat flour was used in the formulation as a gelling agent.

Step 3 (Pre-experiment). Peeled potatoes of the variety Imanta were boiled until done, and mashed manually with a wooden masher until a homogeneous mass was obtained. Then, the mashed potatoes were used for pastry cream preparation in amounts of 5, 10, 20, 30 and 40% of the total cream mass. At first, mashed potatoes, eggs and sugar were mixed manually with a wooden spatula, then milk was added and the mass was mixed again. After that, the mass was heated on an electric stove in a stainless-steel pot until 100 ± 1 °C and held at that temperature for 5 min; then the butter was added. All ingredients were mixed manually with a spatula and cooled down to room temperature (21 ± 1 °C). For the determination of optimal potato proportion in the cream mass, the acceptance of pastry cream sensory attributes such as appearance, colour, aroma, texture, taste and aftertaste were evaluated using a bipolar Just-About-Right (JAR) scale. The majority of the panellists noted a potato taste (70% in the JAR) and aftertaste (73% in the JAR) in the cream if the potato proportion in the cream exceeded 30%. Thereby, the maximum amount of boiled potatoes to be added was established at 30%; this amount was then used in pastry cream formulations in further research steps.

Step 4. The pastry creams were prepared according to the above-described technology, replacing the wheat flour with mashed potatoes. Samples were prepared in triplicate and stored in the refrigerator (4 ± 1 °C) in closed glass containers (500 ± 5 g) until analysis, which was performed the next day. The pastry creams with different potatoes of the eleven varieties, along with the control sample described in Step 1, were tested for colour, pH and textural properties. The most suitable varieties of boiled potatoes were selected for the pastry cream preparation based on the textural properties of obtained pastry creams.

Step 6. The chemical composition and nutritional value of the pastry creams containing potatoes of the four most suitable varieties, which were selected in the previous step, were compared to the control.

Analysis of the chemical composition

The quality parameters of the boiled potatoes and pastry cream were analysed using standard methods: crude protein – LVS EN ISO 5983-2:2009, crude fibre – ISO 5498:1981, fats – ISO 6492:1999, crude ash – ISO 5984:2002/Cor 1:2005, calcium – LVS EN ISO 6869:2002, phosphorus – ISO 6491:1998, potassium – LVS EN ISO 6869:2002, iron – LVS EN ISO 6869:2002, and pH – ISO 10523:2012.

Colour analysis

The colour was determined with a ColorTec-PCM colorimeter (Accuracy Microsensors, New York, USA). The obtained results were processed using the program ColorSoft QCW. Colour was measured in the CIE L* a* b* system. To determine the total colour change for the samples, the total colour difference (ΔE) was calculated according to Aaby *et al.* (2018).

Determination of total phenol content and antiradical activity

The fractions of free phenols and bound phenolic compounds were extracted. Free phenols were extracted as described by Tomsone *et al.* (2020) with some modifications. Sample (5.00 ± 0.01 g) was weight in a beaker and combined with an ethanol: water solution (80:20; V/V) as the solvent. Then the beakers were placed in an ultrasonic bath YJ5120-1 (Oubo Dental, New York, USA) at 35 kHz for 10 min at 20 ± 1 °C. After that, the upper layer was poured into centrifuge tubes and placed in a CM-6MT centrifuge (Elmi Ltd., Riga, Latvia) at 3500 rpm for 20 min. The supernatant was accurately decanted into 25 mL volumetric flasks. The precipitate was re-extracted with ethanol: a water solution using the same procedure. The supernatants were combined in the same volumetric flasks and filled up to the mark with solvent. Bound phenols were extracted as described by Alu'datt *et al.* (2019), which modified Singleton *et al.* (1999). Briefly, 20 mL of 0.1 M NaOH solution was added to the sediment left after free phenol extraction, covered with Parafilm, and kept in the dark at room temperature for 24 h. Then it was filtered, and the filtrate was filled up to the mark in a 25 mL volumetric flask. The sediment left after NaOH extraction was transferred quantitatively to the volumetric flasks, 20 mL of 0.1 M HCl solution was added and the same procedure as with NaOH was performed. Spectrophotometric analyses were performed on these extracts using a JENWAY 6300 spectrophotometer (Barloworld Scientific Ltd., Staffordshire, UK). The result was calculated as the sum of the ethanol: water, NaOH and HCl extracts using their respective calibration curves. The extraction process was performed in triplicate. Total

phenolic content (TPC) was determined by the Folin-Ciocalteu spectrophotometric method (Singleton *et al*., 1999). The result was expressed as mg gallic-acid equivalent (GAE) 100 g^{-1} dry weight (DW). TPC was calculated using a standard curve of gallic-acid solution at different concentrations (0.01–1.00 mg mL^{-1}). Antiradical activity – 2,2-diphenyl-1-picrylhydrazyl (DPPH˙) – was determined according to Yu & Zhou's (2005) method. The result was expressed as mmol Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalent (TE) 100 g^{-1} DW.

