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REDUCING THE AFTER COOKING DARKENING OF THE FRENCH FRIED BY USING DIFFERENT AGENTS

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ABSTRACT: *Potato tubers (Solanum tuberosum L.) were peeled, cut into strips (10 X 10 ml) then blanched in tap water at 90ºC for 3 min (in the first blancher) and at 75 ° C for 10 min (in the second blancher). Different concentrations of anti-darkening agents such as sodium acid pyrophosphate (SAPP), sodium meta bisulphate (SMBS) and citric acid (CA) and their mixtures were added to the blanching water. All after cooking darkening (ACD) agents and their mixtures were significantly (p≤0.05) improved the frozen French fried colour (less graying) except CA, compared with control, also the colour values of treated fried French fries improved (p ≤ 0.5) by blanching with all different ACD agents and their mixtures compared with control, while no significant (p > 0.5) changes was noticed among the fried strips treated with all used ACD mixtures. Blanching the potatoes strips with SAPP (3gm/L) significantly (p ≤ 0.05) improved the frozen French fries strips colour and taste compared to SMBS (3gm/L), while CA did not improve (p > 0.5) the quality attributes, but also had sour and bitter taste compared with control. Strips blanched with mixture of 2 gm/ L SAPP +1 gm/ L CA had significantly (P ≤ 0.05) higher colour and taste than that treated with mixture of 2 gm/ L SMBS + 1 gm/ L CA. The mixture of 1.5 gm/ L SAPP + 1.5 gm/ L SMBS + 1 gm/ L CA was the best mixture for improved the frozen French fries strips colour (waxed white, very light) as well as the fried potato strips taste was more acceptable and odour was very good. No significant (P > 0.05) changes was detected in all sensory attributes of frozen colour, taste, odour, crispiness and texture during storage of French fries strips at -18°C for 90 days.*

Key words: *After-cooking darkening, colour, French fries, blanching, sensory attributes*

INTRODUCTION

After cooking darkening (ACD) is an undesirable potato tuber trait, problematic in processed potato products (Wang-Pruski and Nowak, 2004). It is characterized as a change from a tuber's normal flesh colour to gray, blue, purple, or black (Hughes and Swain, 1962 b). ACD is most common in boiled or steamed potatoes but is also problematic in processed products. (Armstrong, 1963; Dale and Mackay, 1994; Smith, 1987). ACD is caused by the oxidation reaction of the ferrous–chlorogenic acid complex, resulting in a bluish gray compound (Wang-Pruski, 2006). Iron, ascorbic acid, and the ratio of chlorogenic to citric acid (CA) in the potato all appear to influence ACD as well Silva *et al.* (1991). Blanching is one of the most important stages of French fries production technological process, and it is often subjected to modifications (Abu-Ghannam and Crowley, 2006). To prevent the discoloration caused by ACD, processors in French fry industry treat French fried potato strips with sodium acid pyrophosphate (SAPP, $Na_2H_2P_7O_7$),which reduce darkening by complexing the iron in the tuber. In this capacity the iron is held in anonionzable form and cannot take part in the reaction with chlorogenic acid (Smith, 1987; Wang-Pruski and Nowak, 2004). SAPP-treated potatoes often develop a bitter off-flavor chemical taste due to large amounts of PO_4 absorbed from hydrolysis of SAPP solution. (Keng and Weaver, 1979).

Sodium acid sulfate (SAS) has been shown to be an effective acidulant to reduce the enzymatic browning in fresh-cut, potato and apple products (Fan *et al.,* 2009; Calder *et al.,* 2011). SAS was similarly accepted by consumers in comparison to CA and SAPP, which is the industry standard to reduce ACD. Calder *et al.,* 2012).

Organic acids such as citric acid are believed to play a role in competing with chlorogenic acid for iron (Fe) and, as a result, decreasing the severity of ACD (Hughes and Swain, 1962a). Citric acid is one of the most prevalent organic acids naturally found in potatoes with highest concentrations at the apical end where the least amount of ACD develops (Silva *et al.,* 1991).

The objective of this study was to evaluate the best concentrations of different anti-darkening agents and their mixtures, on the blanching water and potato tissue pH, frozen French fries colour as well as the sensory attributes.

