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CLASSIFICATION AND ANALYSIS OF METHODS AND EQUIPMENT FOR DEHYDRATION OF DAMP DISPERSIVE MATERIALS

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Dehydration of damp dispersive materials is a wide spread group of processes in food and processing industry. In particular to this group belong processes of separation of damp dispersive waste of food enterprises (alcoholic bard, beer pellets, beet press, coffee and barley slime) at solid and liquid phases. At majority of Ukrainian food enterprises this waste is poured out on the ground or in nearby ponds, but in case of its separation the solid phase of such materials can be used as valuable additive to agricultural fodders or as fuel. As a result, one can provide a complex solution of problems: waste utilization, prevention of nature pollution and receipt of an additional income from realization of fodders or fuel. There are a lot of methods of dehydration of damp dispersive materials that can be divided at several groups: mechanical, thermal, electro-physical, biological, chemical and combined. An improved classification of main methods of dehydration of damp dispersive materials and equipment for their realization is presented in the article. This classification allows to conduct a more systemized and founded analysis of advantages and disadvantages of the methods, to select an optimal method with consideration of conditions and parameters of a concrete enterprise and processed material. Such analysis and selection can be realized with help of a computer program. There is substantiated high efficiency of mechanical dehydration methods of damp dispersive materials, in particular, the method of pressing on equipment with hydraulic or unbalanced drive. There are proposed a block-scheme of an algorithm of automated analysis of methods and equipment for dehydration of damp dispersive materials for selection of admissible and most effective variants of their processing by such main criterions: as productivity, expenses of energy, specific consumption of materials of equipment and final humidity of processed material.

Key words: *dehydration, hydraulic press, damp dispersive materials, separation, productivity, energy consumption, final humidity.*

F. 4. Fig. 1. Ref. 15.

1. Problem formulation

Dehydration processes have a significant meaning for food and processing industry [1]. In particular to this group of processes belong technologies of separation of dispersive food waste (alcoholic bard, beer pellets, beet press, coffee and barley slime) at hard phase (concentrate) and liquid phase (filtrate) [2, 3]. At majority of Ukrainian food enterprises this waste is poured out on the ground or in nearby ponds, but in case of its separation the solid phase of such materials can be used as valuable additive to agricultural fodders or as fuel [3, 4]. As a result, one can provide a complex solution of problems: waste utilization, prevention of nature pollution and receipt of an additional income from realization of fodders or fuel.

There are a lot of methods of dehydration of damp dispersive materials that can be divided at several groups: mechanical, thermal, electro-physical, biological, chemical and combined [2, 5]. Various types of equipment with mechanical, electro-mechanical, electro-magnetic, pneumatic, hydraulic and combined drive, with different principles of operation and design, of continuous and periodical operation, with higher and lower productivity [2] are created for realization of these methods. Selection of an optimal method and machines for its realization should be fulfilled with consideration of conditions and parameters of a concrete enterprise (its sizes, volumes of production and waste, their physical and mechanical characteristics) [3, 4].

In the opinion of the authors, a classification of methods and equipment for dehydration of damp dispersive materials provides more systemized and founded analysis of their advantages and disadvantages with provision for productivity, energy efficiency, given final humidity of the material. So, elaboration of such classification with provision of a possibility of an automated selection of rational technologies and machines for conditions of a concrete enterprise is an actual problem.

2. Analysis of last researches and publications

The most complete and corresponding classification of the methods and equipment for dehydration of damp dispersive materials is presented in the work [2]. But this classification demands of corrections and abbreviation with consideration of the methods efficiency in conditions of modern high intensive production with ensuring of a possibility of a computerized selection of the most rational method and equipment.

A detailed analysis of methods and machines for dehydration of minerals as part of a technology of their ore-dressing is presented in the work [6]. The authors of the work pick out two main groups of the dehydration methods: mechanical (drainage, thickening, centrifugation, filtration) and thermal (drying). Chemical, physical-chemical and bio-chemical methods (sedimentation with use of flocculants, natural sedimentation, neutralization, chlorination, ozonization, ion-exchange technique, electro-chemical oxidation, extraction of organic components, adsorbtion, flotation, bio-filtration) are also shortly examined in the work, but they are not included in the general classification while they provide mainly disinfection of sewages of enterprises for mineral processing and don’t allow to remove from them basic part of mechanical solid particles.

