DOI 10.31891/2307-5732-2024-343-6-39
УДК 621.928.37

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IMPLEMENTATION OF VORTEX MACHINES IN BAKERY PRODUCTION

Bread production is one of the most essential branches of the food industry, which provides the population with the main food product. The quality of bread, flour confectionery, and products from wheat directly depends on the quality of raw materials, their biological value and production technology, and the equipment used. One of the critical stages in flour preparation is its sifting, which plays a vital role in improving the characteristics of flour and, accordingly, the finished product. The production of food products is accompanied by the generation of waste, which, in any case, enters the environment without proper cleaning, especially in large enterprises with old technologies and equipment. Using such equipment leads to severe illnesses among workers. Currently, liquid waste, a significant pollutant, prevails in food enterprises. Today's urgent problem is cleaning dusty gases at elevators, flour mills, grain mills, feed mills, granaries, grain dryers, and agricultural enterprises. That's why, an experimental and theoretical study was conducted to determine the efficiency of flour capture by improved vortex installations. The separation of solid particles from the dusty flour stream was investigated. The overall efficiency of the device with opposing swirling flows is determined. A sieve analysis of flour was carried out. Fractional size samples of dust-dispersed flour particles were obtained. The process of drying wet flour in devices with opposite swirling flows was studied for its further use in flour confectionery products. The prospective use of the proposed vortex dust collector as a drying device has been proven. The conducted experimental and theoretical research on the determination of the efficiency of improved vortex installations, the separation of solid particles from dusty air based on flour, the determination of the overall efficiency, the size of fractions, the sieve analysis of flour, and the study of wet flour for drying in the ACSF were investigated, which is evidence that that the device with the opposite swirling flows is not only for catching various types of dusty food products but also for drying this or that product, which is quite convenient to use.

Keywords: *flour, flour confectionery, protein, biological value, dust collector, food product*

САВЧЕНКО МАРИНА, РАДЧУК ОЛЕГ, КОШЕЛЬ ОЛЕНА
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Виробництво хліба – одна з найважливіших галузей харчової промисловості, яка забезпечує населення основним продуктом харчування. Якість хліба, борошняних кондитерських виробів, виробів із пшениці безпосередньо залежить від якості сировини, її біологічної цінності та технології виробництва, застосовуваного обладнання. Одним із відповідальних етапів приготування борошна є його просіювання, яке відіграє важливу роль у покращенні характеристик борошна і, відповідно, готового продукту. Виробництво харчових продуктів супроводжується утворенням відходів, які, в будь-якому разі, потрапляють у навколишнє середовище без належного очищення, особливо на великих підприємствах із застарілими технологіями та обладнанням. Використання такого обладнання призводить до тяжких захворювань працівників. Нині на харчових підприємствах переважають рідкі відходи, які є значним забруднювачем. Актуальною проблемою сьогодення є очищення запилених газів на елеваторах, борошномельних, крупорушних, комбікормових заводах, зерносховищах, зерносушарках, сільськогосподарських підприємствах. Тому у роботі проведено експериментальне та теоретичне дослідження щодо визначення ефективності вловлювання борошна вдосконаленими вихровими установками. Досліджено виділення твердих часток із пилового потоку борошна. Визначено загальний ККД пристрою при зустрічних закручених потоках. Проведено ситовий аналіз борошна. Отримано фракційні зразки пилодисперсних частинок борошна. Вивчено процес сушіння вологого борошна в апаратах із протилежними закрученими потоками з метою його подальшого використання в борошняних кондитерських виробах. Доведено перспективність використання запропонованого вихрового пиловловлювача як сушильного пристрою. Проведені експериментальні та теоретичні дослідження з визначення ефективності вдосконалених вихрових установок, виділення твердих частинок із запиленого повітря на основі борошна, визначення загальної ефективності, розміру фракцій, ситового аналізу борошна та дослідження досліджено вологе борошно для сушіння в АКСФ, що свідчить про те, що пристрій із зустрічними закрученими потоками призначений не тільки для уловлювання різного роду пилоподібних харчових продуктів, а й для сушіння того чи іншого продукту, що досить зручно у використанні

Ключові слова: *борошно, борошняні кондитерські вироби, білок, біологічна цінність, пиловловлювач, харчовий продукт*

Introduction

Bread production is one of the most essential branches of the food industry, which provides the population with the main food product. The quality of bread, flour confectionery, and products from wheat directly depends on the quality of raw materials, their biological value and production technology, and the equipment used [1,2]. One of the critical stages in flour preparation is its sifting, which plays a vital role in improving the characteristics of flour and, accordingly, the finished product [3,4].