MATERIALS AND METHODS

Materials

- Potato tubers (*Solanum tuberosum*) diamant variety were purchased from delta land (Minufiya and Behera Governorates) during the winter seasons of year 2011-2012.
- Sodium acid pyrophosphates (SAPP) Food Grade ($Na_2H_2P_2O_7$) E-450 (I) and citric acid monohydrate (CA) E330 were purchased from Samiramis International Trading, Masaken El-Sheraton, Cairo, Egypt.
- Sodium metabisulphite (SMBS) was purchased from Al-Gomhoriya Co. Al-Bahr, Street, Tanta, Egypt
- Shortening (100% palm oils) was purchased from El-Fares El-Arabi Co. Al-Obour City Industrial zone A.

Methods

French fries processing:

Potato tubers were cured for 21 days under rice strew at ambient air conditions (at 15-19 ºC, 60-75 % RH) and stored in darkness (at 10ºC, 85-95% RH, and 0.20-0.25% CO_2) at the cold room for three months until processing. The tuber was reconditioned by gradually raising the temperature to 15 - 17º c in three days.

The reconditioned potatoes tubers were transported to the factory then washed with tap water in tow stage (soaking wash - drum washing), peeled (in steam peeler at 7 par pressure), brushed, cut into strips of 10×10 mm using water pump cutters then graded. Strips were dip blanched in tap water with dip blanching at two stages (blancher"1" 3 min, 90ºC, blancher"2" at 75ºC for 10 min). Different concentrations of sodium acid pyrophosphates (SAPP), sodium metabisulphite (SMBS), citric acid monohydrate (CA) and their mixtures were added to the tap water in the two blanching steps as after cooking darkening agents (ACD). Blanching strips were dried at 90ºC for 15 min, then deep fried at 160ºC for 1 min, pre-cooled for 15 min at -3ºC, frozen at -35ºC for 15 min and stored at -18ºC for 90 days and samples were taken at 15 days intervals and analyzed for sensory attributes.

pH evaluation:

pH tissue and solution were determined with digital pH meter (pHX800, pH digital taster).

Colour measurement:

For colour assay of frozen French fries sample was taken after treatment and the potato strips were matched against a series colour photographs show various degree of darkening after standard frying for frozen French fries (USDA, 1988) to determine the colour number of frozen French fries every colour category was multiplied by the colour number as follows:

Colour standards

Symbol	000	00	0	1	2	3	4
Numerical value	0	1	2	3	4	5	6
Colour code	Extra light	Very light	Light	Medium light	Medium	Dark	Very dark

Sensory evaluation

Panelists (15 trained specialist and familiar with potato French fries from Quality Control Department, El-Badr Company for Food Industry) were provided with a set of 7 randomly coded samples. Sensory attributes were evaluated using a 15-point scale for evaluate colour and 20-score for each flavour, taste, crispiness and odour. Panelists evaluated frozen French fries samples after frying in palm oil at 170°C for 5 min without special lighting and at ambient temperature (25°C). Water was provided for rinsing purposes.

Statistical analysis

The data were statistically analyzed using analysis of variance (ANOVA) and least significant difference (LSD) using SAS (2000). Significant differences between any two means were determined at the $P \leq 0.05$ level. Factorial design were used only to determine the sensory attributes of stored French fries.

RESULTS AND DISCUSSIONS

pH changes

Table 1 shows the changes of blanching solutions and potato tissues pH as affected by blanching with different concentrations of ACD agents. The pH of the blanching solutions decreased from 7.43 (water without additives) to 4.93 (5 gm SAPP/ L). The pH levels of potato tissue was also decreased from 6.33 (water without additives) to 5.03 (5 gm SAPP/ L). Keng and Weaver (1979) reported that SAPP hydrolyzes directly to orthophosphate. Hydrolysis rate depends directly upon temperature and pH of the solution. The best control of after-cooking darkening is attained at pH 5 at 20-25°C. The boiled control results agree with Smith (1958) who reported that boiled potatoes have a pH range of 5.7 to 6.4. While adding of CA decreased the pH of blanching solution from 7.37 (water without additives) to 3.30 (3 gm CA/ L). Also the pH tissue decreased from 6.47 (water without additives) to 4.03 (3 gm CA/ L). The raw potato Katahdin control had an outer pH of 5.85. Previous enzymatic browning research has shown that 3% concentrations of citric acid can significantly lower inner and outer pH surfaces of fresh-cut French fries (Calder, *et al.,* 2011). Nutting and Pfund (1942) also noted that boiling potatoes in acidic solutions (vinegar, citric acid and lemon juice) in the 4.1 to 4.9 pH range also decreased ACD and darkening remained intact or slightly increased in the 8.4 to 10.0 pH range.

