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Minimum sampling number to determine inadequate storage conditions of the potato cv. Markies for frying processing

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Abstract

Potato tubers destined for frying processing are stored at low temperatures to reduce sprout losses and diseases incidence. This study aimed to determine the proper minimum sampling number of potato cv. Markies to assess inadequate storage conditions. Tubers of the potato cv. Markies were stored at 6 and 8 °C for 180 days and fried. The potato sticks coloring was visually determined based on the USDA international grade scale. The repeatability coefficients were estimated by the analysis of variance methods (ANOVA), main components (MC), correlation matrix (PCCo), covariance (PCCv), and structural analysis (SA) based on the correlation matrix. The potato sticks colors of the cv. Markies differed according to the storage temperature. The minimum number of potato sticks required to determine inadequate storage of potato tubers destined for frying with 99% precision are 37, 50, 50, and 50, and with 95% precision are 7, 10, 10, 10, and 10 according to the ANOVA, PCCo, PCCv and SA methods, respectively. The difference in the potato sticks colors according to the storage temperature allows the use of the repeatability coefficient and the minimum sampling number indication in the identification of inadequate storage conditions. The minimum number of fried sticks for sampling and identification of inadequate storage of potato cv. Markies with 95% precision is 10.

Keywords: Processing quality, Postharvest, Sweetening

Introduction

Potato tubers for processing are stored at low temperatures to reduce losses caused by sprouting, wilting, and diseases (Xiao et al., 2018). Nevertheless, storage below 8°C promotes the accumulation of reducing sugars (fructose and glucose) (Bali et al., 2018).

The aldehyde groups of the reducing sugars (RS) react with α-amino acids of nitrogen compounds (Hemmler et al., 2018). Subsequent decomposition of RS is the result of a wide and complex network of chemical reactions producing continuously new intermediates that feed the *Maillard* reaction. Many of these intermediates are highly reactive and exponentially increases the *Maillard* reaction chemical diversity. This makes the *Maillard* reaction a very complex collective reaction, capable of producing thousands of distinct chemical compounds from few early precursors (Hemmler et al., 2018).

Acrylamide is one of the compounds formed during the frying process or dehydration at high temperatures (Govindaraj et al., 2015). This is a potent neurotoxin and a carcinogen of the group 2A (Kumar et al., 2018), that can cause a bitter taste in the french fries (Jansky & Fajardo, 2014). The acrylamide and other products of non-enzymatic *Maillard* reaction leads to irreversible protein modifications in vivo associated with a wide range of diseases (Hellwig & Henle, 2014). Therefore, the quality of tubers destined for industrial processing is conditioned by the sugars (total soluble sugar, non-reducing sugar, and reducing sugar) accumulation, which depends on storage conditions (period and temperature) (Sun et al., 2018) and cultivar.

Tubers stored at temperatures below 8 °C are usually discarded for processing. Methods for sweetening identification include Physico-chemical (sugar quantification), enzyme (activity quantification

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of enzymes related to carbohydrate metabolism), and molecular (gene identification cold-induced expression) parameters (Oladoye et al., 2016). These methods are expensive, time-consuming, and require skilled workers. However, the frying process can reveal tuber storage conditions, aiding in a rapid decision-making in the purchase or rejection of the potatoes.

All varieties used in the frying process market today are susceptible to cold-induced sweetening (Sowokinos, 2001), differing only in intensity. The cv. Markies (Agria x Fianna) is the most used cultivar in fast-food networks worldwide, due to its low reducing sugars accumulation during long-term storage, which reduces darkening. This cultivar has good dormancy, low nitrogen requirement, high tolerance to water stress, late foliage maturity, and is resistant to *Fusarium coeruleum*, *Phytophthora infestans*, Yo potato virus, and the potato cyst nematode (*Globodera rostochiensis*) Ro1 (ADBH Potatoes, 2018).

Storage temperature control is still the best strategy to reduce cold-induced sweetening losses. Nevertheless, the industry requires faster and inexpensive tools and techniques to avoid losses caused by this problem. This study aimed to determine the minimum sampling number of potato sticks of cv. Markies to determine inadequate storage conditions.