The work [7] contains an evaluation of thermal methods of dehydration of fine dispersive materials (first of all – building mixtures). Actually, in the work presented only list of the main methods of drying and equipment for their fulfilment, with definition of advantages and disadvantages of each method. But there is absent a systematic classification of the methods and drying machines that can be used as a foundation for elaboration of the method of automated analysis and synthesis of optimal variants of technological processes and equipment for dehydration of damp dispersive materials.

An author of the work [8] shortly analyzes some most wide spread methods of mechanical dehydration with help of centrifuges and vacuum filters, but this classification is also incomplete and demands of additions and improvements.

There are analyzed thermal methods of dehydration of vegetable raw materials in the work [9], but without indication of quantitative parameters of their energy efficiency.

3. Aim of the researches

The aim of this work is elaboration of a classification of modern high effective methods of dehydration of damp dispersive materials with provision of a possibility of its utilization for conducting of an automated analysis and synthesis of variants of technological dehydration processes with consideration of basic criterions of efficiency: productivity, power consuming, metal consumption, provided final humidity of processed material.

4. Results of the researches

There is a classification of most effective methods and equipment for dehydration of damp dispersive materials, presented at the table 1. There are two main groups of the methods: mechanical and thermal [2].

Mechanical methods are most effective by energy expenses at unit of volume of delated liquid (2,5 ÷ 35 kW / t) and also by productivity (2 ÷ 25 t / h) [1 – 5]. An equipment for realization of mechanical methods has simple and reliable design, compact dimensions. A disadvantage of methods of this group is relatively high final humidity of processed material: 72 ÷ 76% – in case of utilization of screw, roller and hydraulic presses, vibro-shakers and vibro-sieves, centrifuges or separators; 20 ÷ 25% - under using of auger extruders and vibro-presses [1 – 5, 10]. By notion of authors of the article the most prospective method of the mechanical group is vibro-blowing loading on vibro-presses with unbalanced, electromagnetic or hydraulic pulse drive [2 – 5]. They provide high energy efficiency (2,7 ÷ 3,2 kW / t) of dehydration and productivity 20 ÷ 25 t / h [2 – 5]. Final humidity of the processed material 22 ÷ 25% (for alcoholic bard, beer pellets, beet press, coffee and barley slime) is acceptable for using these materials as fuel. But for long storing of the materials and their further utilization as additives to agricultural fodders [2 – 5] the materials should be dried additionally to humidity 8 ÷ 10%. That leads to increase of general energy expenses. Besides, one more shortcoming of vibro-blowing loading on vibro-presses, especially with hydraulic pulse drive is design complexity of the using equipment [3, 4, 10], so this method demands of some improvements.

Table 1

Classification of most effective methods and equipment for dehydration of damp dispersive materials

Groups of methods	Methods	Equipment for realization of the methods
Mechanical	Static pressing	Auger extruders, screw presses, roller presses, hydraulic presses
	Centrifugation	Centrifuges, separators
	Vibration loading	Vibro-shakers and vibro-sieves with unbalanced, electromagnetic or hydraulic pulse drive
	Vibro-blowing loading	Vibro-presses with unbalanced, electromagnetic or hydraulic pulse drive
Thermal	Evaporation	Open and vacuum evaporators
	Drying	Dryers: drum, vacuum roller, spray, vortical, aerofountain, vibration with infra-red radiation

Thermal methods in case of their using demand of maximal power-consuming from 740 kW / t – for vacuum evaporators up to 4500 kW / t – for spray dryers [2 – 5], but provide high enough productivity of dehydration and actually any necessary final humidity of processed material. These methods are effective at a completing stage of the processing process.