Textural properties of pastry cream

Textural properties of the creams – firmness, adhesiveness and cohesiveness – were determined using the TA.HD.plus texture analyser (Stable Micro Systems, Godalming, UK). Pastry cream at 4 ± 1 °C was filled in the container of a back extrusion rig (A/BE) up to 30 mm. A 40 mm compression plate was used, pre-test speed was 1.00 mm s^{-1}, test speed – 1.00 mm s^{-1}, post-test speed – 10.00 mm s^{-1}, distance – 15.0 mm, automatic trigger force 0.049 N. The results were obtained in triplicate using the software Texture EXPONENT 32.

Statistical treatment of data

The obtained data was processed using MS Excel and the statistical program GraphPad Prism8 (GraphPad Software, San Diego, USA). A one-way analysis of variance (ANOVA) followed by Tukey's test was used. For the interpretation of the results, it was assumed that $\alpha = 0.05$ with 95% confidence. To determine the relationship between TPC and DPPH˙, a linear correlation analysis was used.

Results and Discussion

Physicochemical characteristics of boiled potatoes selected for pastry cream production

The colour of the boiled potatoes included in the study (Figure 1) varied from light yellow to dark yellow, except two purple-coloured potato varieties, Blue Congo and American Rose.

The dark colour of some potato varieties may be explained by the presence of anthocyanins in the potato, which according to Campos & Ortiz (2019) was 8.2–55.3 mg 100 g^{-1} (fresh weight) in the variety American Rose and 71.0–453.0 mg 100 g^{-1} (W/W) in Blue Congo providing a reddish-blue colour.

The fibre content in the boiled potatoes varied from 1.34 g 100 g^{-1} DW (Rigonda) to 2.36 g 100 g^{-1} DW (Gala) (Table 2). The potato variety Gala exhibited the highest content of fat (0.29 g 100^{-1} g DW), phosphorus (0.25 mg 100 g^{-1} DW), and potassium (1.84 mg 100 g^{-1} DW) amongst the other varieties studied. Significantly higher protein content was established in the boiled potato variety Blue Congo (12.48 g 100 g^{-1} in DW), followed by American Rose (10.71 g 100 g^{-1} DW) and then Gala (10.54 g 100 g^{-1} DW). The calcium content was similar in all potato varieties analysed in the study (0.01–0.02 mg 100 g^{-1} DW). Significant differences were found between the iron content of different potato varieties. The lowest iron content was in the potato variety Prelma (10.29 mg kg^{-1} DW), whereas Blue Congo (31.19 mg kg^{-1} DW) contained about three times more iron. The potato varieties Gala (27.80 mg kg^{-1} DW) and American Rose (24.53 mg kg^{-1} DW) also exhibited high iron content.

The data obtained proved the presence of phenolic compounds in boiled potatoes, as well as confirmed the strong correlation (r = 0.755) between the content of phenolic compounds and antioxidant activity. Higher total phenolic content corresponded to higher antiradical activity. The highest total phenol content was detected in the potato varieties Blue Congo and American Rose (359 and 390 mg GAE 100 g^{-1} DW, respectively) and the lowest in the potato varieties Imanta and Jelly (124 mg GAE 100 g^{-1} DW). These results are consistent with the previous studies, where