Material and Methods

Potato tubers of the cv. Markies, were obtained in Araxá, Minas Gerais, Brazil (Latitude: 19° 35 '36' 'South, Longitude: 46° 56' 27 '' West, average temperature of 20 °C, 1626 mm annual precipitation), and harvested 120–130 days after planting. Tubers were stored at 6 and 8 ° C for 0, 60, 120, and 180 days. In each period, 5 tubers were peeled and cut into sticks. Ten sticks of each tuber were fried in a 3L capacity electric fryer (Ford®) for 3 minutes at 180 °C. The quantity of oil used was sufficient to reduce the temperature by immersing the sticks. The color of the potato sticks was assessed visually using a grade scale (United States Standards for Grades of Frozen French Fries Potatoes, 1994).

The repeatability coefficients were estimated by analysis of variance (ANOVA), main components (MC), based on correlation matrix (PCCo) and covariance (PCCv), and structural analysis (SA) based on the correlation matrix methods. The repeatability coefficient was estimated using the results of the analysis of variance with the model:

$$Y_{ij}= \mu + g_i + e_{ij}$$

Where: Y_{ij}= is observation for the i-th subsample; μ= mean; g_i= random effect of the i-th subsample under the influence of the permanent environment (i= 1, 2, ..., p); e_{ij}= effect of the temporary environment associated with the j-th measurement in the subsample (j= 1, 2, ...).

The repeatability coefficient was estimated by:

$$r= \hat{\rho}= \hat{Cov}(Y_{ij}, Y_{ij`})/\sqrt{\hat{V}(Y_{ij})\hat{V}(Y_{ij`})} = \hat{\sigma}^2_g/\hat{\sigma}^2_y= \hat{\sigma}^2_g/\hat{\sigma}^2+\hat{\sigma}^2_g$$

Where; Y_{ij} e Y_{ij}'= different measurements in the same individual.

The repeatability coefficients (*r*) estimates were obtained by the method of structural analysis based on the correlation matrix between each pair of temperatures (Mansour et al., 1981). The estimator was the arithmetic mean of phenotypic correlations between genotypes, considering each pair of measurements (Cruz, 2006a). The number of measurements (0) required to estimate the real value of individuals with the desired genotype determination value (R^2) was estimated by: $\eta_0= R^2(1-\hat{r}^2)/(1-R^2)\hat{r}$.

The genotypic determination coefficient (R^2), which represents the percentage of prediction confidence of the real value of selected individuals based on n measurements, was obtained by $R^2 = \eta r/1+r(\eta-1)$.

Estimates were obtained by the repeatability of the procedure using the GENES software (Cruz, 2006b).

A completely randomized design was used, in a subdivided plots scheme, with the plot of temperature and time as subplots. The experimental unit was composed of 10 sticks (n = 10) taken from a sample composed of 5 tubers.

Results and Discussion

The french fries sticks color differed (p>0.05) according to the storage temperature (Figure 1).

Repeatability estimates are important parameters in predicting the response stability to variables (sweetening) related to potato processing.

The difference of the french fries sticks color according to the storage temperature allows the use of the repeatability coefficient (r) and the indication of the minimum sampling number in the identification of inadequate storage for processing. The r is an important estimator that must be obtained to guarantee high precision estimates (Oliveira et al., 2018). Therefore, data obtained by these estimation methods provide information that can optimize production systems and reduce costs (Pivoto et al., 2018) through a rapid decision-making in the potato tubers purchase.

In the United States, the largest consumer of french fries worldwide, 15% of the annual potato output is discarded due to cold-induced sweetening (Clasen et al., 2016). Rapid decision-making in the acquisition of the potato tubers, is one of the most important steps in a company, in addition to planning, direction, and control activities. However, the perception of the managers in the decision-making should be as subjective as possible and based on technical criteria with maximum precision (Martin-Clouaire, 2017).

The r's magnitudes were similar among the different methods and were above 0.6. The r's obtained by the ANOVA were lower than those obtained by the other methods. The r's for the principal components methods based on correlation matrices (PCCo) and covariance (PCCv) and structural analysis based on the correlation matrix (SA) were equal (Table 1).