Besides, in some works are examined several more groups of methods as a part of corresponding technologies of processing: electro-physical (electrolytical, electrocoagulation, electro-flotation), physical-chemical (coagulation and floculation, flotation, exctraction) and biological (anaerobic fermentation, aerobic fermentation) [2, 10], but all these methods can be used for previous separation of firm fraction of damp dispersive materials before its further dehydration.

For realization of an automated selection of optimal variants of dehydration processes and equipment with concederation of concrete demands and conditions there is need to form databases with values of parameters of avalable equipment for dehydration of a real enterprize of food or production industry and physical-mechanical characteristics of processed material [11, 12, 13].

In particular the database 1 (DB1) should contain such main parameters of the equipment as: productivity of dehydration of available machines, t/h (P_1, P_2, ..., P_n); its energy efficiency, kW/t (E_1, E_2, ..., E_n); mass (m_1, m_2, ..., m_n); price (V_1, V_2, ..., V_n); main dimensions – length × width × height ($L_1 \times W_1 \times H_{g1}$; $L_2 \times W_2 \times H_{g2}$; ...; $L_n \times W_n \times H_{gn}$); initial necessary humidity of processed material, % (H_{i1}, H_{i2}, ..., $H_{i.n}$), final humidity of processed material that can be provided, % (H_{f1}, H_{f2}, ..., $H_{f.n}$), where 1, 2, …, n – number of variants of equipment for dehydration. Additionally, depending from a kind of the equipment there is need to point out its main working characteristics. For example, for vibro-presses with unbalanced or hydraulic pulse drive that can be [14]: range of amplitudes $R_{a.i}$ and frequencies $R_{v.i}$ of the executive element, maximal pressure $p_{max.i}$ that can be provided in the middle of a portion of processed material in the press-form (i – the number of the machine in the DB1).

The database 2 (DB2) should include information about of physical-mechanical characteristics of processed material (its daily mass m_d at the enterprise, initial H_i and necessary final H_f humidity, middle size of particles - d_m), parameters the production task (admissible energy efficiency E_a, kW / t) and real conditions of the concrete enterprise (admissible mass m_a, price V_a, main dimensions – length × width × height ($L_a \times W_a \times H_{g.a}$).

There is a block-scheme of an algorithm of automated analysis of methods and equipment for dehydration of damp dispersive materials and selection of the most effective method (fig. 1).

In correspondence with this block-scheme, at the first stage of the analysis on basis of parameters of DB1, DB2 there is realized a check-up of the conditions

$$P_i \geq \frac{m_d}{24}; \quad E_i \leq E_a; \quad m_i \leq m_a; \quad V_i \leq V_a; \quad L_i \leq L_a; \quad W_i \leq W_a; \quad H_{g.i} \leq H_{g.a}; \quad H_{i.i} \leq H_i; \quad H_{f.i} \leq H_f; \quad 1 \leq i \leq n. \tag{1}$$

The base of admissible variants (BAV) of methods and equipment for dehydration is formed by result of this check-up.

At the second stage of for the selected variants is carried out an additional check-up of a possibility of realization at the equipment of optimal for given processed material parameters of loading. For example, for vibro-presses conditions for the check-up are

$$R_{a.i} \leq R_{a.ppt}; \quad R_{v.i} \leq R_{v.opt}; \quad p_{max.i} \leq p_{max.opt}; \quad 1 \leq i \leq k, \tag{2}$$

where k – number of admissible variants after the first stage of the analysis. At that for determination of the $R_{a.ppt}$, $R_{v.opt}$, $p_{max.opt}$, there can be used the results of theoretical or experimental researches [2].

