JAP&T
TPA-Timişoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2011, *17*(2), 134-138

Journal of Agroalimentary Processes and Technologies

Investigations on wastewaters at potato processing and starch recovery and characterisation

Monica Mironescu*

Faculty of Agricultural Sciences, Food Industry and Environmental Protection, "Lucian Blaga" University of Sibiu, Ion Ratiu Street 7-9 Sibiu, 550012, Romania

Received: 17 April 2011; Accepted: 03 June 2011

Abstract

In this paper, a solution for the recovery of starch in wastewaters resulted at potato washing for chips, snacks or fries production is proposed. The water obtained at washing after peeling and cutting into slices are analysed and a large quantity of organic compounds (around 5458 mg $KMnO_4$), starch (1.66%) and protein (0.7%) is found. No pathogenic microorganims as *Salmonella*, pathogenic staphylococci or *Bacillus cereus* are found and the number of coliform bacteria is low. Starch is recovered after protein precipitation at pH 4.5-5 and filtering on sieves with different mesh size (from 1000 μm to 150 μm), followed by washing and retention of starch granules on sieves with 30 μm mesh size. Starch obtained has physical-chemical characteristics (9.36% water, 88.85% starch, 0.080% total ash, 0.79% reducing sugar) and functional properties (Water Holding Capacity WHC at 30^{o}C 2.27%, WHC at 60^{o}C 16.23%, WHC at 80^{o}C 35.33%, WHC at 90^{o}C 99.5%) very near to those of the commercial starch.

Keywords: potato wastewater, microbial charge wastewater, starch recovery, starch, water holding capacity

1. Introduction

After cellulose, starch is the second polysaccharide found in nature, produced by plants as reserve material. The main cultivated actually plants for the starch industrially production are cereals, especially corn, followed by wheat and potato [2].

For the starch production, corn grains are first digested during steeping; this step is capital-intensive and time-consuming (24 to 52 h) and is realised in dilute aqueous SO_2 solution at sub-gelatinization temperature (45–55°C) at acidic pH (4 to 5), created with lactic bacteria [9] which inhibits the survival and multiplication of bacterial pathogens [12]. Then, germ is separated from the other components in the first step of wet milling [6].

After a second intensive wet milling, pulp and proteins are separated by washing on sieves with different sizes, combined with separation on hydrocyclons or by centrifugation. Starch is easily obtained from potato because no steeping or germ removal are necessary; after the disintegration of potatoes in wet mills, pulp and proteins are separated in the same way as at the obtaining of corn starch.

A large quantity of wastewaters are resulting in both processes from corn steeping, corn and potato washing as well as from washing of industrial surfaces (floors and machines) [16]. Russ and Meyer-Pittroff, (2004) recommend to appreciate the food waste by measuring the specific amount of waste production and determining the "specific waste index" which represent the mass of accumulated waste divided by the mass of the saleable product [11].

Corresponding author: *e-mail:* monica.mironescu@ulbsibiu.ro

According to them, in the potato processing industry the specific waste index lies between 0.3 and 0.5; this value is relatively high and near with the specific index of wastes obtained in the meat industry (calf and cow processing) or in the sugar industry (post-extraction of the beet pulp or carbonation sludge) [11]. The waste effluent from processing of potato products from fresh potatoes containing substantial amounts of protein [3] and starch and different techniques are used to treat the wastewaters before discharging as anaerobic and/or aerobic degradation [4], electrocoagulation [7] etc.

The researches on the capitalisation of potato wastewaters are actually oriented on using them as fermentation substrate for microorganisms [5] or for the protein recovery [1]. In this paper the quality of wastewaters obtained from potato industry at the obtaining of potato chips and potato fries is presented and the characteristics of starch separated from these wastewaters are investigated.

.2. Materials and methods

Potatoes types Sante were used. Potato wastewater and starch were obtained from potato washing and from potato cutting at the obtaining of potato chips as presented in Figure 1.

