International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:7, 2013

The Suitability of Potato Cultivars in Production of Chips and Sticks by Using Microwave-Vacuum Drier

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Abstract**—**The aim of present experiment was to evaluate the influence of cultivar to quality parameters of dried potato chips and sticks produced in microwave-vacuum drier. The potatoes before drying were blanched in oil and water at 180ºC and at 85ºC respectively. The moisture content, crispiness, the colour (CIE L*a*b*), the content of ascorbic acid, total carotenoids and total fat content of dried potato chips and sticks was determined The highest ascorbic acid content, high content of carotenoids, low total fat content, low acrylamide content and good crispiness (low breaking force) especially for sticks was determined in the samples of Gundega cultivar.

Keywords**—**Potato, chips, sticks, vacuum-microwave, drying, cultivar, blanching.

I. Introduction

THE potatoes are important source of carbohydrates, vitamin C, and mineral compounds such as potassium, phosphorus and magnesium [1] as well as a good source of vitamins B_1, B_3, B_6, folate, pantothenic acid, and riboflavin. Moreover, potatoes contain dietary antioxidants, which may play an important role in preventing diseases related to ageing [2]. Traditionally, potatoes, which belong to the species *Solanum tuberosum* [3], are a main component of warm meals in many European countries [4], including Latvia where the potato is one of the basic ingredients of traditional meals.

The changes of physical properties and nutritional value of potatoes during storage and cooking might occur significantly. In addition, significant losses of health promoting properties of different potato products during storage may occur as well [5], [6]. The changes also vary depending on the cultivar and growing area [7]-[9]. Although nutrient content depends on a number of factors, the potato cultivar is thought to be among the most significant factors [10].

One of the most popular potato products are potato chips. Unfortunately, all the products which we can find in our market are with high content of salt and fat, therefore these products cannot be recommended as a healthy product [11].

In recent years, due to consumer health concerns, much research has been concentrated on approaches to reduce oil absorption in fried products, revealing that there is a high positive correlation between the fat content and initial water content. The investigations prove that oil is absorbing mostly already after frying during chilling of product [12]. Microwave-vacuum drying (MWVD) is an alternative way to improve the quality of dehydrated products and alternative method of reducing the oil content in fried foods while producing potato chips with the same texture and colour of those fried in atmospheric conditions and, as well as, to reach lower acrylamide content, enhance organoleptic and nutritional quality. [13], [14]. The MWVD method allows getting the product in shorter time with better quality compared to hot air and simple microwave drying methods. Cui, Sju, and Sun [6] investigated the stability of carotenoids in carrots dried in microwave - vacuum dryer. Their results were very similar to results got with freeze-drying method and more higher than to samples dried in hot air dryer. They proved that MWVD method is good alternative to other drying methods with shorter drying time and high quality product. Similar results were got after detection of vitamin C in potatoes dried with hot air and in microwaves – the loses of ascorbic acid after hot air drying was 70%, but after microwave drying – 25%.

Raw potatoes do not contain acrylamide, but high amounts of the precursors for its formation [15], [16]. One of the main pre-cursors in the formation of acrylamide is the presence of asparagine and reducing sugars. During the frying process the oil oxidises and turns to acrolein and acrylic acid. The starch turns to sugars. This specific mixture of compounds in chemical reactions develops large amounts of acrylamide. Temperature and time shown to be most significant factor affecting the amount of acrylamide formed in potatoes during frying [17], [18]. Among the different food products analyzed, the highest levels of acrylamide have been found in French fries, potato chips, and other fried, deep-fat fried, or oven-cooked potato products, together with some crisp bread, biscuits, crackers, and breakfast cereals [19]-[22]. The amount of acrylamide in fried potatoes can be more than 1000μg kg^{-1} [23]. After the directions of European Commission 2010/307/ES appendix part C.2 the content of acrylamide in potato chips is not recommended higher than 1000μg of total mass of product [24].

The objective of this investigation was to evaluate the influence of cultivar to quality parameters of dried potato chips and sticks produced in microwave-vacuum drier.

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II. Materials and Methods

A. Experimental Design

Experiments were carried out at the Department of Food Technology, Latvia University of Agriculture in 2012 and 2013. The object of the research was potato chips and sticks dried in microwave-vacuum drier.

