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SELECTION OF EXCIPIENTS FOR THE DEVELOPMENT OF AN ORAL POWDER CONTAINING DIMETHYLAMINOETHANOL AND SODIUM SUCCINATE

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Dimethylaminoethanol (DMAE) and sodium succinate are promising active compounds with demonstrated nootropic and metabolic potential, making their combination a candidate for the development of a novel drug aimed at improving cognitive function and supporting neurometabolic processes. Oral powders in sachet form represent a technologically rational choice for such a formulation, offering precise dosing, stability, and ease of use. However, the development of a high-quality sachet powder requires careful selection of excipients that are fully compatible with the active substances and capable of ensuring optimal physicochemical and organoleptic characteristics of the final product.

The aim of the study is to scientifically substantiate and select optimal excipients for an oral powder form containing dimethylaminoethanol and sodium succinate, based on a comprehensive assessment of pharmacotechnological indicators.

Materials and methods. Nine powder dosage forms were evaluated using a three-factor Greco-Latin square. Each series containing equal amounts of both active ingredients – dimethylaminoethanol and sodium succinate – in a 1 : 1 ratio. Three levels were studied for each factor: fillers (mannitol, lactose, sucrose), disintegrants/anti-caking agents (croscarmellose sodium, potato starch, magnesium carbonate basic), and solubilizers (PEG 4000, PVP K17, PVP K90). Pharmaco-technological parameters were assessed in duplicate; statistical significance was determined by ANOVA.

Results. The optimal formulation – comprising sucrose (86%), magnesium carbonate basic (2%), and polyethylene glycol 4000 (2%) alongside 5% each of the two active substances – demonstrated the best combination of technological performance and consumer acceptability.

Conclusions. A rational excipient composition for an oral powder sachet containing dimethylaminoethanol and sodium succinate was established through systematic three-factor experimental design and ANOVA

Keywords: oral powder, sachet, dimethylaminoethanol, sodium succinate, excipient selection, Greco-Latin square, pharmaco-technological properties, cognitive function

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1. Introduction

Cognitive disorders have emerged as one of the primary challenges in modern healthcare, largely attributable to the aging population, which is resulting in a rise in individuals experiencing mild cognitive impairment and dementia. The 2024 Lancet Commission perceives this issue as a continuum that requires prevention, intervention, and long-term care, rather than focusing solely on treatment [1]. The significance of this issue is underscored by prevalence statistics: one meta-analysis reported a global pooled prevalence of mild cognitive impairment at 19.7%, while another systematic review estimated a prevalence of 23.7% within geriatric populations, indicating that the pre-dementia stage is both common and often neglected in routine clinical practice [2, 3]. The economic ramifications are equally alarming, as a Lancet Global Health analysis projects a macroeconomic burden of INT\$14,513 billion associated with Alzheimer's disease and other dementias from 2020 to 2050 [4]. Collec-

tively, these findings highlight that cognitive decline represents not just a clinical issue but a considerable public health and socioeconomic challenge.

These trends are significant due to the growing acknowledgment of cognitive decline as an issue throughout the life course, rather than merely a condition linked to advanced age. An analysis examined the burden of dementia among younger populations using Global Burden of Disease data, while another study projected dementia-related deaths through 2050, indicating that this challenge will endure over the long term and exhibit multidimensional characteristics [5, 6]. Consequently, contemporary approaches are increasingly concentrating on early detection, management of risk factors, and timely support for individuals who remain functionally independent, as intervention during the initial stages of mild impairment can slow progression and reduce social and caregiver burdens [7].