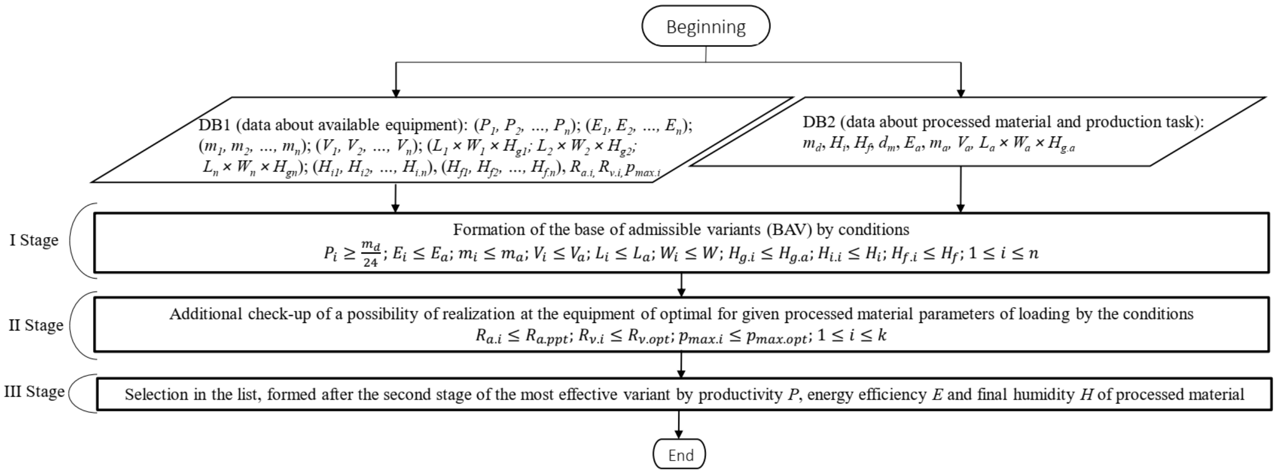

Fig. 1. Block-scheme of an algorithm of automated analysis of methods and equipment for dehydration of damp dispersive materials and selection of the most effective method

At the third stage the variants, that were selected after the second stage of the analysis are graded by main parameters of efficiency (productivity P, energy efficiency E and final humidity H of processed material) and the first variant (the most effective variant) in the ranked list is brought for realization.

In cases when the given final humidity H_f can't be achieved under utilization of one dehydration method and the corresponding equipment there is need with help of data from DB1 and DB2 to select one more or several more units of additional machines. For example, if $H_f = 20 \div 25\%$ there is recommended to use a technology that consists of four stages of dehydration: preliminary separation of liquid and firm phases with help of a vibro-blowing sieve, dehydration on a screw press, vibro-press with hydraulic pulse drive in the closed type press-form and on rolling installation with hydraulic pulse drive [2]. In such cases the analysis is conducted with consideration of the conditions

$$P_i \geq \frac{m_d}{24}; \quad E_i + \sum_{j=1}^{m} E_j \leq E_a; \quad m_i + \sum_{j=1}^{m} m_j \leq m_a;$$
$$V_i + \sum_{j=1}^{m} V_j \leq V_a; \quad L_i + k_L \sum_{j=1}^{m} L_j \leq L_a; \quad W_i + k_W \sum_{j=1}^{m} W_j \leq W_a; \qquad (3)$$
$$H_i + k_H \sum_{j=1}^{m} H_j \leq H_a; \quad H_{i.i} \leq H_{ip}; \quad H_{f.i} \leq H_{fp}; \quad 1 \leq i \leq n.$$

where m – the number of preliminary dehydration stages; k_L, k_W, k_H – coefficients of increase of general dimensions of dehydration technological complex, that consider distances between machines for preliminary dehydration stages; H_{ip}, H_{fp} – intermediate values of initial and final humidity that should be provided at the preliminary dehydration stage. An additional check-up of a possibility of realization of optimal loading parameters for the selected equipment of the preliminary stage is carried out with help of formulas (2).

In cases when necessary H_f can't be achieved under using of mechanical methods ($H_f = 8 \div 10\%$) then for the final stage should be selected a thermal dehydration method and a corresponding equipment for its realization.

