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Chemical Composition of Potato Varieties Grown at Different Cropping Seasons for Industrial Processing

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Abstract

Potato (*Solanum tuberosum* subsp.) is an herbaceous plant whose commercial product is the tuber (edible part). The acceptance of tubers for industrial processing as French fries (sticks) or chips depends on their physicochemical characteristics, mainly the reducing sugar content. Therefore, the aim of this work was to evaluate tubers of the varieties Asterix and Colorado, planted in the summer season, and Asterix and Markies, planted in the winter season, regarding their amylose content, reducing sugars, and other physicochemical characteristics that could influence potato quality. The samples consisted of cultivars produced in the Alto Paranaíba region – Minas Gerais State, from the 2010 summer crops and 2011 winter crops. Physicochemical evaluations demonstrated that it cannot be definitively stated that the different planting seasons (summer and winter) influenced the quality of the analyzed varieties. The Asterix variety (winter crop) showed better results for the evaluated parameters, while the Asterix and Colorado varieties (summer crops) would not be suitable for industrial processing due to their high content of reducing sugars and low dry matter content.

Keywords: Tuber, Asterix; Colorado; Proximate Composition; Reducing Sugars; Amylose

Introduction

Potato (*Solanum tuberosum* L.) is the third most important food crop on the planet, the leading non-grain commodity, and the most commercially important vegetable for Brazil due to its high yield potential and nutritional properties. In addition to its globally recognized carbohydrate content, which constitutes about 80% of total solids, potato features a protein content twice as high as that of cassava; it is a good source of vitamin C and some B-complex vitamins, especially niacin, thiamine, and vitamin B6, as well as a good source of phosphorus, magnesium, and potassium [1].

Potato harvesting can be manual, semi-mechanized, or mechanized, depending on the area and the producer's level of technology. The simplest harvesting method for small areas or those with rugged terrain involves the use of hoes. For larger areas with flat terrain, harvesters can be used; these perform the entire operation of unearthing the tubers and separating them from the soil and plant debris, leaving them ready for grading and packaging. In Brazil, it is common to use furrowers and diggers-available in various types and brands—that bring the tubers to the surface, where they are then gathered by hand and packed into bags right in the field [2].

To be considered of high quality, potatoes must meet minimum characteristics, such as being whole, healthy, firm, with normal external moisture, and free from injuries, insect punctures, adhered soil, and severe deformations. Common potato is defined as that which presents some defect in its quality. Industries in the processed potato sector require higher quality potatoes, needing a minimum sales volume and purchasing availability throughout the year. However, the development of these industries is hindered by the lack of quality raw materials and irregular supply from producers [3].

The acceptance of potatoes for processing into French fries or chips largely depends on the reducing sugar content, as it directly impacts the coloration of the final product. According to the literature, higher contents of reducing sugars in potatoes result in greater browning during the frying process due to the Maillard reaction, consequently leading to higher consumer rejection. The generally accepted reducing sugar content for processing potatoes is below 0.035% on a fresh weight basis for chips and below 0.12% on a fresh weight basis for French fries [4].

In addition to the reducing sugar content, potato cultivars for processing must exhibit a high dry matter content, around 20 to 24%. In order to obtain raw materials with reduced reducing sugar content and high dry matter content, studying harvesting times and methods becomes essential [5]. Therefore, the objective of this work was to evaluate differences in the chemical composition of Asterix, Colorado, and Markies potato varieties cultivated in different seasons of the year (summer and winter).

Material and Methods

Sample Acquisition

The samples consisted of potato tubers (*Solanum tuberosum* L.) of the varieties Asterix (cultivated in the southern region) and Colorado (cultivated in Minas Gerais in the Alto Paranaíba region) from the 2010 summer crop, and Asterix and Markies (cultivated in Minas Gerais in the Alto Paranaíba region) from the 2011 winter crop. The four samples were harvested at the end of the crop cycle at 120 days, and for each treatment, 2 kg of tubers were collected, with sampling performed in nine replicates.

Sample Preparation

The tubers were washed, dried with paper towels, peeled, cut in half transversally, and sliced into slices of approximately 3 mm. The slices were arranged on aluminum trays and taken to a drying oven at 60 °C for 48 hours. After drying, the slices were ground in a micro-mill. The ground samples were packed in capped jars, stored in a dry, cool place, and protected from light.