In Ukraine, the issue is well-documented; however, monitoring remains inconsistent. A national analysis

based on data from the Ministry of Health indicated an average dementia prevalence of 99.72 per 100,000 population, with Alzheimer's disease prevalence at 5.34 per 100,000, and notable regional disparities exceeding sixfold, while vascular dementia constituted 62.59% of cases [8]. Clinical research in Ukraine demonstrates that cognitive impairment imposes a psychological burden. For instance, a study involving 132 older adults in Lviv revealed that individuals with mild cognitive impairment exhibited elevated anxiety, somatic symptoms, depressive symptoms, and overall psychological distress compared to cognitively intact counterparts, a finding particularly pertinent in a country experiencing considerable social stress [9].

The increasing prevalence of cognitive disorders in Ukraine and globally necessitates the exploration of novel treatments capable of targeting multiple pathogenic mechanisms simultaneously. Contemporary reviews indicate that neurodegeneration, vascular impairment, metabolic dysfunction, and chronic stress are all factors contributing to cognitive decline [10].

Dimethylaminoethanol (DMAE) presents a promising option due to its role as a precursor to choline, which may facilitate the formation of acetylcholine. Furthermore, international studies highlight its potential to neutralize hydroxyl, ascorbyl, and lipid radicals, suggesting a plausible function in safeguarding brain tissue from oxidative stress [11].

Sodium succinate represents a promising component due to its direct involvement in cellular energy metabolism as an intermediary in the tricarboxylic acid cycle, which is a crucial pathway for ATP production [12]. An adequate supply of energy is especially vital for nervous tissue, given the high metabolic demands of the brain and the reliance of cognitive processes on efficient mitochondrial function.

The feasibility of combining these compounds is supported by physicochemical studies, which demonstrate that DMAE and sodium succinate do not interact in a manner that would hinder their concurrent use. This combination could be effectively formulated into a single dosage form through technological processing at temperatures up to 105°C [13].

Collectively, this establishes a compelling rationale for a combined therapeutic approach: DMAE may enhance cholinergic transmission and provide antioxidant defense, while sodium succinate may bolster energy-dependent processes in the brain [14]. This aligns with current international evidence, which indicates that succinate supplementation can enhance oxidative metabolism in glial cells experiencing mitochondrial stress [15].

The selection of the appropriate dosage form is a crucial component in the design of therapy, as even an effective active ingredient may not yield successful outcomes if the patient is unable to administer it correctly. Systematic reviews indicate that the characteristics of the formulation significantly influence patient acceptance and adherence, particularly among the elderly and other vulnerable populations [16, 17]. Recent literature underscores the necessity for age-appropriate medications to

strike a balance between safety, efficacy, accessibility, and affordability. Consequently, formulation scientists are increasingly exploring patient-centered alternatives to traditional tablets and capsules [18].

Sachets present an appealing option, as they provide a single-dose powder that is easy to transport, straightforward to open, and convenient to dissolve prior to administration. Additionally, they circumvent many of the stability issues associated with pre-prepared liquid formulations [19]. Recent pediatric studies demonstrate a distinct trend towards single-use systems, including powders for oral solutions, as preservative-free and individually packaged formats mitigate the challenges linked with multi-use suspensions and enhance practical usage for children and other patients who may have difficulty with standard solid dosage forms [20]. Thus, sachets are often regarded as a favourable dosage form when considerations of precise dosing, portability, and ease of administration take precedence over the convenience offered by conventional tablets.

Prior to the formulation of a sachet product, the selection of excipients is a pivotal phase, as these substances significantly influence the technological, biopharmaceutical, and consumer attributes of the final product. Unlike active pharmaceutical ingredients, excipients play an important role in the development of the dosage form and affect various properties, such as powder flowability, bulk density, homogeneity, dosing precision, resistance to caking during storage, dissolution behaviour, and organoleptic characteristics [21]. Given that the proposed formulation includes a combination of dimethylaminoethanol and sodium succinate, it is crucial to identify excipients that ensure compatibility with the active ingredients while delivering optimal pharmaceutical-technological properties of the powder.

Purpose of the study. The purpose of this work is to substantiate the composition of a sachet dosage form containing dimethylaminoethanol and sodium succinate, evaluate the influence of selected excipients on the pharmaceutical-technological properties of the powder mixture, and determine the optimal formulation for the development of a sachet intended to support cognitive function.