In cooperation with the State Priekuli Plant Breeding Institute (Latvia), seven potato (*Solanum tuberosum* L.) cultivars were harvested in 2012. The characterisation of potato cultivars: 'Prelma' – medium early, oval tubers, skin and flesh yellow; 'Imanta' – medium late, tubers oval round, skin light yellow with red eyes, flesh white; 'Brasla' – medium late, round tubers, skin - yellow; flesh – yellow; 'Gundega' - medium late, oval tubers, skin - light red pink; flesh – yellow; 'Blue Congo' – late, long oval, skin - violet; flesh – violet; 'Mozart' – medium late, oval tubers, skin light red, flesh – light yellow; 'Vineta' – medium early, tubers oval round, the skin and flesh yellow.

The samples were cut into slices and sticks. Slices were cut with thickness 1mm with a Philips HR 7605 Food Processor. Sticks were cut manualy 3×3mm wide. The potatoes before drying were blanched in oil (180ºC) and afterwards immersed in hot water (85ºC) (tested as the best pre-treatment method in previous experiments). The drying of prepared potato sticks and slices was occurred in microwave- vacuum dryer MUSSON-1.

The samples were packed in polymer pouches with barrier properties in 100% N_2 gas medium, and were hermetically sealed by MULTIVAC C300 vacuum chamber machine and stored at room temperature +20.0±2°C in dark place.

B. Physical, and Chemical Analysis

The following mechanical, physical and chemical characteristics were analyzed:

Moisture content was determined using standard method ISO 6496:1999 by drying the shredded samples in thermo-chamber at +105±1°C temperature until the stable weight of sample; the mass loss calculation (%) were determined by weighing samples on the electronic scales, by standard LVS ISO 1442: 1997.

The textural properties of potato chips and sticks were measured in terms of the breaking force. A Texture Analyzer TA.XTplus (Stable Microsystems, UK) was used for breaking force determination. The material was placed over the end of a hollow cylinder. A stainless steel ball probe (P/5S) was used for potato chips, and three points bend rig - for potato sticks, moving at a speed of 1mm s^{-1} to potato chips and 3mm s^{-1} to potato sticks over a distance of 5.0mm. The results are expressed in N. The system was equipped with compression cell of 50kg and software Texture Exponent 32. The maximum force (N) was used as an index for the breaking test. The maximum force required for sample compression was calculated as an average of 10 measurements.

The colour of potato samples was measured by "Color Tec-PCM" device (USA). The colour was measured at least in ten various locations of the sample in order to obtain higher accuracy after calculation of the mean value. For data analysis, "ColorSof QCW" software was used. The colour was defined by three co-ordinates according to the CIE (Commission Internationale de l'Eclairage) lab system: L* (lightness) – the vertical co-ordinate that runs from L* = 0 (black) through grey to L* = 100 (white); a* (redness) – the horizontal co-ordinate that runs from –a* (green) through grey to +a* (red); and b* (yellowness) – another horizontal co-ordinate that runs from –b* (blue) through grey to +b* (yellow) [25].

The content of **ascorbic acid** was determined by titration with 0.05-M iodine solution [26]. The potato sample (5g) were poured with 6-% solution of oxalic acid and homogenized. Then the sample was filtered. 2ml of 1-% solution of starch was added to 10ml of filtrate and the filtrate was titrated until the colour changed which does not disappeared during a 30 sec interval. For standard solution of ascorbic acid 20mg of ascorbic acid were dissolved in 100ml of the oxalic acid solution. Two ml of the starch solution was added to 25 ml of the standard-solution and the mixture was titrated. The content of vitamin C (ascorbic acid) mg per 100g of the product dry matter was calculated with the following equation:

$$C = 5000 \cdot \frac{V_{sample}}{m \cdot V_{standard}} \quad (1)$$

where V_{sample} – volume of the iodine solution titrated in a sample, ml; $V_{standard}$ – volume of the iodine solution titrated in a standard solution, ml. *m* – the amount of sample, g.

Carotenoids were analyzed by spectrophotometric method (used the UV/VIS spectrophotometer Jenway 6705) at 440nm [27]. A sample of 2-3g of homogenized potato sample was placed in 100ml conic flask and 20ml of 96% ethanol was added. The sample was stirred on a magnetic stirrer for 15min then 25ml of petrol ether were added and stirring was continued for one more hour. After 3–4 hours when both layers were completely divided, the top yellow layer was used for further detection of carotenoids at 440nm. Carotene equivalent (KE) was found, using a graduation curve with $K_2Cr_2O_7$. The content of carotenoids (mg $100g^{-1}$) was calculated by (2):

$$X = \frac{0.208 \cdot 25 \cdot KE}{36 \cdot a} \quad (2)$$

where 0.208 and 36 coefficients for relationship between $K_2Cr_2O_7$ and carotenoids; *KE* – carotene equivalent by graduation curve; *a* – sample weight, g.