Physicochemical Analyses

i. **pH:** Determined using a digital potentiometer, taking readings directly from the in natura sample homogenized with water at a 1:1 ratio [6].

ii. **Soluble Solids:** Determined using drops of the in natura sample homogenized with water at a 1:1 ratio in a digital refractometer, with automatic temperature compensation at 25 °C, expressed in °Brix [7].

iii. **Moisture Content:** Determined by the gravimetric method using heat, based on the weight loss of the material subjected to heating at 105 °C until constant weight [7].

iv. **Dry Matter:** Calculated by the difference between 100 and the moisture content percentage [7].

v. **Crude Protein:** Determined by the Kjeldahl method through the determination of total nitrogen in the sample, multiplying it by the factor 5.75 used for plant proteins [7].

vi. **Fixed Mineral Residue (Ash):** Determined by calcination of the sample in a muffle furnace at 550 °C until light-colored ash was obtained [6].

vii. **Crude Fiber Fraction:** Determined according to the gravimetric method after acid digestion [8].

viii. **Ethereal Extract (Lipids):** Determined by extraction using the Soxhlet method (gravimetric) based on the amount of material solubilized by the solvent [7].

ix. **Carbohydrates:** Calculated by the difference between 100 and the sum of the percentages of moisture, protein, lipids, fiber, and ash [8].

x. **Reducing Sugars:** Quantified as glucose using the Somogyi-Nelson method, with spectrophotometric reading at 535 nm [10].

xi. **Amylose Content:** Determined by the colorimetric method with modifications, with spectrophotometric reading at 610 nm [11].

xii. **Starch Content:** Estimated by Keer's formula through the quantification of non-reducing sugars, calculated by the difference between carbohydrates and reducing sugars, expressed as glucose [12].

Experimental Design and Statistical Analysis

The experimental layout was a Completely Randomized Design (CRD) consisting of four treatments and nine replicates per treatment. Experimental results were evaluated by Analysis of Variance (ANOVA) and Means Test (Scott-Knott) at a 5% probability level, using the SISVAR software [13].

Results And Discussion

Proximate Composition

Table 1 presents the means of the proximate composition of potato varieties Asterix (summer and winter crops), Colorado (summer crop), and Markies (winter crop).

Regarding moisture content, the Colorado variety (summer crop) differed from the others, showing the highest content (82.98%), while the Asterix variety (summer crop) showed the lowest content (79.47%). The Asterix and Markies varieties (winter crop) showed intermediate values and did not differ significantly from each other at the 5% significance level. The chemical composition of potatoes regarding moisture can range from 63% to 87%. Literature data [9] shows that Brazilian potatoes have around 82.9% moisture content, while other authors found 81.47% for the Asterix variety [12].

For dry matter content, the Asterix variety (summer crop) showed the highest content (20.53%) and the Colorado variety (summer crop) showed the lowest content (17.01%), differing significantly from each other. The Asterix and Markies varieties

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(winter crop) presented intermediate values and did not differ significantly from each other. The dry matter levels found for the Asterix (winter and summer crops) and Markies (winter crop) varieties are consistent with literature recommendations stating that dry matter content should be higher than 18% to obtain high-quality French fries. However, some studies in the literature evaluating the physicochemical and frying quality of potato tubers in the winter crop found lower dry matter contents, such as 16.70% for Asterix and 17.20% for Markies [14].

In industrial unit operations, a higher dry matter content reduces the thermal load required for water evaporation, thereby optimizing the processing time. The Asterix Summer cultivar exhibited the highest percentage of dry matter, followed by the Asterix Winter and Markies varieties. In the processing of potato chips or French fries, dehydration occurs by mass transfer during deep-fat frying. Potatoes with a high total solids content exhibit a lower oil uptake rate, resulting in a finished product with improved digestibility [15].

With respect to lipid content, the Asterix and Colorado varieties (summer crop) showed no significant difference from each other, averaging 0.06%, which is below the values found for the Asterix and Markies varieties (winter crop) that also did not differ from each other, averaging 0.20%. The average lipid content reported in the literature can vary from 0.02 to 0.20% in tubers. The levels found were higher than those reported by some authors, who observed lipid contents ranging from 0.06 to 0.11% for the Asterix cultivar.

The lipid contents quantified in this study were higher than those reported by Jorge and Lunardi [16], who observed 0.1% lipids in cv. Monalisa; Silva, Cerqueira, and Silva [17], who stated that fresh potatoes contain approximately 0.26% and Stertz, Rosa, and Freitas [18], who obtained 0.14%. Bregagnoli [3] observed that lipid levels ranged from 0.07% to 0.08% for cv. Atlantic and from 0.06% to 0.11% for cv. Asterix, which are values close to those determined in the present study.

For fiber content, the Asterix variety (winter crop) showed the highest mean (0.85%), differing significantly from the Asterix and Colorado varieties (summer crop) and Markies (winter crop) at a 5% probability level. Other authors found lower values, reporting 0.54% for Asterix and Markies varieties grown in the winter crop.

The fiber contents obtained on a dry basis (Table 1) were lower than the range reported by Burton [19], who states that potatoes can exhibit from 1.0% to 10% fiber on a dry basis. Fernandes et al. [14] found a value of 0.54% for the Asterix and Markies cultivars grown during the winter crop, which are lower than those determined in the present study. Furthermore, the Brazilian Table of Food Composition [9] indicates that Brazilian potatoes present 1.2% of dietary fiber.