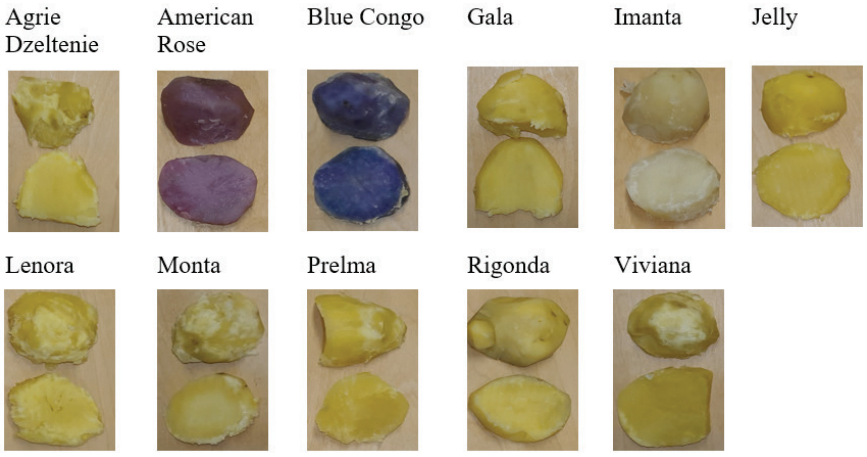


Figure 1. Boiled potato colour of different varieties used in the experiments.

Table 2

Chemical composition of the boiled potatoes

Potato variety	pH	Crude protein (g 100 g^{-1} DW)	Crude fibre (g 100 g^{-1} DW)	Fats (g 100 g^{-1} DW)	Crude ash (mg 100 g^{-1} DW)	Minerals (mg 100 g^{-1} DW)				TPC (mg GAE 100 g^{-1} DW)	DPPH$^{\cdot}$ (mM TE 100 g^{-1} DW)
						Ca	P	K	Fe		
Agrie Dzeltenie	5.87 ± 0.04^{f}	7.62 ± 0.12^{e}	1.70 ± 0.06^{e}	0.15 ± 0.02^{bcd}	3.93 ± 0.07^{b}	0.01 ± 0.001^{b}	0.17 ± 0.01^{cd}	1.63 ± 0.04^{bc}	2.13 ± 0.01^{e}	172.90 ± 7.45f^{g}	12.52 ± 0.36^{de}
American Rose	5.74 ± 0.01^{g}	10.71 ± 0.07^{b}	1.87 ± 0.02^{cd}	0.16 ± 0.01^{bc}	3.36 ± 0.09^{d}	0.02 ± 0.002^{a}	0.22 ± 0.01^{ab}	1.43 ± 0.08^{def}	2.45 ± 0.01^{c}	389.61 ± 17.04^{a}	14.87 ± 0.49^{b}
Blue Congo	5.69 ± 0.01^{g}	12.48 ± 0.08^{a}	1.76 ± 0.02^{de}	0.15 ± 0.02^{bcd}	3.73 ± 0.09^{bc}	0.02 ± 0.001^{a}	0.20 ± 0.01^{bcd}	1.65 ± 0.07^{b}	3.12 ± 0. 02^{a}	359.37 ± 15.86^{b}	18.72 ± 0.74^{a}
Gala	6.05 ± 0.01^{d}	10.54 ± 0.09^{b}	2.36 ± 0.07^{a}	0.29 ± 0.03^{a}	4.37 ± 0.08^{a}	0.02 ± 0.001^{a}	0.25 ± 0.01^{a}	1.84 ± 0.05a	2.78 ± 0.01^{b}	190.60 ± 8.30^{ef}	15.06 ± 0.38^{b}
Imanta	6.07 ± 0.01^{cd}	7.31 ± 0.10^{e}	1.75 ± 0.02^{de}	0.17 ± 0.01^{b}	3.09 ± 0.02^{e}	0.01 ± 0.001^{b}	0.16 ± 0.02^{d}	1.30 ± 0.02^{f}	1.45 ± 0.07^{f}	123.46 ± 5.17^{h}	9.45 ± 0.37^{g}
Jelly	6.18 ± 0.02^{a}	6.75 ± 0.14^{f}	2.09 ± 0.07^{b}	0.08 ± 0.01^{e}	3.42 ± 0.05^{d}	0.02 ± 0.004^{a}	0.18 ± 0.02^{bcd}	1.47 ± 0.09^{cde}	1.46 ± 0.01^{f}	123.94 ± 5.08^{h}	12.58 ± 0.36^{de}
Lenora	5.70 ± 0.03^{g}	6.61 ± 0.18^{f}	1.76 ± 0.03^{de}	0.10 ± 0.01^{de}	3.14 ± 0.09^{e}	0.01 ± 0.002^{b}	0.16 ± 0.01^{d}	1.33 ± 0.02^{ef}	1.24 ± 0.01 ^{h}	178.27 ± 7.14f^{g}	10.78 ± 0.45^{fg}
Monta	6.16 ± 0.01^{ab}	8.00 ± 0.11^{d}	1.74 ± 0.04^{de}	0.13 ± 0.01^{bcde}	2.93 ± 0.08^{e}	0.02 ± 0.003^{a}	0.18 ± 0.02^{bcd}	1.27 ± 0.02^{f}	1.36 ± 0.01^{g}	232.86 ± 10.43^{d}	12.65 ± 0.39^{d}
Prelma	6.12 ± 0.02^{bc}	7.53 ± 0.12^{e}	1.99 ± 0.03^{bc}	0.09 ± 0.01^{e}	3.52 ± 0.07^{cd}	0.01 ± 0.002^{b}	0.22 ± 0.02^{ab}	1.48 ± 0.08^{cde}	1.03 ± 0. 01^{i}	266.94 ± 12.47^{c}	13.45 ± 0.57^{cd}
Rigonda	5.93 ± 0.02^{e}	7.98 ± 0.09^{d}	1.34 ± 0.03^{f}	0.11 ± 0.02^{cde}	3.78 ± 0.09^{b}	0.01 ± 0.001^{b}	0.21 ± 0.01^{abc}	1.57 ± 0.07^{bcd}	1.44 ± 0.01^{f}	152.92 ± 6.23^{gh}	11.23 ± 0.45^{ef}
Viviana	6.09 ± 0.02^{cd}	9.54 ± 0.14^{c}	1.76 ± 0.08^{de}	0.13 ± 0.03^{bcde}	2.93 ± 0.04^{e}	0.02 ± 0.001^{a}	0.19 ± 0.01^{bcd}	1.27 ± 0.01^{f}	22.27 ± 0.15^{d}	219.69 ± 9.44d^{e}	14.82 ± 0.47^{bc}