Total fat content. Determination of total fat content was by using the SoxCapTM2047 in combination with Soxtec extraction systems.

The content of acrylamide in samples was detected in certificated laboratory of Food safety, animal health, and environment scientific institute BIOR using High performance liquid chromatography method (HPLC) Acquity UPLC in combination with mass spectrometer QTRAP 5500.

C. Statistical Analysis

The results were processed by mathematical and statistical methods. Data were presented as a mean ± standard deviation (SD). The Statistics on completely randomized design were determined using the General Linear Model (GLM) procedure SPSS, version 16.00. Two-way analyses of variance ($p \leq 0.05$) were used to determine significance of differences between moisture content, crispiness, colour changes, ascorbic acid and total carotenoids in potato sticks and chips of seven cultivars.

III. Results and Discussion

The moisture content of different cultivar potato chips significantly ($p=0.002$) varied between 5.7-10.3%. The cultivar with the lowest moisture content was 'Mozart' but the highest moisture content was to chips of cultivar 'Blue Congo' (Fig. 1).

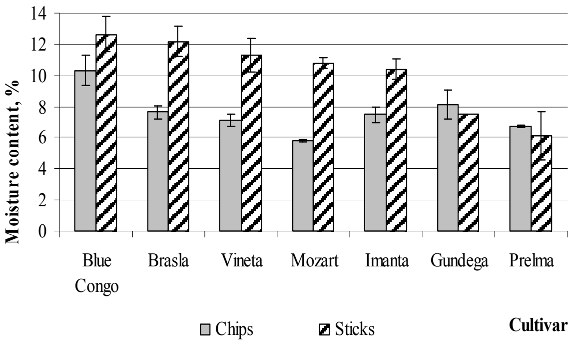

Fig. 1 The moisture content in chips and sticks

The moisture content of potato sticks was significantly ($p=0.001$) higher than to potato chips, and it differed significantly ($p=0.007$) between cultivars from 6.1 to 12.6% (Fig. 1). The cultivar with the lowest moisture content was 'Prelma', but the highest moisture content was again to cultivar 'Blue Congo'.

The moisture content did not influence the breaking force and crispiness of the potato chips and sticks (there were no correlation between moisture content and breaking force).

The acrylamide content was significantly different ($p<0.001$) between cultivars both in potato chips and sticks (Fig. 2). In the processedsticks of cultivar 'Prelma' had the highest content of acrylamide (2100±5μg kg^{-1}) which is much higher than the recommendations of European Commission 2010/307/ES appendix part C.2. The acrylamide content in all other samples was lower than the recommended maximal amount (1000μg) [24]. The highest acrylamide content in potato chips was to samples of cultivars 'Mozart' (554±2.1μg kg^{-1}) and 'Prelma' (475±2.1μg kg^{-1}).

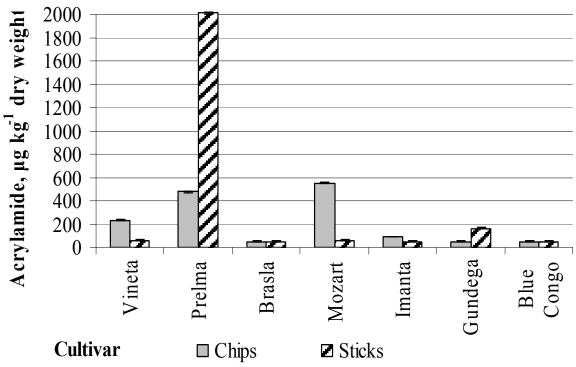

Fig. 2 The acrylamide content in chips and sticks

The samples with the lowest acrylamide content which did not exceed 50μg kg^{-1} were chips and sticks of cultivars 'Brasla', and 'Blue Congo'. Therefore the content of acrylamide does not directly depend from cultivar, but mostly from the ability of different cultivars to loose moisture in the same drying conditions. The lower moisture content was connected with faster drying of product what caused already the Maillard reaction of reducing sugars with asparagine, formation of brown colour [28]-[30], and rapid increase of acrylamide content (Fig. 2). The relations between the moisture content and formation of acrylamides is stated also by other authors in experiments with French frees [31].