Sifting flour removes large particles, impurities, and unnecessary elements, increasing flour quality. The main functions of sieving are: 1. Improving the quality of flour - removing impurities and particles that can affect the texture and taste of bread. 2. Homogeneity of raw materials - Ensuring the uniform distribution of particles, which contributes to the stability of the dough kneading process. 3. Reduction of humidity - evaporation of a part of the moisture, which allows you to avoid problems with flour caking [5,6].

Modern sieving technologies have improved significantly. The main types of sifters used in bread production [7,8]: mechanical sieves: Use physical methods to separate particles. This is the most traditional method but may need more effectiveness.

Aerodynamic sifters: Use airflow to separate light impurities, increasing flour's purity. Electronic sifters: Innovative technologies that allow you to control the sifting process with maximum precision. Mechanical flour sifters are devices used to clean flour from impurities and improve its quality before further processing or use in baking. They help remove grains that have not passed through the sieve and reduce the content of various impurities that can affect the taste and texture of finished products [9,10].

Mechanical sifters usually consist of a sieve (or deck) on which the flour is located and a mechanism that ensures the movement of the sieve. There are several types of mechanical sifters [11,12]: Vibrating sieves: Use vibrations to ensure the passage of flour through the sieve. Vibrations help increase sieving efficiency, as flour particles move faster and do not stick to the surface of the sieve. Centrifugal sieves: Use centrifugal force to separate large particles from small ones. This allows you to achieve the desired result faster. Rotary sifters: The flour moves through the sieve thanks to a rotating mechanism that ensures uniform sifting in these devices.

The advantage of using mechanical sifters is that they improve flour quality. Sifting helps remove grains and impurities that can affect the texture and taste of the finished product [13,14]. Another advantage is increased uniformity. Evenly sifted flour provides a more stable result during baking. Also, using such sifters allows for the reduction of the costs of raw materials, improvement of the quality of flour, reduction of its costs, and increased production efficiency. An equally important factor is the reduction of waste. The removal of impurities reduces the amount of waste, which positively affects the environment, ensuring product safety and improving the quality of raw materials, which enhances the protection of the final product [15,16].

The production of food products is accompanied by the generation of waste, which, in any case, enters the environment without proper cleaning, especially in large enterprises with old technologies and equipment [17-19]. Using such equipment leads to severe illnesses among workers [20-23]. Currently, liquid waste, a significant pollutant, prevails in food enterprises. Today's urgent problem is cleaning dusty gases at elevators, flour mills, grain mills, feed mills, granaries, grain dryers, and agricultural enterprises.

Literary analysis

Dust-collecting units used to clean dusty flows generated at enterprises are diverse in design; in most cases, cleaning is carried out due to centrifugal force. Cyclones are used for grain dust cleaning. Cyclones are also used for sticky dust.

Dust collection is the process of capturing dust in the places of its release and accumulation with the help of local suction devices of the exhaust ventilation system (hoods, umbrellas, sleeves, hoods, etc.) with subsequent cleaning of dusty air (gases) in special dust collection devices. Air cleaned of dust enters the atmosphere, serves for further purification of gaseous components, or is entirely or partially re-directed into the technological process for secondary use.

Currently, there are two systems of dust collection - technological and sanitary. The technological system is intended for air purification from gases or dust and is used for technical needs (pneumatic transport). Sanitary - to protect the air pool from contamination by radionuclides, chemicals, or biologically active compounds. Dust collection is characterized by the effectiveness of general and fractional indicators of cleaning air (gases) from dust.