Practically, 2.00 kg of potatoes (well washed previously) were peeled and the resulted peeled potatoes (1.85 kg) were washed with 1 l sterile distilled water, in order to avoid the possible charge of water with salts and microorganisms; the wastewater resulted is considered as Wastewater I in Figure 1. After cutting as chips, they were washed again with 1 l sterile distilled water and the collected waters are refered as Wastewater II in Figure 1. The sieves used for filtering have all quadratic holes with different mesh sizes. At filtering I, II and III the protein aggregates were separated. It was considered that only starch granules and very small proteins which were not precipitated by acid remained in water and they were washed with demineralised water. In the final filtering, filtering IV, starch granules remained on sieve and proteins and particles smaller as 20 μm passed through the holes. The mesh size of sieves was chosen taking into account the dimension of isolated starch granules; the granules diameter was measured microscopically by using AxioLab microscope and the AxioVision software (Carl Zeiss Instruments) and it varied in the domain 20 – 105 μm.

The mean diameter was 56 μm. An example of measuring the isolated starch granules is presented in Figure 2.

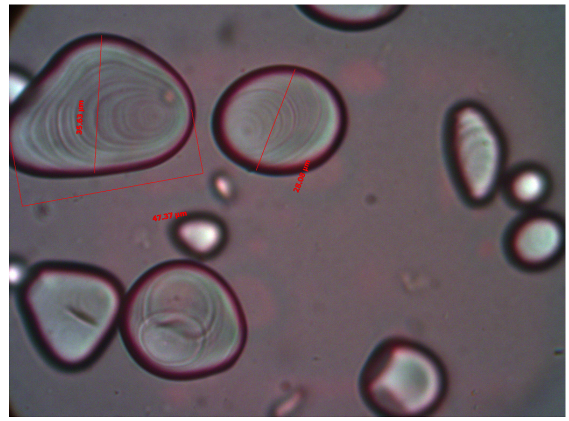

Figure 2. Starch granules isolated from wastewater and measement of their dimension.

After obtaining, the wastewaters were refrigerated for maximal 4 hours and then analysed. Two types of investigations were realised: microbiological and physical-chemical analysis. For the microbiological analysis, different cultivation media were used:

- Plate Count Agar PCA for determining the total number of bacteria;
- Malt Agar for determining the total number of fungi (yeasts and moulds);
- MacConkey-Agar for determining *Salmonella* and coliform bacteria;
- *Bacillus cereus* Agar for determining the pathogenic moulds *Bacillus cereus*;
- Mannitol Salt Phenol-Red Agar for determining the pathogenic staphylococci (*Staphylococcus aureus*, *S. epidermis*);
- Cetrimide-Agar for determining the bacteria belonging to the genus *Pseudomonas*.

The physical-chemical analyses on wastewaters and on isolated starch were:

- Dry matter, determined by water evaporation and drying at 105^{o}C for 4 hours;
- pH, determined with a pH-meter (Hanna Instruments);
- Acidity, measured by titration with NaOH 0.1n with phenolphthalein as indicator;
- Starch content, determined by the Evers method. The method consists on hydrolysis of a small quantity of product (5.000 g) in aqueous solution with concentrated sulphuric acid at 100^{o}C for 15 minutes, followed by protein precipitation with

phosphowolframic acid, filtration and polarimetric analysis;

- Protein content, determines as follows: filtration through 30 µm filters and precipitation at isoelectric pH 4.5 – 5[15] of a known quantity of waste (25 ml in a 50 centrifuge tube), centrifugation at and weighting of the residue, considered as total protein;
- Total ash, determined by dry evaporation and dry mineralization at 600°C for 3 hours;
- Conductometric ash, measured with a Hanna Instruments conductometer;
- Organic compounds, determined with potassium permanganate [13]. Shortly, the wastewaters are boiled for 15 minutes with $KMnO_4$ in excess, the potassium permanganate remained is treated with oxalic acid and the rested oxalic acid is titrated with potassium permanganate; the total amount of organic compounds is expressed as mg of $KMnO_4$;
- Reducing sugars, by using the Luff-Schoorl method [10]. Briefly, a known quantity of product is treated with cupric citrate in excess for 10 minutes at boiling, followed by rapid cooling and treatment of the exceeding cupric citrate with KI and H_2SO_4 under continuously agitation; the iodine ions formed are dosed with $Na_2S_2O_4$ in the presence of soluble starch as indicator.