The pH of blanching water and potato tissue was slightly decreased with increasing the SMBS concentrations. The pH of blanching solution decreased from 7.43 for control (water without additives) to 5.27 for the water contained 5 gm SMBS/ L. The pH of potato tissue also decreased from 6.33 in control (water without additives) to 5.63 (5 gm SMBS/ L). These results are to close to that reported by Calder *et al*., 2011 who stated that 3% concentrations of sodium acid sulphate can significantly lower inner and outer pH surfaces of fresh cut French fries.

Colour attributes of frozen French fry

Table 2 shows the coluor of frozen French fries strips blanched in different concentration of ACD agents. The colour of control samples (blanched in water without additives) was light grey (2.7). Adding of 1 gm SAPP/ L to the blanching medium improved the colour of the strips to medium light (2.5). Also, increasing of SAPP concentration up to 3 gm SAPP/ L improved the colour to light and very light (1.5, 0- 00) while increasing the concentration of SAPP over 3 gm/ L did not affect the colour. Sodium acid pyrophosphate (SAPP) has been effectively utilized by potato processors to reduce ACD especially for boiled, fried, and dehydrated products, as discussed by Wang-Pruski and Nowak (2004). Increasing the concentration of SAPP solution has little effect on its stability at various temperatures and pH, and also made no great improvement on the color of the French-fry strips after par frying Keng and Weaver (1979).

Table (1). Blanching solution and potato strips tissue pH as affected by blanching with different concentrations of ACD agents.

ACD agents	Concentration (gm/liter)	pH of blanching solution	pH change (%)	pH of potato tissue	pH change (%)
SAPP	0	7.43		6.33	
	1	6.96	-6.32	6.13	-3.16
	2	6.76	-9.02	6.03	-4.74
	3	5.43	-26.92	5.63	-11.06
	4	5.10	-31.36	5.33	-15.80
	5	4.93	-33.65	5.03	-20.54
CA	0	7. 43		6.33	
	1	4.97	-33.11	5.17	-18.32
	2	4.13	-44.41	4.60	-27.37
	3	3.30	-55.59	4.03	-36.33
SMBS	0	7.43		6.33	
	1	6.33	-14.80	6.17	-2.53
	2	5.67	-23.69	6.03	-4.74
	3	5.63	-24.23	5.87	-7.27
	4	5.47	-26.38	5.67	-10.43
	5	5.27	-29.07	5.63	-11.06

Table (2). Colour attributes of frozen French fry as affected by blanching with different concentrations of ACD agents.

ACD agents	Concentrations (gm/ L)	Color stander for frozen French fries
SAPP	0	2.7 (0,1) medium, light grey
	1	2.5 (0,1)medium light
	2	2 (0) Light
	3	1.5 (0,00) light, very light
	4	1.5 (0,00)light, very light
	5	1.5 (0,00) light, very light
CA	0	2.7 (0,1) medium, light grey
	1	2.7 (0,1) medium, light grey
	2	2.7 (0,1) medium, light grey
	3	2.7 (0,1) medium, light grey
SMBS	0	2.7 (0,1) medium, light grey
	1	2.4 (0,1) medium light
	2	2.1 (0) Light
	3	1.7 (0,00) light, very light
	4	1.6 (0,00) light, very light
	5	1.6 (0,00) light, very light

On the other hand, the colour of frozen French fries strips blanched in different citric acid (CA) concentrations did not changed neither by adding CA nor by increasing its concentration. Several researches maintained that there is no considerable effect of CA treatment in French fries strip colour. Sapers and Miller (1995) also observed a tough outer layer formed around boiled potatoes that were previously treated with heated dips that contained citric acid. Hughes and Swain (1962b) reported that in tuber, CA is always found in concentration grater than both Fe and chlorgenic acid but this does not lead to complete reduction in the occurrence of ACD. Meanwhile, Silva *et al.* (1991) stated that CA is one of the most prevalent organic acids naturally found in potatoes with highest concentrations at the apical end where the least amount of ACD develops. On the other side, some researches concluded that CA is also an effective iron chelator which has a stronger affinity to bind with iron than chlorogenic acid; the CA/ iron complex is colorless which helps to reduce ACD (Hughes and Evans, 1967).