The results are the mean values (n = 3) with standard deviation. The values with different superscript letters in the same column are significantly different ($p < 0.05$)

Fang *et al.* (2022b) reported total phenol content in the range of 370–550 mg 100 g^{-1} DW in boiled potatoes depending on the variety.

The highest antiradical activity was in the potato variety Blue Congo and the lowest in Imanta, which was also the lightest variety studied, and the overall data was consistent with the total phenol content. The high phenol content in boiled potatoes of the varieties Blue Congo and American Rose, which, as mentioned above, are both dark-coloured and contain anthocyanin pigments, aromatic phenolic compounds, and antioxidants, can be explained by the presence of anthocyanins (Campos & Ortiz, 2019). Antioxidant activity reflects the ability to inhibit all molecules with high oxidation-reduction potential, whereas antiradical activity characterises the ability of components to react with free radicals (Brainina *et al.*, 2019).

Physicochemical characteristics of pastry creams

Knowing that potatoes have a high nutritional value and a relatively neutral taste (Singh *et al.*, 2020), the idea arose to apply them in pastry cream production creating a product with enhanced nutritional (crude fibre, iron, potassium) and total phenol content. It was important to determine the effect of the potatoes on the pastry cream colour, texture and nutritional value. According to Hunjek *et al.* (2020), potato cultivar type had a significant influence on boiled potato sensory properties, such as taste, creaminess, moistness, etc. Moreover, it is necessary to take into consideration that new ingredients in recipes can affect sensory properties of the final product differently. Some chefs note that new interesting ingredients can help to balance flavour and taste (Palczak *et al.*, 2020), as well as to improve consumer acceptance of the new product and the sustainability of the resources used (David-Birman *et al.*, 2022).

Colour

Pastry creams with 30% potatoes differed significantly depending on potato variety used, especially when the potato varieties Blue Congo and American Rose were used – creams had a bluish-grey and pink colour, respectively (Figure 2).

The addition of potatoes to pastry cream can significantly influence the lightness and the yellowness (component b*) of the final product. An increase in the intensity of the colour yellow was observed in the creams with the potato varieties Viviana and Rigonda, whereas a significant decrease of the same component and an increase in the intensity of the colour blue was observed in the cream samples with the potato varieties American Rose and Blue Congo (Table 2).