The ascorbic acid content was similar ($p=0.426$) both in potato chips and sticks, but there were significant differences between cultivars ($p<0.001$). The highest ascorbic acid content was to chips and sticks of cultivar 'Gundega' (97.25±5.3 and 89.33±4.9mg 100g^{-1} of dry weight), but the lowest ascorbic acid content was to chips and sticks of cultivars 'Blue Congo' and 'Vineta'(Fig. 3).

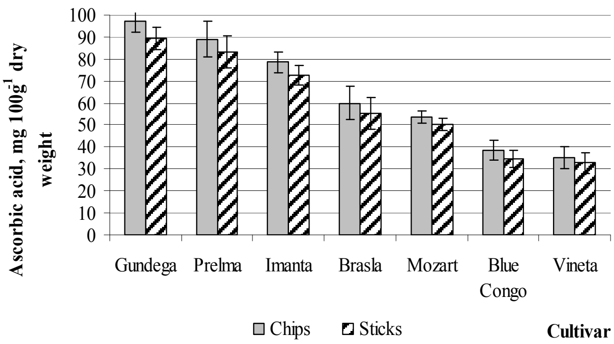

Fig. 3 The ascorbic acid content in chips and sticks

The total content of carotenoids significantly ($p=<0.001$) differed between potato cultivars but there were no significant variations between chips and sticks ($p=0.189$) although the sticks of cultivars 'Gundega', 'Brasla' and 'Imanta' contained notably higher content of carotenoids compared with chips (Fig. 4). The fluctations of total carotenoid content could be explained with different soaking of oil into potato chips and sticks.

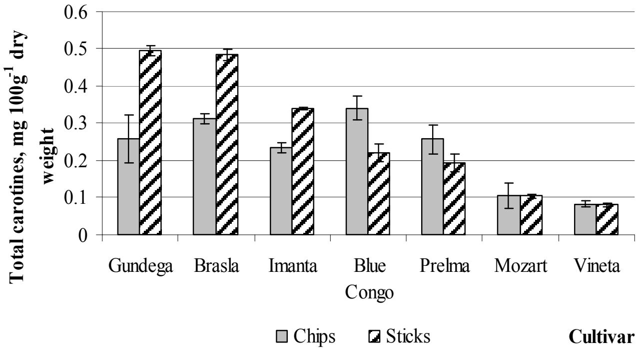

Fig. 4 The total carotenoids in the in chips and sticks of different potato cultivars

The highest content of carotenoids was to sticks of cultivars ‘Gundega’ and ‘Brasla’ (0.48 and 0.49 mg $100g^{-1}$) but from chips the highest content of carotenoids was detected in cultivar ‘Blue Congo’ (0.34 mg $100g^{-1}$).

There were no significant differences **in total fat content** between sticks and chips (p=0.665), and also between cultivars used for production of chips (p=0.229). Only for potato sticks the cultivar had significant (p=0.005) influence to the total fat content of product. The total fat content in the dried potato products varied between 4.59 and 6.17% (Fig. 5) and it is much lower than it is reported for traditionally made potato chips with fat content more than 30 % [1]. The cultivar with the lowest fat content both for chips and sticks was ‘Vineta’, but the highest fat content was to cultivars ‘Brasla’ and ‘Blue Congo’.

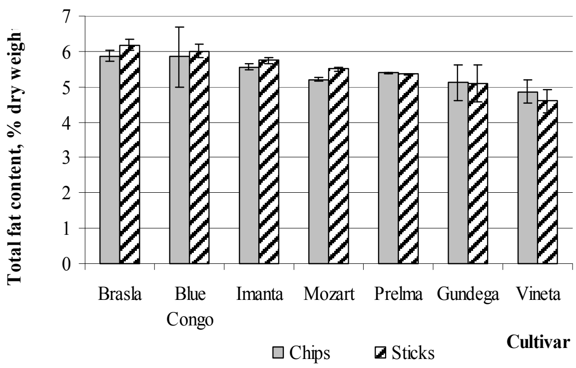

Fig. 5 The total fat content in the in chips and sticks of different potato cultivars

The **breaking force** of potato chips and sticks was from 8.3 to 27.7 N, and there were big fluctuations and standard deviations between replications because of differences to outside appearance of dried chips and sticks (Fig. 6).