While The colour of French fries strips blanched in different sodium metabisulphite (SMBS) concentrations was measured by colour standers for frozen French fried potatoes (table2). The strips color of frozen control samples was light grey (2.7) and it improved to medium light (2.4) when blanched in 1gm SMBS/ L. Also, increasing of SMBS concentration up to 4 gm/ L improved the colour to light, very light (1.6, 0-00) while increasing the concentration of SMBS over 4 gm/ L did not affect the colour. Fan *et al.* (2009) and Calder *et al.* (2011) reported that Sodium acid sulfate has been shown to be an effective acidulant to reduce the enzymatic browning in fresh-cut potato. Calder *et al.* (2012) reported that sodium acid sulfate was similarly accepted by consumers in comparison to citric acid and sodium acid pyrophosphate, which is the industry standard to reduce ACD.

Sensory attributes of French fry strips

Sensory attributes of French fry strips as affected by blanching with different concentration of ACD agents are given in Table 3. The colour of frozen French fries was enhanced ($P \leq 0.05$) with increasing of SAPP concentration up to 3 gm/ L. Texture, odor and crispiness did not affected by increasing SAPP concentration. The control frozen samples received a slightly lower mean score for colour compared to the other treatments (SAPP, CA, SAS), which indicates that it may have appeared darker than the other treatments. Panelists commented that the control sample was "slightly dark," "a few dark areas," and "slight graying," which confirmed our observations (Calder *et al.,* 2012). SAPP has been effectively utilized by potato processors to reduce ACD especially for boiled, fried, and dehydrated products, as discussed by Wang-Pruski and Nowak (2004). On the other hand their is a problem associated with addition of SAPP is the presence of an unpleasant chemical taste to the tubers when a higher concentration is applied (Mazza and Qi, 1991).

No significant ($P > 0.05$) changes were noticed in both frozen and fried French fry strips treated with different concentrations of CA (table 3). Meanwhile, the sour taste was enhanced ($P \leq 0.05$) with increasing of CA concentration up to 1 gm/ L. Increasing the CA concentration over that had a negative effect ($P \leq 0.05$) compared with control. Crispiness and texture did not affect ($P > 0.05$) by blanching in the different concentrations of CA. CA-treated potatoes were scored significantly ($P \leq 0.05$) lower for flavour than the other treatments several panelists commented that CA samples were sour or bitter. CA received the lowest scores for almost all the sensory attributes, except for color (Calder, 2012).

Significant ($P \leq 0.05$) improve of the frozen French fries colour with increasing of SMBS concentration to 3 gm/ L compared with control. No significant ($P > 0.05$) effect was observed among the frozen strips blanched in a solution contained 3gm/ L and 5gm/ L of SMBS. Meanwhile, all SMBS concentrations significantly ($P \leq 0.05$) improved the color of fried French fry strips. On the other hand, increasing of SMBS

Table 3

concentration in blanching solution had a negative affect ($P \leq 0.05$) on the taste and the odour compared with control. Generally, increasing the SMBS concentration did not significantly ($P > 0.05$) affect the fried strip texture and crispiness compared with control (table 3). The SAS-treated potatoes received slightly, but significantly ($P \leq 0.05$) lower texture scores (5.53 to 5.64; neither like nor dislike) compared to the other treatments (SAPP-CA) which confirmed previously mentioned observations of a waxy outer layer. Panelists made similar comments when describing the texture of SAS- and CA-treated potatoes, such as "pickled texture," "case hardening," "rubbery," "slightly harder exterior," "scaly texture," and "chewy." However, several panelists commented that these treatments would be acceptable in potato salad products (Calder *et al.,* 2012).