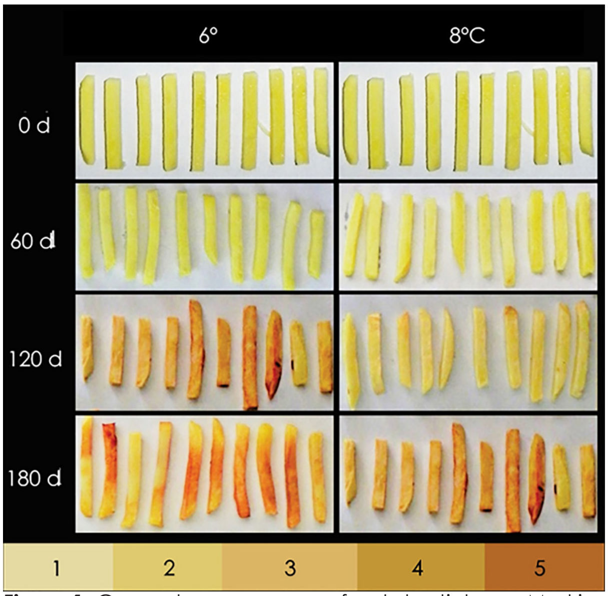

Figure 1. General appearance of potato sticks cv. Markies stored at 6 and 8 °C for 0, 60, 120 and 180 days. Grading manual for frozen fried potatoes (Scale of notes of coloring of the chips (United States Standards for Grades of Frozen French Fries Potatoes, 1994).

Table 1. Repeatability coefficients (r), determination (R^2) estimates and the minimum replication number by analysis of variance (ANOVA), main components based on correlation matrices (PCCo) and covariance (PCCv), and structural analysis in the correlation matrix (AS) methods to determine inadequate storage conditions of potato cv. Markies for frying.

mean of 10 replications			Minimum replication number							
			ANAVA		PCCo		PCCv		SA	
r	*r*^	R^2	η_0	$^{-1}$	η_0	$^{-1}$	η_0	$^{-1}$	η_0	$^{-1}$
0.667	95.239	0.80	1.481	1	2.000	2	2.000	2	2.000	2
0.780	96.430	0.85	2.099	2	2.833	3	2.833	3	2.833	3
0.667	95.240	0.90	3.333	3	4.500	5	4.500	5	4.500	5
0.667	95.240	0.95	7.037	7	9.500	10	9.500	10	9.500	10
0.667	95.240	0.99	36.667	37	49.500	50	49.500	50	49.500	50

The similarity in the magnitude of the r's indicates the precision estimates of the analysis. Estimates of r's above 0.6 are considered high (Resende et al., 1996), which indicates that the increase in the replication number results in a lower precision increase. The smallest r's values obtained by the ANOVA method are due to the inclusion of the periodicity factor in the experimental error, underestimating the repeatability. This is related to the similarity of r's to PCCo, PCCv and SA, indicating that these methods are more efficient estimators since they consider the cyclical component of the phenomenon (Abeywardena, 1972). The methods used do not have significant variation and the r's have few variations, independently of the method, indicating that the choice between them (PCCo, PCCv, and SA) does not affect the precision of the estimates (Borges et al., 2010).

The minimum number of french fries required to determine inadequate storage of potato tubers cv. Markies for processing with 99% precision are 37, 50, 50, and 50 and with 95% precision are 7, 10, 10, 10, and 10 according to the ANAVA, PCCo, PCCv, and SA methods, respectively. The difference is 81, 80, 80, and 80% (Table 2).

The difference in the number of french fries sticks required to determine the inadequate storage of potato tuber destined for processing with 99 and 95%

precision is high. Therefore, the smaller R^2 (0.95) must be considered to spare time, resources, and raw materials. The R^2 estimates should be enough to reach a reasonable degree of confidence, in a way that an increase in the replication number is not necessary, since the estimate precision does not increase, which avoids costs and time-consuming labor (Laviola et al., 2013).

The repeatability coefficient allows the determination of the minimum sampling number to identify inadequate storage conditions of tubers with minimum cost and labor.

Conclusions

The minimum sampling number of french fries sticks to determine inadequate storage conditions of potato cv. Markies with 95% precision is 10.

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