2. Research planning (methodology)

To identify the optimal excipient composition for the oral powder sachet, a three-factor experimental design based on a hyper-Greco-Latin square was applied. Three factors were studied:

- factor A (filler-sweetener) – mannitol (a_1), lactose (a_2), or sucrose (a_3);
- factor B (disintegrant/anti-caking agent) – croscarmellose sodium (b_1), potato starch (b_2), or magnesium carbonate basic (b_3);
- factor C (solubilizer) – polyethylene glycol 4000 (c_1), low-molecular polyvinylpyrrolidone K17 (c_2), or high-molecular polyvinylpyrrolidone K90 (c_3).

Nine formulations were prepared in duplicate to minimize random experimental error.

The concentrations of the excipients were selected based on their intended technological functions, litera-

ture-reported pharmaceutical applications and preliminary formulation trials. For each excipient, the selected concentration was kept constant throughout the experimental design, allowing the effect of excipient type to be evaluated within each factor.

Each batch was produced by a standardized sequential mixing protocol. First, 0.15 g of filler was introduced into the mortar to saturate its working surface and reduce active substance loss. Next, 0.25 g of dimethylaminoethanol was added and triturated for 1–2 minutes, followed by 0.25 g of sodium succinate, with continued trituration for 2 minutes to ensure uniform dispersion of the active ingredients. The remaining filler was incorporated in portions with constant stirring (30–40 seconds per addition). Factor B excipient was then added – disintegrants (croscarmellose sodium or potato starch, 0.30 g) with mixing for 1–2 minutes, or anti-caking agent (magnesium carbonate basic, 0.10 g) with intensive mixing for 2–3 minutes. Factor C solubilizer (0.10 g) was introduced last and mixed for 1 minute. Final blending lasted 3–5 minutes until complete visual homogeneity, after which the mass was sieved through a 0.5–0.8 mm mesh to eliminate agglomerates.

The following pharmaco-technological parameters were evaluated for each formulation: uniformity of dosed units ($\pm\%$), angle of repose ($^\circ$), Carr compression index ($\%$), powder appearance (score), and organoleptic assessment of solution taste (score). The statistical significance of each factor's influence on every indicator was determined by one-way ANOVA, enabling identification of dominant excipients and formation of a ranked preference series per functional group, which formed the basis for final composition selection.

3. Materials and methods

The study utilized two active pharmaceutical substances: dimethylaminoethanol (Sigma-Aldrich, USA) and sodium succinate (Anmol Chemicals Private Limited, India), each incorporated at 0.25 g per sachet unit dose (total weight 5.0 g). Nine excipients were investigated across three functional groups: fillers-sweeteners (mannitol, lactose, sucrose), disintegrants and anti-caking agents (croscarmellose sodium, potato starch, magnesium carbonate basic), and solubilizers (polyethylene glycol 4000, low-molecular polyvinylpyrrolidone K17, high-molecular polyvinylpyrrolidone K90). All substances met the requirements of the State Pharmacopoeia of Ukraine. Equipment included porcelain mortar No. 4–5, pestle, sieves (mesh 0.5–0.8 mm), and an analytical balance (± 0.0001 g). All work was performed at the Laboratory for Standardization and Development of Medicinal Products, Zaporizhzhya State Medical and Pharmaceutical University. The study was conducted from November 2025 to May 2026.

Each experiment was performed twice to reduce experimental error. For the statistical evaluation of the acquired data, an analysis of variance (ANOVA) was executed to assess the statistical significance of the individual components and their possible correlations. The following research methods were employed to evaluate

the technological and analytical properties of the powder formulations:

Uniformity of dosage units. Evaluated by individually weighing 20 sachets on analytical balances to determine the average mass and individual percentage deviations. Compliance required that no more than two sachets deviated by more than $\pm 7.5\%$ from the average.