Depending on the previous preliminary results, a mixtures of the optimum concentrations (which gave the best colour and sensory attributes) from these additives was used. Therefore, the rest of this study was conducted only on the following ACD mixtures, 3 gm SAPP + 1 gm CA/ L, 3 gm SMBS + 1 gm CA/ L, 2 gm SAPP + 1 gm CA/ L, 2 gm SMBS + 1 gm CA/ L and 1.5 gm SAPP + 1.5 gm SMBS + 1 gm CA/ L.

Effect of different ACD mixtures on the pH of blanching solution and potato tissue

Table 4 shows the pH of blanching solution and potato tissue as affected by blanching with mixtures of ACD agents. The pH of blanching solution was changed from 7.43 in tap water to 5.43 after adding SAPP 3 gm/ L to the blanching water, while adding 3 gm/ L of SMBS decreased the pH to 5.63. The mixture of CA and SAPP (3 gm SAPP + 1 gm CA/ L) as well as CA and SMBS (3 gm SMBS + 1 gm CA/L) decreased the pH to 3.23 and 3.83, respectively. While the mixture of SAPP and CA (2 gm SAPP + 1 gm CA/ L) decreased the pH to 3.27 and mixture of SMBS and CA (2 gm SMBS + 1 gm CA/ L) decreased the pH to 3.47. Meanwhile, the mixture of the three agents (1.5 gm SAPP + 1.5 gm SMBS +1 gm CA/ L) decreased the pH to 3.37.

The pH of the strips tissue was decreased from 6.33 for the strips blanched in tap water to 5.63 for that blanched with 3 gm SAPP/ L, 5.87 for that blanched with 3 gm SMBS/ L, 5.33 with the mixture of 2 gm SAPP + 1 gm CA/ L, and it reached to 5.57 with the mixture of 2 gm SMBS + 1 gm CA/ L and to 5.07 for that blanched with the mixture of 3 gm SAPP + 1 gm CA/ L and to 5.53 with the mixture of 3 gm SMBS + 1 gm CA/ L and to 5.47 when a mixture of 1.5 gm SAPP + 1.5 gm SMBS + 1gm CA/L was used in blanching solution.

The influence of pH on ACD has been researched and acidic solutions (pH 4.5) have been found to reduce ACD in boiled potatoes while more alkaline solutions (pH 9.6) increase blackening (Smith *et al.,* 1942).

Effect of different ACD mixtures on the frozen French fries colour

Table 5 shows the frozen French fries colour as affected by blanching with different mixtures of ACD agents. The frozen French fries strips colour improved from medium, light grey (2.7) for control strips to light 2 for the strips blanched with 3 gm SMBS/ L and light, very light 1.5 for the strips blanched with 3 gm SAPP/ L. The mixture of 2 gm SAPP/ L + 1 gm CA/ L improved the colour of strips to very light (1), while mixing of SMBA and CA by the same concentration improved the colour to light 1.8 in the same side. The mixture of 3 gm SAPP + 1 gm CA/ L improved the colour of strips to very light (0.9), while mixing of SMBA and CA by the same concentration improved the colour to light 1.75. The highest improve of frozen strips colour (waxed white, very light, 0.7) was detected when the strips blanched with the mixture of 1.5 gm SAPP + 1.5 gm SMBS + 1 gm CA/ L.

This improve of the French fry colour may be due to the functions of SAPP as an iron chelator in the potato that reduces the ability of iron to bind with chlorogenic acid, and therefore, reducing the after cooking darkening (Mazza and Qi, 1991).

Table (4): The pH of blanching solution and potato tissue as affected by blanching with different mixtures of ACD agents.

Mixtures of ACD agents (gm/ L)			pH of blanching solution	pH change (%)	pH of potato tissue	pH change (%)
SAPP	SMBS	CA				
0	0	0	7.43		6.33	
3	0	0	5.43	-26.92	5.63	11.06
0	3	0	5.63	-24.23	5.87	-7.27
3	0	1	3.23	-65.52	5.07	-19.90
0	3	1	3.83	-48.45	5.53	-12.63
2	0	1	3.27	-55.29	5.33	-15.80
0	2	1	3.47	-53.30	5.57	-12.01
1.5	1.5	1	3.37	-54.64	5.47	-13.59

Table (5): Frozen French fries colour as affected by blanching with different mixtures of ACD agents.