In terms of colour, the most similar to the control cream were the creams with the potato varieties Monta and Imanta, for which the total colour difference ΔE was insignificant. The largest differences in colour compared to the control (ΔE) were established for the creams prepared with the potato varieties Blue Congo and American Rose, which added blue and rose tones, respectively. These creams were darker than the control sample. The cream with the potato variety American Rose was characterised by the coordinates of the red component, whereas for other creams this coordinate corresponded to the green tones. Thus, the selection of a suitable potato variety could help to obtain pastry cream of a specific colour. Similar data on significant discoloration of pastry creams

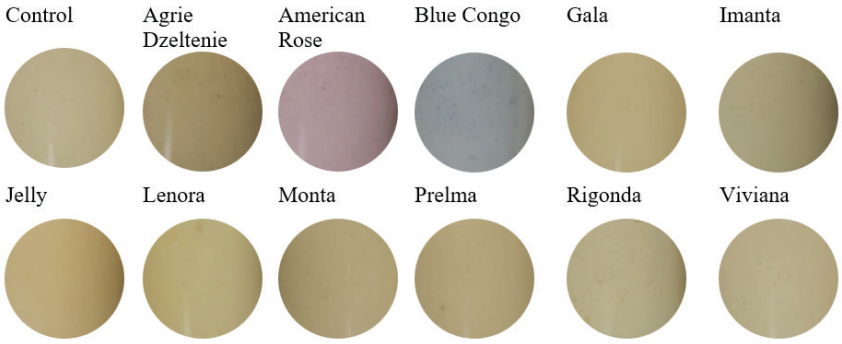


Figure 2. Colour of pastry creams with potato additive.

Table 3

Colour components of pastry creams with 30% potato additive and control cream sample

Cream sample	Colour components			DE
	L*	a*	b*	
Control	68.15 ± 0.74^{d}	-5.86 ± 0.24^{efgj}	15.74 ± 1.28^{cg}	-
Agrie Dzeltenie	60.42 ± 1.03^{ef}	-3.13 ± 0.68^{bc}	15.68 ± 1.02^{d}	8.15
American Rose	55.82 ± 1.05^{j}	0.32 ± 0.48^{a}	5.12 ± 0.59^{i}	17.37
Blue Congo	57.39 ± 1.24^{i}	-4.32 ± 0.13^{efj}	2.76 ± 0.52j	16.90
Gala	59.99 ± 0.56^{eg}	-4.49 ± 0.20^{egj}	15.07 ± 0.44^{d}	8.25
Imanta	69.17 ± 0.45^{c}	-5.05 ± 0.07^{h}	14.00 ± 0.46^{efg}	2.20
Jelly	59.10 ± 0.73^{fg}	-2.67 ± 0.48^{bc}	10.28 ± 1.07^{gh}	11.00
Lenora	60.92 ± 3.38^{ef}	-4.11 ± 1.38^{cdefgj}	12.37 ± 3.12^{cefgh}	8.12
Monta	68.94 ± 0.47^{c}	-5.06 ± 0.32^{h}	17.36 ± 0.34^{b}	1.99
Prelma	57.56 ± 0.61^{h}	-3.93 ± 0.15^{de}	13.60 ± 0.73^{efg}	10.93
Rigonda	71.82 ± 0.34^{b}	-5.52 ± 0.06^{i}	18.62 ± 0.35^{a}	4.72
Viviana	72.45 ± 0.44^{a}	-5.39 ± 0.22^{i}	18.83 ± 0.46^{a}	5.36

The results are the mean values (n = 10) with standard deviation. The values with different superscript letters in the same column are significantly different ($p < 0.05$).

have been obtained in the Horincar *et al.* (2020) study, in which an anthocyanin containing additive (from eggplant) was added to the pastry creams; the creams became darker, the intensity of the yellow colour decreased significantly and the intensity of the red colour increased significantly as a result of the addition of an anthocyanin-containing additive.

pH of the pastry creams

The pH values of the pastry creams with boiled potatoes were close to neutral, similar to the pH of the control cream; it can be concluded that the addition of 30% potatoes with a lower pH (~ 6) did not affect the overall pH of the cream. No significant differences in the pH of the cream samples analysed were observed. The pH in the pastry creams with potatoes varied from 6.69 to 6.99.

The obtained pH values were slightly higher than those mentioned in literature (Smith *et al.*, 2004) for creams used in baked bread products (pH 5.8–6.6), but this is most likely influenced by the ingredients included in the recipe and preparation, as well as no data being available in literature on creams with potatoes.

Effect of potatoes on the pastry cream texture

From a culinary point of view, it is important that the cream is strong enough to retain its shape and can be used as a filling in confectionery products. Potatoes affected pastry cream firmness (Figure 3), which indicated the force required to cause a certain deformation in the pastry cream samples (Horincar *et al.*, 2020).