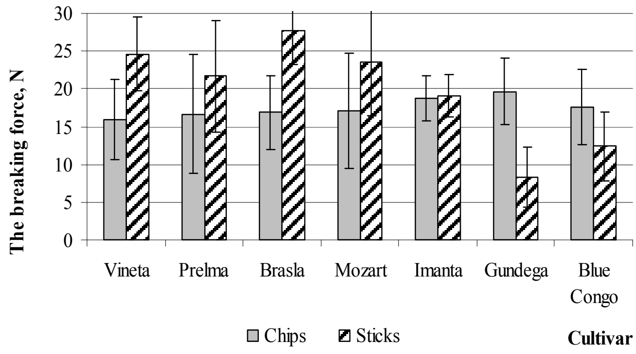

Fig. 6 The breaking force of dried different cultivar chips and sticks

There were no significant differences in maximal breaking force between sticks and chips (p=0.152), and also between cultivars used for production of chips (p=0.9). But the cultivar had significant (p=0.000) influence to the maximal breaking force of potato sticks (Fig. 6). The cultivar with the lowest braking force was ‘Gundega’, what means that the samples of this cultivar had the best crispiness.

The colour (L*a*b*) values help better to characterise the colour differences between evaluated samples.

TABLE I
THE COLOUR (L*a*b*) VALUES OF POTATO CHIPS AND STICKS

The type of product	Cultivar	Colour value L*	a*	b*
Chips	Brasla	51.04±9.8	-2.41±4.0	24.09±4.4
	Gundega	52.96±7.9	-4.19±3.7	29.90±4.5
	Imanta	53.51±6.9	-2.90±2.3	16.81±4.3
	Mozart	51.15±9.3	2.23±3.8	19.34±4.7
	Prelma	47.40±6.7	-0.31±2.5	21.15±4.2
	Vineta	50.79±6.4	-0.26±6.8	26.31±7.8
	In Average	51.03±7.9	-1.21±4.6	22.72±6.6
Sticks	Brasla	47.86±4.3	-1.66±4.1	24.56±5.9
	Gundega	53.00±6.2	-1.42±3.0	25.23±4.2
	Imanta	51.38±7.2	-1.34±2.6	16.33±4.0
	Mozart	50.85±6.9	-0.50±3.5	15.84±6.5
	Prelma	45.29±7.1	3.18±2.6	16.51±4.8
	Vineta	47.97±4.4	-0.76±3.4	23.09±6.8
	In Average	49.32±6.6	-0.35±3.6	19.99±6.6

Significant differences were found between evaluated cultivars in colour values a* (p=0.002), and b* (p=<0.001) for potato chips, and colour values L* (p=0.014), a* (p=0.000), b* (p=0.000) for potato sticks (Table I).

Darker potato chips were obtained from potatoes produced from ‘Prelma’, ‘Mozart’, and ‘Vineta’ cultivars, while darker sticks - from ‘Prelma’ cultivar. The colour value a* of all these samples was very close to zero or even positive (more red), while in fresh potatoes the value a* is stable negative (green) from -3 to -6 [32]. Also the value L* was lower to all evaluated chip and straw samples compared to fresh potatoes where L* values ranged from 65 to 71 [32].

There was negative correlation (r=-0.633, significant at the level 0.05) between colour value L* and acrylamide content, and positive correlation (r=0.773, significant at the level 0.01) between a* value and acrylamide content. Therefore the colour value a* - a representor of brown colour, could be as good indicator of acrylamide content in dried potato products.

IV. Conclusion

Obtained results show that more suitable potato cultivar for production of dried potato chips and sticks is 'Gundega' cultivar with the highest ascorbic acid content, high content of carrotenoids, low total fat content, low acrylamide content, and good crispiness (low breaking force) especially for potato stick production.

The negative correlation between colour value L* and acrylamide content, and positive - between a* value and acrylamide content could be as good indicator of acrylamide content in dried potato products.

Acknowledgment

The research has been prepared within the framework of the State Research Programme "Sustainable use of local resources (earth, food, and transport) – new products and technologies (NatRes)" (2010.-2013.) Project No. 3. Sustainable use of local agricultural resources for development of high nutritive value food products (Food)".

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