Mixtures of ACD agents (gm/ L)			Colour stander for frozen French fries
SAPP	SMBS	CA	
0	0	0	2.7 (0,1) medium, light grey
3	0	0	1.5 (0,00) light, very light
0	3	0	2 (0) Light
3	0	1	0.9 (00,000) very light
0	3	1	1.75 (0,00) light, very light
2	0	1	1 (00) very light
0	2	1	1.8 (0) light
1.5	1.5	1	0.7 (00,000) very light, waxed white

Effect of different ACD mixtures on the frozen French fries sensory attributes

Sensory attributes of French fry strips as affected by blanching with different mixtures of ACD agents are illustrated in Table 6. The colour values of frozen French fries strips significantly ($P \leq 0.05$) improved from 7.10 for control samples to 12.80 for that blanched with 3 gm SAPP/ L and reached to 13.38 with the sample treated with a mixture of 2 gm SAPP + 1 gm CA/ L. Whereas, it improved ($P \leq 0.05$) to 10.37 with using the concentration of 3 gm SMBS/ L and reached to 12.02 in the mixture of 2 gm SMBS + 1gm CA/ L, which was still significantly ($P \leq 0.05$) higher compared to control samples. The highest ($P \leq 0.05$) colour value (14.06) was noticed when the mixture of SAPP, SMBA and CA (1.5/1.5/1 gm/ L, respectively) were used.

Generally, the colour values of fried French fries treated significantly ($p \leq 0.5$) improved by blanching with all different after cooking darkening agent mixtures (SAPP/ SMBS/ CA, 3/0/0, 3/0/0, 3/0/1, 0/3/1, 2/0/1, 0/2/1 and 1.5/1.5/1 gm/ liter, respectively)

Reducing the after cooking darkening of the french fried by using……...

Table 6

compared with control, while no significant ($p > 0.05$) changes was noticed among the fried strips treated with all used ACD mixtures compared with each other. No significant ($P > 0.05$) different was observed among all French fries strips taste treated with different ACD and control except that treated with 3 gm SMBS/ L which decreased significantly ($p \leq 0.05$) compared with control. On the other hand, no significant ($p > 0.05$) changes was observed in the fried strips odour among all French fries strips treated with different ACD mixtures and control except the fried strips treated with 3 gm SMBS/ L which showed significant ($p \leq 0.05$) decreased compared with control. The fried strips crispiness and texture did not affect significantly ($P > 0.05$) by blanching with the ACD agents mixture compared with control.

Effect of different ACD mixtures on the on the sensory attributes of freeze stored (-18 C for 90 days) French fries.

Sensory attributes of freeze stored (-18 °C for 90 days) French fries as affected by blanching with different mixtures of ACD agents are presented in Table7. No significant ($P > 0.05$) changes was detected in all sensory attributes of frozen colour, taste, odour, crispiness and texture during storage of French fries strips at -18 C for 90 days (Table 7) .

The French fries strips blanched in the mixture of CA/ SMBS/ SAPP (1 gm/ 1.5 gm/ 1.5 gm/ l gm, respectively) had the highest ($P \leq 0.05$) sensory acceptability compared with the other additives followed by the strips blanched with SAPP/ CA which had a higher taste, texture and crispiness compared with the other agents. On the other side, the controls samples (blanched in tap water) had the worst sensory quality.

Conclusions:

Generally, blanching the strips with after cooking darkening agent (ACD) mixtures improved the frozen French fries strips colour compared with using of single agent. The result also indicated that reducing blanching solution and tissue pH is not the main effective factor on ACD, whereas the ACD reagent type is the main effective factor and the pH is the co-factor.

