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Study of Aluminum-Free Complex Leavening Agent for Preparation of Deep-Fried Twisted Dough Stick

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Alum ($AlK(SO_4)_2 \cdot 12H_2O$) was used widely in the preparation of the traditional chinese wheat flour food, deep-fried twisted dough stick (DFTDS) as a leavening agent. However, alum was harmful to human health for long-term intake because of its high aluminum contents. The aim of the study is to determine effects of the aluminum-free complex leavening agent (AFCLA) in the preparation of deep-fried twisted dough stick. Through orthogonal tests and sensory evaluation, the optimal combination of aluminum-free complex leavening agent was identified, that 3.2 % sodium bicarbonate, 2.8 % glucono-delt-lactone, 0.4 % cream tartar and 0.8 % calcium dihydrogen phosphate. It could be used to replace alum completely as both leavening agent and nutrients and was great significance to improve the processing technology in the preparation of deep-fried twisted dough stick.

Key Words: Deep-fried twisted dough stick, Aluminum-free complex leavening agent, Orthogonal tests, Sensory evaluation, stydy.

INTRODUCTION

Deep-fried twisted dough stick (DFTDS, names Youtiao in China) is a traditional breakfast food in China and consumed popularly. In the traditional preparation of DFTDS, alum is often used to react with edible alkali ($NaHCO_3$ or Na_2CO_3) to increase the leavening efficiency of DFTDS. The chemical action principle of alum in making DFTDS is as follows.

$$2AlK(SO_4)_2 \cdot 12H_2O + 6NaHCO_3 \rightarrow A1_2O_3 \cdot 3H_2O + K_2SO_4 + 3Na_2SO_4 + 6CO_2\uparrow + 24H_2O$$

Alum contains aluminum, that belongs to low toxicity element in toxicology. However, because of its low rate of excretion in the human body, which give a negative impact to human, even can lead to certain diseases[1]. It was reported that long-term intake of high aluminum would be harmful to human health and led to osteoporosis, memory losses and even dementia[2]. Therefore, the aluminum content in flour products was limited to be not more than 100 mg/kg (expressed as dry weight[3]) in China according to National Food Hygiene Standards. A recent survey in some regions of China demonstrated that average aluminum concentrations of DFTDS are five times the national standard[2]. This showed that alum abuse is popular

in some regions of China. Today, more and more people are concerned about food safety of their daily food. Food industry is putting a lot of effort to develop the diet food products containing less aluminum or aluminum-free to meet the demand in the market. There is no aluminum-free complex leavening agent (AFCLA) which has been applied present in the DFTDS marketplace for the moment and nor is there much study in the literature regarding to it. It is of great significance to develop AFCLA and improve the processing technology of DFTDS. The objective of this study is to investigate the effect of AFCLA and the possibility to replace alum in the preparation of DFTDS.

EXPERIMENTAL

Wheat flour and vegetable oil were obtained from local retailer in Shijiazhuang. Sodium bicarbonate, cream tartar, calcium dihydrogen phosphate, glucono-delt-lactone, alum and salt were of edible grade and provided by the local reagent retailer.

Electronic balance was provided by Sartorius Scientific Equipment Co. Ltd. (Beijing, China). Normal balance was purchased from Wuhan Balance Instrument Factory (Wuhan, China). Biochemical Incubator was provided by Shanghai Xun Industrial Co. Ltd. (Shanghai, China). Induction cooker and SP-2100 spectrophotometer were purchased each from Electronic Equipment Factory of Tianjin Central Baptist (Tianjin, China) and Shanghai spectrometer Co., Ltd. (Shanghai, China).