Regarding ash contents, the Markies (winter crop) and Colorado (summer crop) varieties showed no significant difference from each other. The Asterix varieties from both summer and winter crops presented an average of 0.84%, differing from the others. The obtained ash contents were higher than those described by the Brazilian Table of Food Composition [9], which reports 0.6% ash and Trindade [20] reported na ash content range from 0.40% to 0.87% across the analyzed cultivars. The author further states that acceptable ash leves for potatoes range from 0.44% to 1.90%.

The Asterix and Markies varieties (winter crop) showed the highest average for protein content (2.28%) and differed significantly from the Asterix and Colorado varieties (summer crop), which presented an average of 0.22%. Previous studies in the literature reported a protein content of 1.85% for the Asterix variety. Belanger et al. [21] cited by Quadros [12], states that a factor contributing to lower protein content during tuber development is the increase in average mass and starch acumulation, with decrease the protein concentration. Regarding starch quantification, the Asterix and Colorado summer crop cultivars exhibited higher values than the Asterix and Markies winter crop varieties.

For total carbohydrates, the Asterix variety (summer crop) showed the highest mean (18.71%) and a significant difference from the others. The Colorado (summer crop) and Markies (winter crop) varieties did not present significant differences between each other. The carbohydrate values obtained are in line with literature reports stating that carbohydrates correspond on average to 18.4% of the fresh tuber (ranging from 8.0 to 29.4%), being one of the components that most heavily influence potato quality for consumption or industrial processing.

Reducing Sugars

Table 2 presents the means for reducing sugar content of Asterix and Colorado (summer crop) and Asterix and Markies (winter crop) potato varieties.

Regarding reducing sugars, the Asterix and Colorado varieties (summer crop) presented the highest average (0.45%), with a significant difference from the Asterix and Markies varieties (winter crop). According to the literature, reducing sugar contents below 0.1% on a dry matter basis indicate that the potato is suitable for frying, as seen in the winter crops of Asterix and Markies ; values between 0.1 and 0.3% are considered of questionable quality and contents above 0.3%, as observed in the summer crops of Asterix and Colorado, are unsuitable for frying.

Reducing sugar contents below 0.1% on a dry matter basis indicate high suitability for frying, as observed in the Asterix Inverno and Markies Inverno cultivars. Contents between 0.1% and 0.3% are considered of questionable quality, whereas levels above 0.3% such as in the Asterix summer and Colorado summer cultivars are unsuitable for frying [22]. For potato chips, the acceptable reducing sugar threshold must be below 0.2%, while for French fry production, it must be below 0.4% [4,23]."

Table 1: Proximate composition means of Asterix and Colorado varieties

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from the summer crop and Asterix and Markies from the winter crop.

Variety	Moisture (%)	Dry Matter (%)	Lipids (%)	Fibers (%)	Ash (%)	Proteins (%)	Carbohydrates (%)
Asterix (summer)	79.47c	20.53a	0.08b	0.64b	0.84b	0.24b	18.71a
Colorado (summer)	82.97a	17.02c	0.05b	0.49b	0.89a	0.19b	15.38b
Asterix (winter)	81.87b	18.13b	0.22a	0.84a	0.84b	2.22a	13.99c
Markies (winter)	81.06b	18.93b	0.19a	0.59b	0.93a	2.33a	14.87b

*Means followed by the same letter in the same row do not differ significantly from each other by the Scott-Knott test at a 5% significance level.

Table 2: Reducing sugar content of Asterix and Colorado varieties from the summer crop and Asterix and Markies from the winter crop.

Variety	Reducing Sugars (%)
Asterix (summer)	0.483a
Colorado (summer)	0.428a
Asterix (winter)	0.160b
Markies (winter)	0.074b

*Means followed by the same letter in the same column do not differ significantly from each other by the Scott-Knott test at a 5% significance level.

Table 3: Amylose and starch content of Asterix and Colorado varieties from the summer crop and Asterix and Markies from the winter crop.

Variety	Amylose Content (%)	Starch Content (%)
Asterix (summer)	18.73a	82.63a
Colorado (summer)	18.32a	81.60a
Asterix (winter)	19.08a	70.96b
Markies (winter)	18.06a	72.69b

*Means followed by the same letter in the same column do not differ significantly from each other by the Scott-Knott test at a 5% significance level.

Table 4: pH and total soluble solids means of Asterix and Colorado varieties (summer crop) and Asterix and Markies (winter crop).