Four of the eleven potato varieties studied formed sufficiently firm creams with 30% potatoes and were comparable to the firmness of the control cream sample. Creams with the potato varieties Imanta and American Rose were comparable to the control cream and there were no significant differences in their firmness. Pastry creams with the boiled potatoes of Rigonda and Viviana formed firmer textures than the control, which was also considered acceptable. Whereas creams with potatoes of the Lenora, Jelly, Blue Congo and Prelma varieties were too soft. The pastry cream firmness largely depends on the gel structure formed by various ingredients. According to the study of Zaidul *et al.* (2006), amylose content, phosphorous content and starch granule size play a significant role in the starch pasting properties. Phosphorus exists in the form of phosphate monoesters and phospholipids within different starches. The phosphate monoesters form covalent bonds with the amylopectin proportion of the starch, enhancing viscosity in the starch pastes (Zaidul *et al.*, 2007). The current study did not reveal direct correlations between texture of pastry cream and any ingredient of boiled potatoes. However, the pastry cream samples with the most acceptable firmness incorporated potatoes of the varieties Imanta having high starch content, American Rose with high phosphorus content, and Rigonda with high amylose content. During pastry cream production, it is important that the cream is not too firm and does not become stiff upon cooling, as this may make it difficult to use in confectionery.

The adhesiveness of the pastry creams with potatoes (Figure 4) showed similar tendencies as in the case of cream firmness. Adhesiveness indicates the outflow of samples (Horincar *et al*., 2020; Nguyen *et al*., 2015). Also, for this attribute, four of the potato varieties mentioned above showed satisfactory results compared to the control sample. Cream with the potato variety Viviana exhibited the highest

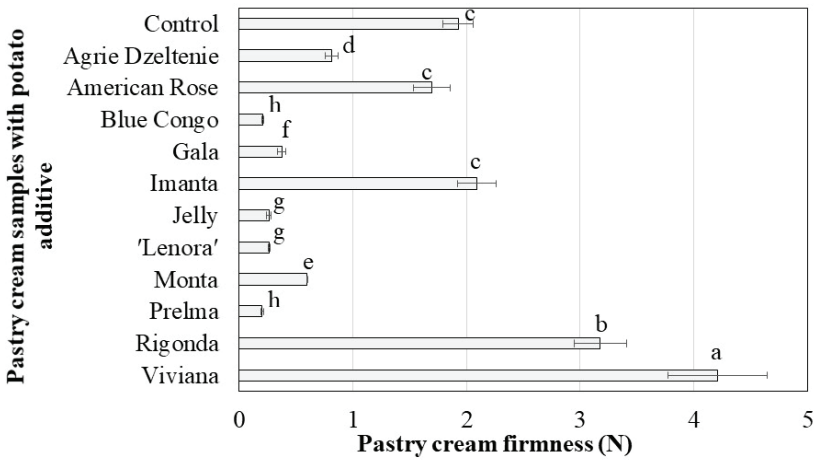


Figure 3. Pastry cream firmness.

The results are the mean values (n = 10) with standard deviation, and the values with different letters are significantly different ($p < 0.05$).