Dust collection is divided into:

- under gravity – based on naturally deposited dust particles from a slowly moving dust and gas stream; used to capture particles larger than 500 μm; is carried out in chamber dust collectors;
- under the action of centrifugal forces - carried out in cyclones; cyclones are used to separate relatively coarse dust; there are battery cyclones, which are designed to separate dust up to 5 μm in size and are units consisting of separate small-sized cyclones that function in parallel;
- dust collection by filtering is a process of cleaning dusty gases and air from solid particles when gases are passed through a porous partition; filters are used to implement this process;
- Electric dust collection - gases and air are cleaned under electric forces. This is one of the most advanced dust collection methods; devices include electric air filters [18].

Works [15-17] analyzed the drying process, which is widely used in food and processing industries. The task of drying is wider than the extraction of moisture. Still, at the same time, it is also a technological process during which the properties of materials change: physicochemical, structural-mechanical, biological, and technological. During grain processing at dry grain mills, the yield of flour increases, and the energy consumption for its production decreases, so such flour is better stored. Product drying is carried out to prevent or slow down biological, physicochemical, and other processes, increase shelf life, reduce transport costs, reduce the area of warehouses during storage, concentrate nutrients, and obtain qualitatively new products with high biological value.

Currently, there is a small amount of use of ACSF conducting experimental research, which was done and is being done by foreign and domestic experts in this field, namely O.R. Yakuba and M.Yu. Savchenko-Pererva, V.P. Kuts, based on the analysis of their works, once again testifies to the insufficient study of the trapping process in ACSF. Therefore, this determines the relevance of research on separating solid particles and increasing capture efficiency in vortex dust collectors.

The purpose and objectives of the article. The article aims to obtain high-quality flour by conducting an experimental study by separating solid particles from flour and determining the overall efficiency of capture by determining the fraction of captured particles.

To achieve the goal, the following tasks were set:

• conduct an analysis of materials and literary sources about the process of dust collection in the ACSF;
• perform an experimental study based on the capture of flour;
• make calculations regarding the efficiency of the dusting process;
• determine the size of the fraction of trapped particles.

The object of research is the process of drying and catching flour.

The subject of the research is the catching and drying of various types of dusty food products while preserving the quality of the products for further production stages.

Research methods focus on cleaning gases from dust particles to protect the atmosphere from dust pollution.

The scientific novelty is the determination of more effective work and productivity of the ACSF based on theoretical, practical, and experimental research methods.

Materials and methods

Before conducting research, it is necessary to know flour's physical and chemical properties because further results depend on this.

The moisture content of both wheat and rye flour should be no more than 15%. When flour with high humidity spoils much faster during storage, it has a lower water absorption capacity than dry flour. Dry flour should crumble after squeezing it in the palm of your hand [2].

Ashiness (or whiteness) characterizes the type of flour. First of all, the amount of ash depends on the content of peripheral grain particles in the flour, which are the primary carriers of mineral substances and cause the darkening of the flour. If the flour is of a low grade, it contains a significant amount of peripheral grain particles, so its ash content is higher, and the whiteness index is lower than that of high grades of flour [3].

The mass fraction of metallomagnetic impurities should be at most 3 mg per 1000 g of flour. The size of their particles should be no more than 0.3, and the mass of ore or slag grains should be no more than 0.4 mg. The mass fraction of impurities of vegetable origin is normalized in the grain prepared for grinding. These impurities include harmful impurities (bitter, soot, horns) and an admixture of grains of other cultures - rye, barley, and sprouted grains. Harmful impurities, the mass fraction of which should be no more than 0.05, including knotweed or mustard (together or separately) - no more than 0.04, chrysanthemum - no more than 0.1%.

Also, an important indicator not specified in the regulatory and technical documentation but is of great importance is the acidity of the flour. Acidity characterizes the freshness and type of flour and affects the taste and smell. Acidic phosphates, free fatty acids, and carboxyl groups of protein compounds cause the acidic reaction of flour.

Acid phosphates: KH_2PO_4, $Ca(H_2PO_4)_2$, $Mg(H_2PO_4)_2$ - is formed as a result of the hydrolysis of organophosphorus compounds, and fatty acids - as a result of the hydrolysis of fats. Wheat flour of the II grade and wallpaper, rye hulled, and wallpaper contain much more of these compounds than in low-waste flour, which is why their acidity is higher [1].