Experimental method

Action principle of aluminum-free complex leavening agent: The AFCLA prepared in this study consisted of sodium bicarbonate, cream tartar, calcium dihydrogen phosphate and glucono-delt-lactone. Its action principle was that the phosphate and organic acid salts reacted with $NaHCO_3$ to produce $CO_2\uparrow$ to make the dough expansing. The chemical reactions were as follows:

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2\uparrow + 2H_2O$$
$$3Ca(H_2PO_4)_2 + 8NaHCO_3 \rightarrow Ca_3(PO_4)_2 + 4Na_2HPO_4 + 8CO_2\uparrow + 8H_2O$$
$$KHC_4H_4O_6 + NaHCO_3 \rightarrow KNaC_4H_4O_6 + CO_2\uparrow + H_2O$$

Glucono-delt-lactone of NACLA was not acid itself, but would be of acidity function after been heated and hydrolyzed. In addition, it had the effects of improving flavour, antioxidation, saving vegetable oil and bacteriostasis[4].

Orthogonal test design of aluminum-free complex leavening agent: The level choice of each factor in orthogonal test mainly considered their reaction amounts with sodium bicarbonate and their current market pricet. The four factors, sodium bicarbonate, cream tartar, calcium dihydrogen phosphate and glucono-delt-lactone were selected to do the orthogonal tests L_9 (3^4). The factors and levels were shown in Table-1.

Preparation of aluminum-free complex leavening agent: After inspecting and screening, the raw materials were mixed well in proportion and then weighting and packaged.

TABLE-1
FACTORS AND LEVERS OF ORTHOGONAL TESTS

Levers	Sodium bicarbonate (%) (A)	Glucono delt-lactone (%) (B)	Cream tartar (%) (C)	Calcium dihydrogen phosphate (%) (D)
1	3.2	1.6	0.4	0.6
2	3.6	2.2	0.8	0.8
3	4.0	2.8	1.2	1.2

Preparation of deep-fried twisted dough stick: The mixture of AFCLA and salt which had been mixed in proportion was dissolved in 10 times warm water (40 °C), then required propor-tions of wheat flour was added and together mixed untill a homogeneous, smooth and soft dough was obtained. This was then covered over and allowed to ferment for about 0.5 h at room temperature. After fermentation, the eased dough was cut and moulded into shape required and deep fried for about 1 min with vegetable oil at 180 °C.

Influence of aluminum-free complex leavening agent on expansion rate and sensory properties of deep-fried twisted dough stick: Determination of expansion rate of DFTDS. Expansion rate was expressed as the ratio of total volume of DFTDS before and after deep-fried.

Sensory evaluation: Sensory evaluation of samples prepard with different formula combinations was carried out with a 7 member panel of which were the research assistants or graduate students of Food Engineering department. Panel experienced with sensory evaluation of foods were pre-trained before actual analyses. Panelists ranked the samples by 100-point hedonic scale of which 1 being the worst and 100 being the best for their appearance, taste (mouthfeel) and overall preference. The samples were cooled down to 40 °C upon preparation before serving to the panelists.

Note: The material content on the table was expressed as the weight per cent of each material accounting for flour, the same below.

RESULTS AND DISCUSSION

Orthogonal test results of aluminum-free complex leavening agent formula: Because AFCLA is the leavening agent, expansion rate would be considered the primary judgement index and sensory scores was considered the secondary judgement index. Table-2 shows that the influencing order of the four factors on expansion rate was A > D > B > C and the optimal combination was $A_1B_3C_1D_2$. On sensory evaluation, the both were A > D > C > B and $A_1B_3C_1D_3$. After comprehensive consideration, $A_1B_3C_1D_2$ was identified as the optimal combination, that 3.2 % sodium bicarbonate, 2.8 % glucono-delt-lactone, 0.4 % cream tartar and 0.8 % calcium dihydrogen phosphate.

Influence of sodium bicarbonate addition on sensory properties of deep-fried twisted dough stick: It could be seen from Table-2 that the sodium bicarbonate addition had a significant effect on the expansion rate and sensory properties of DFTDS. It was decomposed into sodium carbonate residue after heating, made the

product alkaline and affected the taste of products. Table-3 revealed that when its addition reached to 3.6 %, there was a slightly alkaline taste, but it did not affect the consumption, when reached to 4 %, there was a strong alkali flavor and the DFTDS was not fit to eat.