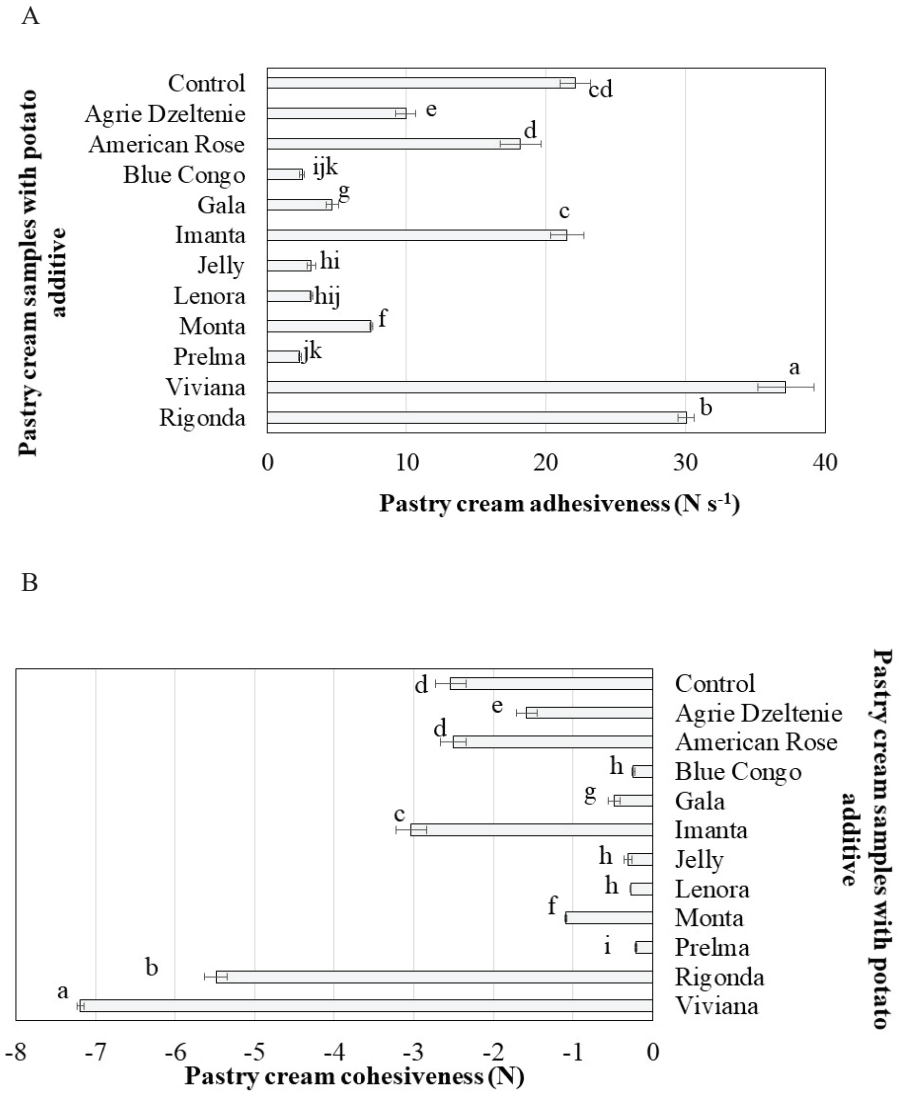


Figure 4. Pastry cream adhesiveness (A) and cohesiveness (B).

The results are the mean values (n = 10) with standard deviation, and the values with different letters are significantly different ($p < 0.05$).

adhesiveness, followed by the cream with the potato variety Rigonda, whereas no significant differences were found between the cream with potato variety Imanta and the control sample.

Four samples (American Rose, Imanta, Rigonda and Viviana) showed acceptable binding values (Figure 4). The cohesiveness of the cream with other potato varieties studied was not sufficient to form a cream suitable for pastry filling. Our study did not allow us to conclude which component was responsible for the texture formation. Protein content of the potatoes (Table 2) correlated with pastry cream texture. Only dietary fibre may have some impact on the pastry cream's textural properties. However, further studies on soluble and insoluble parts of dietary fibre are necessary.

In present research, a significant impact of boiled potatoes on the textural properties of pastry cream was suggested, similar to the research of Horincar *et al.* (Horincar *et al*., 2020) where microencapsulated bioactive compound powder from eggplant peel had a significant influence on the pastry cream's textural properties.

It can be concluded that four of the eleven potato varieties, Viviana, Rigonda, Imanta, and American Rose, may be considered suitable for use in pastry cream production and are able to ensure sufficient textural properties of the ready product. In further studies, creams containing potatoes of the varieties Viviana, Rigonda, Imanta, and American Rose were used to evaluate the quality parameters of the prepared creams.