Angle of repose. Measured by pouring sieved powder through a funnel from a fixed height to form a cone on a horizontal surface. The height (h) and base diameter (d) of the cone were measured, and the angle was calculated using the equation to indirectly characterize powder flowability

$$\text{tg}(a) = \frac{h}{0.5d}.$$

Compression index (Carr index). Calculated to further assess powder compressibility and flowability using the initial bulk volume (V_0) and the tapped volume (V_{10}). The index was determined using the formula

$$C = \frac{V_0 - V_{10}}{V_0} \times 100.$$

Organoleptic properties. The appearance of the powder and the taste of the resulting solution were evaluated subjectively and scored on a point-based system.

Regarding the appearance of the powder:

- a score of 5 points was assigned to a uniform powder devoid of visible agglomerates or foreign particles;
- a score of 4 points indicated minor inconsistencies in uniformity or the presence of a limited number of agglomerates;
- a score of 3 points denoted noticeable heterogeneity and/or multiple agglomerates;
- a score of 2 points reflected significant heterogeneity with numerous agglomerates;
- a score of 1 point was given to a distinctly heterogeneous powder characterized by extensive agglomeration.

In terms of the flavour of the resulting solution:

- a score of 5 points corresponded to a pleasant flavour without any significant unpleasant aftertaste;
- a score of 4 points indicated a generally acceptable taste with a slight unpleasant aftertaste;
- a score of 3 points denoted a moderately unpleasant taste that remained within acceptable limits;
- a score of 2 points represented a distinctly unpleasant taste;
- a score of 1 point corresponded to a very unpleasant taste that was deemed unacceptable for oral consumption.

Statistical evaluation of the results was performed using three-way analysis of variance (ANOVA). The analysis included the calculation of the sum of squares (SS), degrees of freedom (df), mean squares (MS), and the experimental Fisher's F-value (F_{exp}), which was compared with the critical F-value at a significance level of $p = 0.05$. Experimental data were processed using Microsoft Excel (Version 2024). Based on the ANOVA results,

the statistical significance of the effects of the investigated factors, as well as the residual variance (factor interactions), on the quality characteristics of the powder formulations was assessed.

4. Results

Following the execution of the experimental design and subsequent calculations, the primary data were compiled into a comprehensive results matrix (Table 1).

An analysis of variance (ANOVA) was then performed in Microsoft Excel for each studied parameter to evaluate the statistical significance of each factor and identify the optimal excipients for the formulation.

The evaluation of the uniformity of dosage units established that only the nature of the disintegrant/anti-caking component (Factor B) exerts a statistically significant effect on this indicator. The influences of the fillers-sweeteners (Factor A) and the solubilizers (Factor C) were found to be statistically insignificant regarding the uniformity of powder dosing (Fig. 1).

The results indicate that the highest and most favourable values for the uniformity of the dosage units were achieved when using basic magnesium carbonate (b_3). Croscarmellose sodium (b_1) provided slightly lower uniformity values, whereas potato starch (b_2) demonstrated the least pronounced positive effect on ensuring the uniformity of the dosed powder units.

For the angle of natural slope of the powder, the mathematical analysis established that the factors studied can be arranged in the following order of overall influence: factor B > factor C > factor A (Fig. 2).

Factor B was identified as the primary factor influencing this indicator. The studied excipients within this group are arranged in the following descending order of influence: magnesium carbonate basic (b_3) > croscarmellose sodium (b_1) > potato starch (b_2).

A comparison of the studied solubilizers showed that, in terms of their influence on the angle of natural slope, they are located in the following order of preference: polyethylene glycol 4000 (c_1) > low-molecular-weight polyvinylpyrrolidone K17 (c_2) > high-molecular-weight polyvinylpyrrolidone K90 (c_3).