Also, flour's acidity depends on its storage duration and conditions. In conditions that favor the enzymatic hydrolysis of flour polymers and the intensification of oxidation processes, the acidity of flour increases.

Flour consists of particles ranging in size from 1 to 240 microns. The components of flour are starch grains with a size of 1 to 50 μm, intermediate protein particles with a size of no more than 20 μm, individual cells of the endosperm with a size of 40 to 150 μm, bran particles with a size of 40 to 240 μm. Quantitative ratios of these components can vary widely depending on the variety, protein content, starch in the wheat grain, and the degree of mechanical impact on the grain and its processing products during the milling process.

Drying removes moisture from solid, liquid, and gaseous materials. The origin of the flour, regardless of its nature, must be dried at a sufficiently high speed and temperature. Tiny particles of flour raw material have a developed surface. However, there is a problem with drying flour - a high fire danger level in the contact process of the heated flour mixture with oxygen. However, at the moment, this problem is irrelevant to the current technological approach. Modern equipment is thought out and designed in such a way that all dangerous nuances are taken into account. There is a vast selection of different types of flour-drying equipment: vertical pneumatic dryers, drum dryers, high-speed mixers, vacuum drying equipment, and freeze-drying. However, the thermoradiation (infrared radiation) drying method is used most in the food industry. In my work, I use ACSF, the operation principle, given below [4].

The dust collector works like this, Fig. 1: Dust gas can enter the housing simultaneously through the central axial inlet (3) with swirled (4) and the tangential or spiral external inlet (2) of the gas flow. A secondary stream fed through the za vortexer (2) moves down from the upper part of the case (1). In the process of movement, it gradually mixes with the axial flow, which moves from the bottom to the mountain through the swirler (4), between the two conical shells (7) and (8) through the opening (9). As it rises, the lower axial flow gradually mixes with the external flow and exits into the outlet pipe (5). In the contaminated rotating gas flow, under the action of centrifugal forces, suspended dust particles are directed to its periphery, and from there, together with the secondary flow, they fall near the walls down to the conical shell (7), and through the hole (11) between the shells (7) and (10) are poured into a conical hopper (6), and then into a container [5].

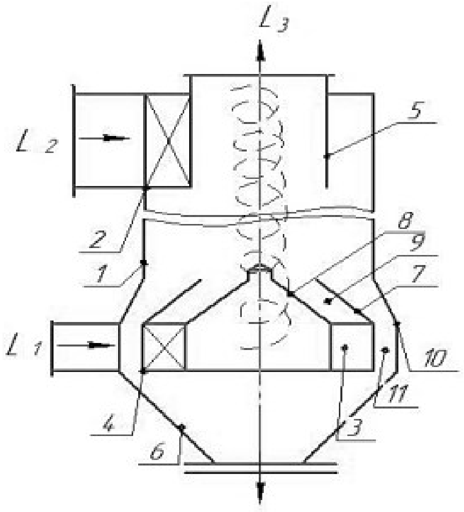

Fig. 1. Scheme of the vortex dust collector: 1 – body; 2 – tangential or summer external entrance; 3 – central axial input; 4 – swirler; 5 – output pipe; 6 – conical hopper; 7,8 – conical washer shells; 9 – opening between shells; 10 – housing shell; 11– hole between the case and washer.

Results

First, we determined the fractional efficiency, which can be determined by theoretical, practical calculation, sieve analysis, and microscopy. Unfortunately, it was impossible to decide on a microscopic method, as the products were too glued together under the influence of oils, so it was impossible to see the image of the fractions under a microscope. The overall efficiency is determined by dusting the air through two channels for 24 seconds with dried flour and wet flour for 15 seconds, with a weight corresponding to the planes of the inlet nozzles. Thus, G_1 = 40 g of flour enters the secondary pipe of the ACSF with a length of a_2 = 0.09 m, relative to wet flour, G = 25 g, and G_2 = 20 g, wet G = 14 g, to the primary one, with a length of a_1 = 0.045 m, wet G = 14 g (optimal weight for this experiment) [5].