For the analysis of the water holding capacity (WHC), a method described firstly by [8], modified by[14] and adapted for this research was used. This property was evaluated at different temperatures (30, 60, 80 and 90ºC). The analysis was carried out in 50 mL leak proof centrifuge tubes, by maintaining a suspension of 5.000 g starch in 25 ml deionised water in water bath under agitation at the selected temperature for 30 minutes; then, the samples were centrifuged (3,400 rpm for 15minutes) and the supernatant was separated. The pellets, containing the starch granules which retained water, were weighed. The ratio between the final starch mass and the initial dry matter was considered as WHC.

Potato wastewater and potato starch were obtained in triplicate. In the case of potato wastewaters, Wastewater I and Wastewater II resulted at each of the three experiments (see Figure 1) were numbered with WW_a, WW_b and WW_c and analysed separately. Also, starches obtained from all three experiments were numbered with St_a, St_b and St_c. The physical-chemical characteristics of a commercial potato starch were also determined.

3.Results and discussion

The results obtained at the microbiological analysis of wastewater are presented in Table 1. A relatively large number of bacteria are found on potatoes, even they were preliminary washed. Fungi are in a reduced number, as well as *Pseudomonas sp*. Some coliform bacteria and pathogenic staphylococci were identified in two from the three analysed samples, but they could arrive in wastewater from the workers hands. *Salmonella* and *Bacillus cereus* are absent in all three analysed samples.

The results indicate that they contain a high quantity of organic compounds (predominant starch and proteins), reason for what these wastes could be considered valuable by-products if appropriate technical means are used to increase the value of the subsequent products and to exceed the cost of reprocessing.

The commercial potato starch has the characteristics: pH 6. 87; water content 10,22; starch 89.14; total ash 0.0870%; reducing sugars 0.43%; WHC at 30°C 1.96%; WHC at 60°C 16.7%; WHC at 80°C 35%; WHC at 90°C 100%. Table 3 shows the physical-chemical characteristics of starch separated from the potato wastewaters.

The values obtained for starch samples isolated from potato wastewaters indicate high starch concentration (around 88.8%) and low ash and reducing sugars content. The final product has good physical-chemical characteristics, very near to those of the commercial potato starch. So, this starch can be used successful in food applications. For large chips, snacks or fries factories, the recovery of starch from wastewaters resulted at potato washing could be a solution for reducing the total amount of organic compounds. Recycling, reprocessing and eventual utilization of starch which passed in the washing waters at potato washing offer potential of returning this by-product to beneficial uses rather than its discharge to the environment which might cause detrimental environmental effects.

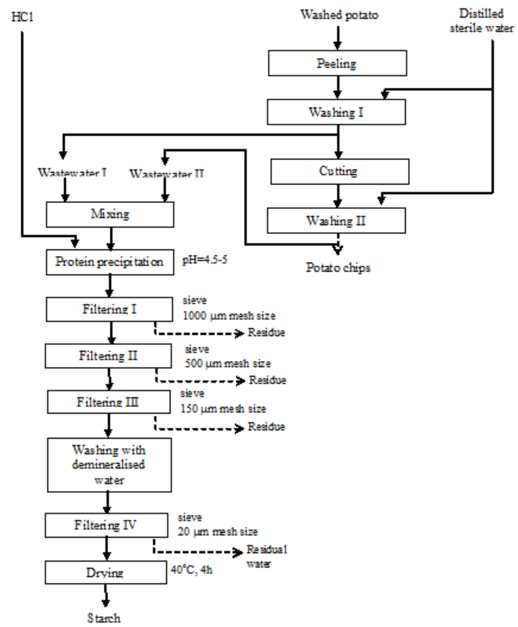

Figure 1. Chart flow of the obtaining of wastewaters and starch at potato processing