If mass m_d can't be dehydrated with of one unit of equipment there is need to select several more units of this equipment by conditions

$$P_i p \geq \frac{m_d}{24}; \quad E_i p \leq E_a; \quad m_i p \leq m_a; V_i p \leq V_a; \quad L_i k_L p \leq L_a;$$
$$W_i k_W p \leq W_a; H_i k_H p \leq H_a; \quad H_{i.i} \leq H_{ip}; \quad H_{f.i} \leq H_{fp}; \quad 1 \leq i \leq n, \qquad (4)$$

where p – number of the units of equipment.

5. Conclusions

1. Existing classifications of methods and equipment for dehydration of damp dispersive materials are incomplete and don't allow to use these classifications for automated analysis and well-founded selection of the most effective variant of technology of processing with consideration of real conditions of concrete enterprise and physical-mechanical characteristics of processed material.

2. There is proposed an improved classification of methods and equipment for dehydration of damp dispersive materials that can be used for systemized analysis of advantages and disadvantages of the methods and machines.

3. A block-scheme of an algorithm of automated analysis of methods and equipment for dehydration of damp dispersive materials is presented in the work. The elaborated classification and the algorithm allow

on a base of information about available equipment for dehydration, processed material, concrete conditions of real enterprise of food industry and demands of production task to select admissible and the most effective variants of a processing technology with consideration of the criterions: productivity, energy efficiency, , specific consumption of materials of equipment and final humidity of processed material.

References

[1] Cherevko, O. I., Poperechny, A. M. (2014). *Procesy i aparaty harchovyh vyrobnycztv [Processes and apparatuses of food productions]*. Harkiv: Svit Knyg [in Ukrainian].
[2] Sevostianov, I. V. (2020). *Tekhnolohiia ta obladnannia dlia vibroudarnoho znevodnennia volohykh dyspersnykh materialiv : monohrafiia [Technology and equipment for vibro-blowing dehydration of damp dispersive materials : monograph]*. Vinnytsia: VNAU [in Ukrainian].
[3] Sevostianov, I. V., Lutsyk, V. L. (2017). Ustanovka dlia bahatostadiinoho znevodnennia vidkhodiv kharchovykh vyrobnytstv [Installation for multistage dehydration of food productions waste]. *Visnyk mashynobuduvannia ta transportu, 1*, 105–113 [in Ukrainian].
[4] Sevostianov, I. V. Polishchuk, O. V., Slabkyi, A. V. (2015) Rozrobka ta doslidzhennia ustanovky dlia dvokomponentnoho vibroudarnoho znevodnennia vidkhodiv kharchovykh vyrobnytstv [Elaboration and research of installation for two-component vibro-blowing dehydration of food productions waste], *Vostochno-evropeiskyi zhurnal peredovykh tekhnolohyi*, 5/7 (77), 40–46 [in Ukrainian].
[5] Sevostianov, I., Ivanchuck, Ya. Kravets, S. (2020). Elaboration and researches of highly effective installation for vibro-blowing dehydration of dispersive waste of food productions. *Tekhnika, enerhetyka, transport APK, 3 (110).* 24–33. [in English].
[6] Biletskyi, V.S., Oliinyk, T.A., Smyrnov, V.O., Skliar, L.V. (2019). *Tekhnika ta tekhnolohiia zbahachennia korysnykh kopalyn. Chastyna III. Zakliuchni protsesy. [Technique and technology mineral enrichment. Part III. Final processes]*. Kryvyi Rih: Kryvorizkyi natsionalnyi universytet [in Ukrainian].
[7] Zamizkyi, O., Omelchuk, D. (2018). *Analiz isnuyuchykh sposobiv sushky tonkodyspersnykh materialiv [Analysis of existing methods of drying fine materials]*. Hirnychyy visnyk, 103, 191-197 [in Ukrainian].
[8] Bogdanov, A. (2016). *Tekhnologiya mekhanicheskogo obezvozhivaniya. Monografia [Mechanical dewatering technology. Monograph]*. Dnepropetrovsk: NGU [in Ukrainian].
[9] Gosovsky, R. (2018). *Zakonomirnosti filtratsiinoho sushinnia orhanichnoi syrovyny dlia vyhotovlennia alternatyvnoho palyva [Regularities of filtering drying of organic raw materials for manufacturing of alternative fuel]*. Dissertation of candidate of technical sciences. Lviv: National University “Lvivska Politehnica” [in Ukrainian].
[10] Sevostianov, I., Krayevsky, S., Sevostianov V. (2021) Ustanovky z gidroprivodom dlya rozdilennya vologih dispersnyh system [Installations with hydraulic drive for separation of damp dispersive systems]. *Tekhnika, enerhetyka, transport APK, 3 (114)*, 104–112. [in Ukrainian].
[11] Sevostianov, I., Kravets, S., Pidlypna, M. (2020). Use of criterial synthesis and analysis for modernization of objects of machine building production. *Engineering, Energy, Transport AIC, 2 (109).* 88–96. [in English].
[12] Sevostianov, I., Pidlypna, M. (2020). Model of optimization of functioning of modern polygraphic and publishing complexes. *Engineering, Energy, Transport AIC, 4 (111).* 90–99. [in English].
[13] Sevostianov I., Tokarchuk O., Pidlypna M. (2021) Automated technological projection of classification processes of dry dispersive materials. *Engineering, Energy, Transport AIC, 2 (113).* 15–21. [in English].
[14] Iskovych-Lototskyi, R. D., Obertiukh, R. R., Sevostianov, I. V. (2006). *Protsesy ta mashyny vibratsiinykh i vibroudarnykh tekhnolohii [Processes and machines for vibration and vibro-blowing technologies]. Monograph.* Vinnytsia: UNIVERSUM-Vinnytsia [in Ukrainian].