Sieve analysis of the study. To do this, we take 10 g of the product, weigh it, place the sieves from larger diameter to more minor, and pour it on the upper sieve, after which the product moves to the lower sieve and so on, until it remains entirely on the surface. Then, we pour into the container and weigh the samples to determine the fractions. The obtained results are shown in Table 1.

Table 1

The results of the sieve analysis of the study

Indicators flour before ACSF		Indicators flour after ACSF	
sieve cell size	Indicators, g	sieve cell size	Indicators, g
0,3	5,1670	0,3	4,6630
0,2	1,4705	0,25	1,9140
0,16	1,8440	0,16	1,2525

To determine the hundredth number of fractions, it is necessary to calculate the formula quickly:

$$\eta i = Gi/Gcom \times 100\,\% \quad (1)$$

де η_i – the number of the corresponding fraction, %;
G_i – the mass of the corresponding fraction, g;
G_{com} – total mass of fractions, 10 g.
η_{300} = 5, 1670 g/10 g × 100 % = 51,6 %;
η_{200} = 1,4705 g/10 g × 100 % = 14,7 %;
η_{160} = 1,8440 g/10 g × 100 % = 18,4 %;
η_{300} = 4,6630 g/10 g × 100 % = 46,6 %;
η_{250} = 1,9140 g/10 g × 100 % = 19,1 %;
η_{160} = 1,2525 g/10 g × 100 % = 12,5 %.
To determine the error of the results of the sieve analysis of flour, we use the following formula:

$$\eta\% = (Gcom - Gf)\,/Gcom \times 100\,\% \quad (2)$$

де $\eta_{\%}$ – error of sieve analysis results, %;
$G_{f.}$ – the sum of the masses of all the obtained fractions, g;
G_{com} – total mass of fractions, 10 g.
$\eta_{\%}$ = (10g−(5,1670 g+1,4705 g+1,8440 g)) /10 g × 100 % = 15 %
The error is up to ACSF – 15%
$\eta_{\%}$ = (10g−(4,6630 g+1,9140 g+1,2525 g)) /10 g × 100 % = 21%
Error after ACSF – 21%

60 g of the studied material was fed to the ACSF. In the final result, flour yield was 37 g (+7.1 g of impurities). The calculation of the overall efficiency was determined based on the weight of dust G_{vl} captured in the hopper of the ACSF to the weight of dust G_{vx} that enters the device during the period of the experiment τ:

$$\eta\, flour = (Gvl\,/Gvx) \times 100\,\% \tag{3}$$

Calculation of the overall efficiency of the captured flour:

$$\eta\, flour = (37\,/60) \times 100\,\% = 61\%, \tag{4}$$

Calculation of the total efficiency of the captured flour (in brackets, the efficiency ranges, including impurities):

$\eta_{\text{flour}} = (37 +(7,1))\ /60) \times 100\ \% = 73,5\%$

Research was also conducted on wet flour; for the development of this experiment, 3 g of water and 36 g of flour were taken, and the moisture content was approximately 15%. 39g was used to enter the apparatus; after the capture, they received 36g of already dried flour, and therefore, there is proof that ACSF dries products.

Calculation of the overall efficiency of captured wet flour:

$$\eta ov = (36\,/39) \times 100\,\% = 92\% \tag{5}$$

In the process of work, the ACSF received the following data:

With the help of an anemometer, the indicators of flows L_1 = 13.8 m^3 /s were determined and L_2 = 14.8 m^3 /s; the height of the liquid column h = 18 cm = 0.18 m; duration of each experiment τ = 24 s.

To find the total pressure losses, you need to use the formula:

$$P = \rho g h, \tag{6}$$

where ρ is the density of water, 1000 kg/m^3;

g – acceleration of free fall, 9.81 N/kg;

h is the height of the liquid column, 0.18 m.

P = 1000 kg/m^3 × 9.81 N/kg × 0.18 m = 1765.8 Pa

Conclusions

The conducted experimental and theoretical research on the determination of the efficiency of improved vortex installations, the separation of solid particles from dusty air based on flour, the determination of the overall efficiency, the size of fractions, the sieve analysis of flour, and the study of wet flour for drying in the ACSF were investigated, which is evidence that that the device with the opposite swirling flows is not only for catching various types of dusty food products but also for drying this or that product, which is quite convenient to use.

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