Table 1. Microbiological characteristics of wastewaters resulted at potato processing in the three experiments

No.	**Colonies, CFU/ml**	**Values**		
		WW_a	WW_b	WW_c
1.	Total number of bacteria	10^3	$1.5 \cdot 10^3$	$2.5 \cdot 10^3$
2.	Total number of fungi (yeasts and moulds)	10^1	10^2	$2 \cdot 10^2$
3.	*Salmonella*	0	0	0
4.	Coliform bacteria	8	12	25
5.	*Bacillus cereus*	0	0	0
6.	Pathogenic staphylococci	0	0	10
7.	*Pseudomonas sp.*	6	10	14

Table 2. Physical-chemical characteristics of wastewater resulted at potato processing

No.	**Characteristic**	**Values**			
		WW_a	WW_b	WW_c	Mean value
1.	pH at 20°C	6.4	6.3	5.9	6.20
2.	Dry matter, %	2.68	2.76	2.57	2.67
3.	Organic compounds, mg $KMnO_4$	5469	5455	5450	5458
4.	Starch, %	1.60	1.75	1.64	1.66
5.	Total protein, %	0.73	0.71	0.66	0.70
6.	Total ash, %	0.1408	0.1261	0.1920	0.1530
7.	Conductometric ash, mS/cm	0.508	0.493	0.502	0.50
8.	Acidity, degree	2.21	2.29	2.25	2.25

Table 3. Physical-chemical characteristics of starch obtained from wastewater resulted at potato processing

No.	**Characteristic**	**Values**			
		St_a	St_b	St_c	Mean value
1.	pH at 20°C	6.35	6.27	6.4	6.34
2.	Water content, %	9.37	9.42	9.29	9.36
3.	Starch, %	89.25	88.94	88.37	88.85
4.	Total ash, %	0.0076	0.0092	0.0071	0.080
5.	Reducing sugars, %	0.80	0.85	0.72	0.79
6.	WHC at 30°C, %	2	2.3	2.5	2.27
7.	WHC at 60°C, %	16.5	16.2	16	16.23
8.	WHC at 80°C, %	35	35.5	35.5	35.33
9.	WHC at 90°C, %	98.5	100	100	99.50

4. Conclusions

The waters resulted at potatoes washing for chips, snacks or fries production are valuable wastes, which contain organic compounds as proteins (around 0.7%) and starch (around 1.66%). Because these wastewaters are obtained from already washed potatoes, they have a low microbial charge, including small amount of coliforms, and no pathogens as *Salmonella*, *Bacillus cereus* or staphylococci.

For the starch recovery, the procedure proposed in this work begins with protein precipitation, followed by passing on sieves with mesh diameters from 1000 μm to 150 μm for protein aggregates separation and a final sieving on sieve with 20 μm mesh size for starch recovery, starch granules remaining on sieve.

The starch obtained on this way was dried and the physical-chemical characteristics were analysed. The product obtained in this way shows high starch content (around 88.85%) and low water (9.36%) and ash (0.080%) content. The functional property WHC at different temperatures is high and increases with temperature, starch retaining 16.23% from the water added at 60^{o}C, 35.33% from the water added at 80^{o}C or 99.5% from the water added at 100^{o}C. All these characteristics are near the values obtained for a commercial starch (water content 10,22; starch 89.14; total ash 0.0870%, WHC at 60^{o}C 16.7%; WHC at 80^{o}C 35%; WHC at 90^{o}C 100%). In conclusion, this starch can successful used as food ingredient.