КЛАСИФІКАЦІЯ ТА АНАЛІЗ МЕТОДІВ І ОБЛАДНАННЯ ДЛЯ ЗНЕВОДНЕННЯ ВОЛОГИХ ДИСПЕРСНИХ МАТЕРІАЛІВ

Зневоднення вологих дисперсних матеріалів є широко поширеною групою процесів у харчовій та переробній промисловості. Зокрема, до цієї групи належать процеси сепарування вологих дисперсних відходів харчових підприємств (спиртової барди, пивної дробини, бурякового жому, кавового та ячмінного шламу) на тверду та рідку фази. На більшості харчових підприємств України ці відходи зливаються на землю або у найближчі водойми, однак у разі їхнього розділення тверда фаза таких матеріалів може бути використана як цінна добавка до сільськогосподарських кормів або як *паливо. В результаті можна забезпечити комплексне вирішення завдань утилізації відходів, запобігання забрудненню навколишнього середовища та отримання додаткового прибутку від реалізації кормів чи палива. Існує безліч способів зневоднення вологих дисперсних матеріалів, які можна розділити на кілька груп: механічні, термічні, електрофізичні, біологічні, хімічні та комбіновані. У статті представлено вдосконалену класифікацію основних методів зневоднення вологих дисперсних матеріалів та обладнання для їх реалізації. Дана класифікація дозволяє провести більш систематизований та обґрунтований аналіз переваг та недоліків методів, вибрати оптимальний метод з урахуванням умов та параметрів конкретного підприємства та перероблюваного матеріалу. Такий аналіз і вибір можна здійснити за допомогою комп'ютерної програми. Обґрунтовано високу ефективність механічних методів зневоднення вологих дисперсних матеріалів, зокрема методу пресування на обладнанні з гідравлічним або дебалансним приводом. Запропоновано блок-схему алгоритму автоматизованого аналізу методів та обладнання для зневоднення вологих дисперсних матеріалів та вибору допустимих та найбільш ефективних варіантів їх переробки за такими основними критеріями як продуктивність, енерговитрати, матеріаломісткість обладнання та кінцева вологість матеріалу, що переробляється.*

Ключові слова: *зневоднення, гідравлічний прес, вологі дисперсні матеріали, сепарування, продуктивність, енерговитрати, кінцева вологість.*

Ф. 4. Рис. 1. Літ. 15.

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