Table 7

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تقليل تكون اللون الداكن بعد طهى البطاطس النصف مقلية باستخدام مواد مختلفة

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الملخص العربى

تم تقشير درنات البطاطس (صنف الدايمونت) بالبخار وتقطيعها الى أصابع (10 × 10 مم) ثم سلقها فى ماء الصنبور على 90°م لمدة 3 دقائق (المرحلة الأولى من السلق) ثم على درجة حرارة 75°م لمدة 10 دقائق (المرحلة الثانية من السلق). تم تقدير تأثير التركيزات المختلفة من محسنات اللون بعد الطهى (الصوديوم أسيد بيروفوسفات، الصوديوم ميتاباى سلفيت و ملح الليمون ومخاليطهم المختلفة) على حموضة ماء السلق ونسيج البطاطس وعلى لون أصابع البطاطس المجمدة النصف مقلية وكذالك صفات الجودة الحسية لأصابع البطاطس بعد التصنيع مباشرة وأثناء مدة التخزين المجمد على –18°م لمدة 90 يوم.

أظهرت النتائج أن جميع محسنات اللون بعد الطهى ومخاليطها باستثناء ملح الليمون، أدت الى تحسن معنوى فى لون أصابع البطاطس المجمدة (تقليل اللون الرمادى) مقارنا بالعينة القياسية. كما تحسن لون البطاطس بعد القلى بشكل معنوى مع كل المعاملات مقارنا بالعينة القياسية على الرغم من أنه لم يلاحظ أى تغير معنوى بين العينات المعاملة بمحسنات اللون ومخاليطها مقارنة ببعضها البعض.

سلق أصابع البطاطس فى تركيز 3 جم/ لتر صوديوم أسيد بيروفوسفات أدى الى تحسن لون أصابع البطاطس المجمدة وطعمها بشكل معنوى مقارنة بتلك المعاملة مع 3 جم/ لتر صوديوم ميتاباى سلفيت بينما ملح الليمون لم يقلل من صفات الجودة فقط ولكن أيضا كان له أثر سلبى من حيث تكوين الطعم الحامضى المر. كانت الأصابع التى تم معاملتها بمخلوط الساب وملح الليمون بنسبة 2: 1 جم/ لتر الأفضل فى اللون والطعم من التى تم معاملتها بمخلوط الصوديوم ميتاباى سالفيت وملح الليمون بنسبة 2: 1 جم/ لتر. فى حين كان مخلوط الصوديوم أسيد بيروفوسفات والصوديوم ميتاباى سلفيت وملح الليمون بنسبة 1.5: 1.5: 1 جم/ لتر بالترتيب صاحب أفضل نتائج من حيث لون أصابع البطاطس المجمدة (الأبيض الشمعى) والطعم الأكثر قبولا والرائحة الجيدة. وأيضا لم يلاحظ أى تغيرات معنوية على جميع خصائص الجودة من لون وطعم ورائحة وقوام أثناء فترة التخزين على –18°م لمدة 90 يوم.

Table 3. Sensory attributes of French fry strips as affected by blanching with different concentrations of ACD agents.

Sensory attributes	Score		Control	SAPP concentrations (gm/ liter)					CA concentrations (gm/liter)			SMBS concentrations (gm/ liter)				
				1	2	3	4	5	1	2	3	1	2	3	4	5
Colour	30	15 frozen	7.10 d	9.20 c	11.10 b	12.80 a	13.10 a	13.20 a	7.10 d	7.20 d	7.30 d	8.30 cd	9.15 bc	10.37 ab	11.06 a	11.22 a
		15 fried	11.90 b	12.88 a	12.90 a	13.10 a	13.20 a	13.30 a	13.10 a	13.20 a	13.10 a	12.80 a	13.10 a	13.00 a	13.20 a	13.15 a
Taste	10		7.92 a	8.50 a	9.00 a	8.90 a	8.50 a	7.88 ab	8.50 a	6.10 b	3.80 c	8.20 a	7.50 ab	7.00 abc	6.50 bcd	5.90 cd
Odour	20		17.80 a	18.00 a	18.10 a	18.30 a	18.20 a	18.00 a	18.20 a	18.00 a	18.10 a	18.20 a	17.10abc	16.30bcd	15.50cde	14.90 de
Crispiness	20		16.90 a	17.00 a	17.10 a	17.20 a	17.30 a	17.20 a	17.10 a	17.06 a	17.22 a	17.05 a	17.10 a	17.50 a	17.50 a	17.80 a
Texture	20		16.20 a	15.90 a	16.10 a	16.20 a	16.30 a	16.20 a	16.30 a	16.10 a	16.50 a	16.10 a	16.20 a	16.50 a	16.40 a	16.50 a

Means in the same row with different letters are significantly different ($P \leq 0.05$).