References

1. Barta, J., Hermanova, V., Divis, J., Effect of low-molecular additives on precipitation of potato fruit juice proteins under different temperature regimes, *Journal of Food Process Engineering 2008*, *31*(4), 533–547, doi: 10.1111/j.1745-4530.2007.00167.x
2. de Baere, H., Starch policy in the European Community, *Starch/Stärke* **1999**, *51*(6), 189-193, doi: 10.1002/(SICI)1521-379X(199906)51:6<189::AID-STAR189>3.0.CO;2-G
3. GonzalezJ.M., Lindamood J.B., Desai N., Recovery of protein from potato plant waste effluents by complexation with carboxymethylcellulose, *Food Hydrocoll.* **1991**, *4*(5),355-363, doi:10.1016/S0268-005X(09)80131-8
4. Hadjivassilis, I., Gajdos, S., Vanco, D., Nicolaou, Treatment of wastewater from the potato chips and snacks manufacturing industry, *Water Science and Technology* **1997**, *36*(2-3), 329-335, doi:10.1016/S0273-1223(97)00405-8
5. Huang, L.P., Bo Jin, B., Lant, P., Zhou, J., Simultaneous saccharification and fermentation of potato starch wastewater to lactic acid by *Rhizopus oryzae* and *Rhizopus arrhizus*, *Biochemical Engineering Journal* **2005**, *23*(3), 265-276, doi:10.1016/j.bej.2005.01.009
6. Ji, Y., Seetharaman, K., White, P.J., Optimizing a small-scale corn-starch extraction method for use in the laboratory, *Cereal chemistry* **2004**, *81*(1), 55-58
7. Kobya, M., Hiz H., Senturk, E., Aydiner, C., Demirbas, E., Treatment of potato chips manufacturing wastewater by electrocoagulation, *Desalinisation* **2006**, *190*(1-3), 201-211, doi:10.1016/j.desal.2005.10.006
8. Leach, H.W., McCowen, I.D., Schoch, T.J., Structure of the starch granule. I. Swelling and solubility patterns of various starches, *Cereal Chemistry* **1959**, *36*, 534-544
9. Mironescu, M., Georgescu, C., Mironescu, V., Effect of lactic bacteria on corn steeping, *Proceedings of the Internal. Symp. Biotechnology* **2008**, 123-129
10. Mironescu, V., Mironescu, M., *Obţinerea şi asigurarea calităţii produselor zaharoase*, Ed. Universităţii Lucian Blaga Sibiu, 2000, vol I
11. Russ, W., Meyer-Pittroff, R., Utilizing waste products from the food production and processing industries, *Critical Reviews in Food Science and Nutrition* **2004**, *44*, 57–62
12. Sefa-Dedeh S., Cornelius, B., Amoa-Awua, W., Sakyi-Dawson, E., Afoakwa O., The microflora of fermented nixtamalized corn, *International Journal of Food Microbiology* **2004**, *96*, 97– 102
13. Shaabani, A., Tavasoli-Rad, F., Lee. D.G., Potassium permanganate oxidation of organic compounds, *Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry* **2005**, *35*(4), 571-580, doi: 10.1081/SCC-200049792
14. Takizawa, F.F., de Oliveira da Silva, G., Konkel, F.E., Demiate, I.M., Characterization of tropical starches modified with potassium permanganate and lactic acid, *Brazilian Archives of Biology and Technology* **2004**, *47*(6), 921-931, http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-89132004000600012
15. van Koningsveld, G.A., Gruppen, H., de Jongh, H., Wijngaards, G., van Boekel, M., Walstra, P., Voragen, A., The solubility of potato proteins from industrial potato fruit juice as influenced by pH and various additives, *Journal of the Science of Food and Agriculture* **2002**, *82*(1), 134–142, doi: 10.1002/jsfa.1015
16. Vlyssides, A., Barampouti E.M., Mai S., Stamatoglou E., Rigaki K., Hydrolysis of starch using Fenton's reagents as a key for waste integrated management in a potato processing industry, *Chemical Engineering Transactions*, **2009**, *18*, 165-170, doi: 10.3303/CET0918025