Variety	pH	Soluble Solids (°Brix)
Asterix (summer)	5.85b	2.70b
Colorado (summer)	5.80b	2.56b
Asterix (winter)	5.73c	2.55b
Markies (winter)	6.00a	3.93a

*Means followed by the same letter in the same column do not differ significantly from each other by the Scott-Knott test at a 5% significance level

Fernandes et al. [14], when evaluating the physicochemical and frying quality of potato tubers from the winter crop, found reducing sugar contents of 0.17% for the Asterix cultivar and 0.18% for the Markies variety on a fresh matter. This corresponds to approximately 0.03% reducing sugars on a dry matter, values that are lower than those determined for the respective cultivars in the present study (Table 2).

Amylose and Starch

Table 3 presents the means for amylose and starch contents of Asterix and Colorado varieties (summer crop) and Asterix and Markies (winter crop).

For amylose content, the evaluated varieties showed no significant differences among each other, with an overall average of 18.55%. Although the percentage values found for amylose are below those reported by other authors (around 25.4%), this behavior is justified by the fact that the starch was not previously defatted for analysis. A well-known property of amylose is its ability to form a paste (or gel) after the starch granule has been

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cooked, that is, gelatinized. This behavior is prominent in specific starches containing higher amylose contents. A higher amylose content leads to a greater degree of starch gelatinization, which subsequently reduces the firmness of the matrix.

Regarding starch levels, there was a significant difference between the different planting seasons. The Asterix and Colorado varieties (summer crop) did not differ from each other and presented the highest average (82.11%), but differed significantly from the Asterix and Markies varieties (winter crop), which had a lower average (71.83%). The starch levels found differ from values described in previous studies, which reported 78.20% for the Asterix variety and 74.40% for the Markies variety.

The starch contents presented in Table 4 differ from the 78.20% reported by Fernandes et al. [14] for the Asterix cultivar. However, the value of 72.70% obtained for the Markies variety is close to the 74.40% found by Fernandes et al. [14], who also state that starch represents 60% to 80% of the tubers' dry matter and directly influences the texture of the processed products.

pH and Total Soluble Solids

Table 5 presents the means for pH and total soluble solids of Asterix and Colorado (summer crop) and Asterix and Markies (winter crop) potato varieties.

For pH determination, the Markies variety (winter crop) showed the highest mean and differed significantly from the Asterix variety (winter crop). The Asterix and Colorado varieties (summer crop) presented an average pH of 5.82, showing no significant difference between each other. The obtained pH values differ from the 6.18 found by some authors for the Asterix variety. The same author found a pH value of 6.40 for the Markies variety, which is relatively close to the pH 6.00 found in the present study for the same variety.

The pH of the tuber pulp indicates the likelihood of deterioration due to microbial growth and enzymatic activity. The lower the tuber pulp pH, the lower the probability of fermentation. Thus, pH can regulate enzymatic activity, particularly phosphorylase enzymes (responsible for starch breakdown into glucose-1-P) and invertase (responsible for sucrose breakdown into glucose and fructose), which interfere with the final quality of the tubers.

Regarding Total Soluble Solids (SS) values, the Markies variety (winter crop) presented the highest mean (3.93), with a significant difference from the others. The Asterix and Colorado varieties (summer crop) and Asterix (winter crop) did not differ from each other, averaging 2.61 (noting that the 5.79 in the original text likely conflicts with the tabular data presented) [24]. The soluble solids values found in this work were lower than those cited in similar studies, where authors found values of 4.25 for the Asterix variety and 5.27 for the Markies variety.

Other literature reports state values around 5.12 for the Asterix variety and mention that studies evaluating 18 potato clones obtained soluble solids ranging from 3.91 to 6.72. Total soluble solids content is used as an indirect measure of sugar content, ranging from 2% to 25% depending on species, maturation stages, and climate. For potatoes intended for frying, higher soluble solids content is expected.

Cardoso [25] reports that that the Total Soluble Solids content is used as an indirect measurement of sugar content, ranging from 2% to 25% depending on the species, maturity stages, and climate. Soluble solids indicate the amount of substances dissolved in the vacuolar sap (sugars, vitamins, phenolics, pectins, and organic acids). For potatoes intended for processing, a higher total soluble solids content is required to provide better suitability for frying.

Conclusion

Based on the analytical results obtained, it cannot be definitively stated that the different planting seasons (summer and winter) influenced the quality of the analyzed varieties in a totally negative or positive way. Significant differences were detected between planting seasons for the parameters moisture, dry matter, lipids, proteins, reducing sugars, starch content, and pH, but no differences were detected for fiber, ash, carbohydrates, amylose, and soluble solids. To draw a solid conclusion regarding the effect of planting seasons on potato quality, further comparative studies are required, taking into account differences in crop conditions and soil analysis.

Finally, it is concluded that the Asterix and Colorado varieties (summer crop) would not be suitable for industrial processing due to their high content of reducing sugars, and the Colorado variety furthermore for presenting a low dry matter content.

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