Table 4

Chemical composition and energy values of the pastry creams

Cream sample	Crude protein (g 100 g^{-1} DW)	Crude fibre (g 100 g^{-1} DW)	Fats (g 100 g^{-1} DW)	Crude ash (mg 100 g^{-1} DW)	Minerals (mg 100 g^{-1} DW)				TPC (mg GAE 100 g^{-1} DW)	$DPPH^{\cdot}$ (mM TE 100 g^{-1} DW)
					Ca	P	K	Fe		
Control	10.14 ± 0.11^{a}	0.35 ± 0.02^{c}	19.34 ± 0.23^{a}	1.33 ± 0.02^{d}	0.17 ± 0.01^{a}	0.21 ± 0.02^{a}	0.25 ± 0.02^{b}	1.22 ± 0.02^{d}	152.65 ± 6.32^{d}	32.22 ± 0.81^{c}
With American Rose	8.72 ± 0.14^{c}	0.65 ± 0.07^{a}	19.72 ± 0.18^{a}	1.89 ± 0.01^{a}	0.15 ± 0.01^{b}	0.21 ± 0.01^{a}	0.57 ± 0.01^{a}	1.23 ± 0.01^{d}	244.79 ± 10.24^{a}	45.70 ± 1.85^{a}
With Imanta	8.80 ± 0.17^{c}	0.59 ± 0.03^{ab}	18.14 ± 0.11^{c}	1.89 ± 0.03^{a}	0.13 ± 0.01^{c}	0.21 ± 0.01^{a}	0.56 ± 0.08^{a}	1.28 ± 0.02^{c}	201.98 ± 9.09^{b}	41.53 ± 1.76^{ab}
With Rigonda	9.42 ± 0.09^{b}	0.35 ± 0.01^{c}	18.87 ± 0.14^{b}	1.75 ± 0.02^{b}	0.12 ± 0.02^{cd}	0.21 ± 0.01^{a}	0.50 ± 0.07^{a}	1.51 ± 0.01^{a}	173.72 ± 7.62^{cd}	39.12 ± 1.56^{b}
With Viviana	9.03 ± 0.09^{c}	0.55 ± 0.02^{b}	19.44 ± 0.11^{a}	1.63 ± 0.09^{c}	0.14 ± 0.01^{bc}	0.20 ± 0.02^{a}	0.45 ± 0.04^{a}	1.34 ± 0.01^{b}	191.21 ± 8.06^{bc}	41.83 ± 1.91^{ab}

The results are the mean values (n = 3) with standard deviation. The values with different superscript letters in the same column are significantly different ($p < 0.05$).

Effect of potatoes on the nutritional value of pastry cream

The addition of potatoes increased the fibre content of the cream twofold (with the potato variety American Rose), which may be considered as a health-promoting factor. Compared to the control sample, all creams with added potatoes showed a decrease in protein content, which can be explained by the changes in the proportions of ingredients in the formulation.

According to the results (Table 4), the addition of potatoes in pastry cream can double the total potassium content compared to the control sample. A significant increase in iron content in the pastry creams, especially with the incorporation of the potato varieties Rigonda and Viviana, was observed due to the use of plant material containing these minerals (Table 2). Similar results were obtained in studies on the influence of potato flour on the quality of steamed bread, where elevated ash content was obtained in potato-steamed bread in comparison to wheat steamed bread (Liu *et al.,* 2016). Calcium content in the developed pastry creams with potato was significantly lower (Table 4) than its content in the control sample, because of a relatively high Ca content in wheat flour in comparison to potato (Rahman *et al.*, 2015).

The highest total phenol content and antiradical activity were determined to be in the pastry cream samples made with the potato variety American Rose (244.79 ± 10.24 mg GAE 100 g^{-1} and 45.70 ± 1.85 mM TE 100 g^{-1}, respectively), which indicated 1.6 times higher total phenol content and 1.4 times higher antiradical activity compared to the control sample (152.65 ± 6.32 mg GAE 100 g^{-1} and 32.22 ± 0.81 mM TE 100 g^{-1}, respectively). Overall, total phenol content and antiradical activity were significantly higher in all pastry cream samples with potatoes, in comparison with pastry cream with wheat flour. For a deeper understanding of specific phenols having antiradical activity, further studies are required, because the selected colorimetric method is only suitable for total phenol determination. In addition, a Folin-Ciocalteu reagent can reduce other non-phenolic compounds. Some research data is available about the use of potatoes in the food industry altering phenol content and exhibiting health-promoting effects in humans (Akyol *et al.*, 2016). Five times the total phenol content and eleven times the antiradical activity was determined to be in blends with sweet potato for making wheat bread in comparison to wheat (de la Barca *et al.*, 2022).

Limitations of the study

In preliminary experiments, the determination of optimum potato proportion in pastry cream was done with the potato variety Imanta. The determined proportion (30% of cream mass) was subsequently used for the other 10 varieties. Optimally, the proportion would have been established for each variety, which would lead to a huge number of analyses. Therefore, some potato varieties could have a better performance at different proportion than the one selected in this study.

Additional analysis of starch granule size and gelatinisation temperature could have given

better insights in the gelling mechanism and better explanation of the textural properties.

Conclusions

The effect of potatoes on pastry cream's quality attributes is variety dependent. Therefore, the selection of the most suitable varieties among those available is required. The inclusion of 30% potatoes in the formulation of pastry cream allowed for double the fibre and potassium content. The potato variety American Rose significantly increased phenolic content and antiradical activity of the pastry cream, additionally giving a specific colour to the final product. Potatoes can be used as a substitute for wheat flour in gluten-free pastry cream production, providing acceptable texture and increasing the nutritional value of the final product.

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