TABLE-2
RESULTS AND RANGE ANALYSIS OF ORTHOGONAL TESTS

Test	A	B	C	D	Expansion rate	Sensory scores
1	1	1	1	1	6.04	95.4
2	1	2	2	2	5.86	93.5
3	1	3	3	3	5.28	90.2
4	2	1	2	3	4.17	71.3
5	2	2	3	1	4.40	78.6
6	2	3	1	2	5.56	91.6
7	3	1	3	2	5.80	92.6
8	3	2	1	3	5.11	88.7
9	3	3	2	1	5.68	92.4
k_1	5.72 (93.0)	5.33 (86.4)	5.57 (91.9)	4.85 (88.8)		
k_2	4.71 (80.5)	5.12 (87.5)	5.24 (85.7)	5.37 (92.6)		
k_3	5.53 (91.2)	5.56 (91.4)	5.16 (87.1)	5.74 (83.4)		
R	1.01 (12.5)	0.44 (5.0)	0.41 (6.2)	0.89 (9.2)		
Influencing order		A > D > B > C (A > D > C > B)				
Optimal combination		$A_1B_3C_1D_2$, ($A_1B_3C_1D_3$)				

A = Sodium bicarbonate, B = Glucono-delt-lactone, C = Cream of tartar,
D = Calcium dihydrogen phosphate

TABLE-3
INFLUENCE OF SODIUM BICARBONATE ADDITION
ON SENSORY PROPERTIES OF DFTDS

Test	Sodium bicarbonate (%)	Smell	Appearance	Flavor	Texture	Sensory scores
1	2.8	20	19	20	17	76
2	3.0	22	21	22	22	87
3	3.2	24	24	24	23	95
4	3.4	24	23	22	23	92
5	3.6	17	22	17	21	76
6	3.8	10	23	10	22	65
7	4.0	5	23	5	23	56

Verified test of optimal formula combination: The verified results on the expansion rate, the sensory evaluation of the optimal combination and the traditional "alum" formula were shown in Tables 4 and 5.

TABLE-4
VERIFIED RESULTS OF OPTIMAL FORMULA COMBINATION

Verified test	Expansion rate	Sensory scores
1	6.07	94.6
2	6.12	95.8
3	6.05	93.2
Mean value	6.08	94.5

TABLE-5
RESULTS ON SENSORY EVALUATION AND EXPANSIVITY OF "ALUM"

Test	Expansion rate	Sensory scores
1	5.87	89.6
2	5.73	91.3
3	5.64	92.8
Mean value	5.74	91.2

Alum reacted slowly with the edible alkali, led to the dough fermentation time up to 5 h or more and less gas been released[5]. However, for AFCLA, the gas released methods and carbon dioxide production rates were different, when the acid salts of AFCLA reacted with edible alkali. They had also different influences on the colour, taste and texture of DFTDS. Therefore, the use of the AFCLA consisted the acid salts can play the role of combined effects and was of adventages of larger carbon dioxide gas production and higher fermentation speed compared with the conventional alum formular. Both results in Tables 4 and 5 shown that the DFTDS prepared in optimal combination had the excellent sensory and expansion rate results and could completely replace the traditional alum formula.

Conclusion

Aluminum-free complex leavening agent could replace the traditional alum completely to make DFTDS. It was convenient in use and made the dough leavening fast. The sensory quality made from NACLA was superior to that of alum. The optimal formula combination derived from the experiment is 3.2 % sodium bicarbonate, 2.8 % glucono-delt-lactone, 0.4 % cream tartar and 0.8 % calcium dihydrogen phosphate.

Aluminum-free complex leavening agent met the requirements of China National Food Hygiene Standard and used safety. It not only avoided the hazards of aluminum to human body, but also supplemented the needs of human body with nutrients of calcium and phosphorus. Therefore, it could be used as both leavening agent and nutrients.

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