Table (6): Sensory attributes of French fry strips as affected by blanching with different mixtures of ACD agents.

Sensory attributes	Score		Control	Treatments*							LSD
				1	2	3	4	5	6	7	
Colour	30	15 frozen	7.10^{d}	12.80 ^{ab}	13.50 ^{a}	13.38 ^{a}	10.37 ^{c}	12.04 ^{a}	12.02 ^{b}	14.06 ^{a}	1.08
		15 fried	11.9^{0b}	13.10 ^{a}	13.10 ^{a}	13.04 ^{a}	13.00 ^{a}	13.08 ^{a}	13.18 ^{a}	13.06 ^{a}	0.81
Taste	10		7.92^{bc}	8.90 ^{a}	9.12 ^{a}	9.10 ^{a}	7.00 ^{c}	8.50 ^{a}	8.50 ^{ab}	9.50 ^{a}	1.02
Odour	20		17.80^{ab}	18.30 ^{ab}	18.10 ^{a}	18.04 ^{ab}	16.30 ^{b}	16.94^{a}	17.06 ^{ab}	19.02 ^{a}	1.49
Crispiness	20		16.90^{a}	17.20 ^{a}	17.50 ^{a}	17.55 ^{a}	17.50 ^{a}	17.46 ^{a}	17.50 ^{a}	18.00 ^{a}	1.25
Texture	20		16.20^{a}	16.20 ^{a}	16.50 ^{a}	16.50 ^{a}	16.50 ^{a}	17.10 ^{a}	16.96 ^{a}	17.50 ^{a}	1.20

Means in the same row with different letters are significantly different ($P \leq 0.05$).
*1= SAPP (3gm/ L), 2= SAPP (3gm/L) + CA (1gm/ L), 3= SAPP (2gm/L) + CA (1gm/ L), 4= SMBS (3gm/ L), 5= SMBS (3gm/ L) + CA (1gm/ L), 6= SMBS (2gm/ L) + CA (1gm/ L), 7= SAPP (1.5gm/ L) + SMBS (1.5gm/ L) + CA (1gm/ L)

Table (7): Sensory attributes of freeze stored (-18 °C for 90 days) french-fries as affected by blanching with different mixtures of ACD agents.

Sensory Attributes	Storage period (Day)							LSD	Treatments*						LSD
	0 .0	15	30	45	60	75	90		Control	1	2	3	4	5	
Colour (frozen)	11.58 [a]	11.5 [a]	11.42 [a]	11.33 [a]	11.25 [a]	11.25 [a]	11.25 [a]	3.66	5.71 [f]	13 c	13.5 [b]	10 [e]	12 d	14 [a]	0.35
Taste	8.66 [a]	8.67 [a]	8.67 [a]	8.67 [a]	8.67 [a]	8.42 [a]	8.42 [a]	0.89	8 [c]	9 b	9 [b]	7.36 [d]	8.86 b	9.36 [a]	0.18
Odour	17.67 [a]	17.67 [a]	17.75 [a]	17.75 [a]	17.75 [a]	17.75[a]	17.75[a]	1.08	18 [b]	18.b	18 [b]	16.35[d]	17 c	19 [a]	0.11
Crispiness	17.33 [a]	17.33 [a]	17.5 [a]	17.5 [a]	17.5 [a]	17.5 [a]	17.5 [a]	0.40	17 [d]	17.42[bc]	17.35 [c]	17.50 [b]	17.50 [b]	18 [a]	0.13
Texture	16.5 [a]	16.58 [a]	16.75 [a]	16.75 [a]	16.75 [a]	16.75 [a]	16.75 [a]	0.78	16 [e]	16.42 [cd]	16.35 [d]	16.50 [c]	17 [b]	18 [a]	0.13

Means in the same row with different letters are significantly different ($P \leq 0.05$).
*1= SAPP (3gm/ L), 2= SAPP (2gm/ L) + CA (1gm/ L), 3= SMBS (3gm/ L), 4= SMBS (3gm/ L) + CA (1gm/ L),
5= SAPP (1.5gm/ L) + SMBS (1.5gm/ L) + CA (1gm/ L)