Based on the calculated average values, the investigated fillers can be arranged in the following sequence regarding their influence on the angle of natural slope of the powder: sucrose (a_3) > lactose (a_2) > mannitol (a_1).

For the powder appearance indicator, the mathematical analysis established

that all investigated factors exert a statistically significant effect. Factor A (the nature of the filler) demonstrated the greatest overall influence, while Factor B and Factor C had a comparable effect on the indicator, allowing the factors to be arranged in the following overall sequence of influence: A > B $\approx$ C (Fig. 3).

Based on the calculated average values, the investigated fillers can be arranged in the following descending sequence regarding their influence on the appearance of the powder: sucrose (a_3) > mannitol (a_1) > lactose (a_2).

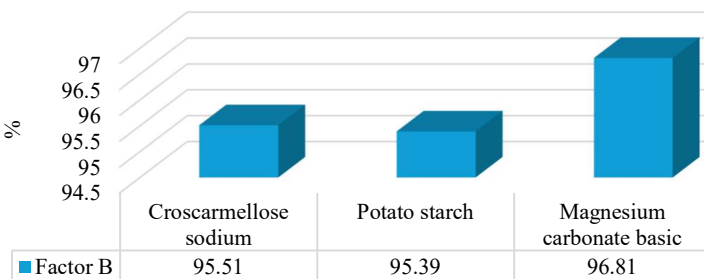
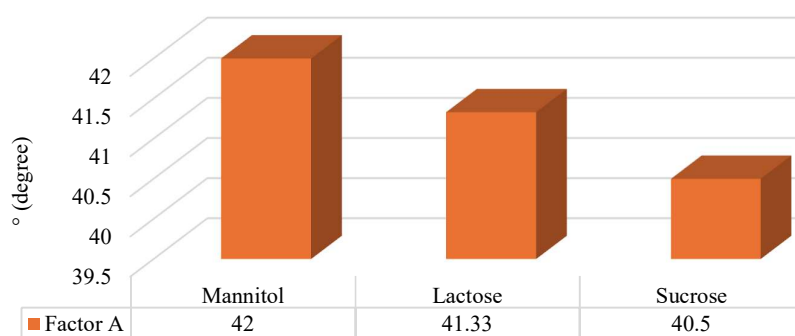
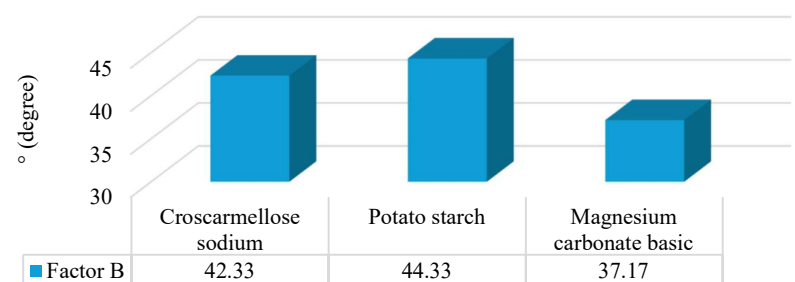


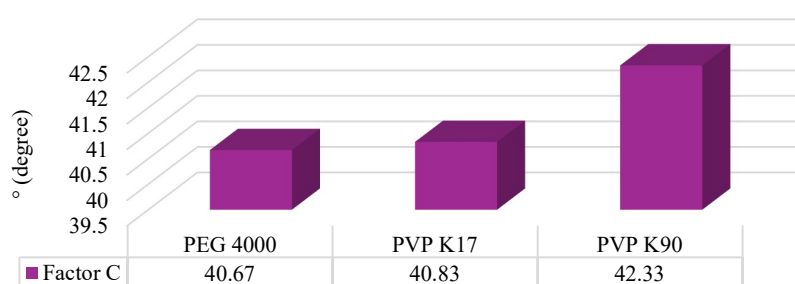
Fig. 1. Average values of the influence of factor B on the uniformity of powder dosage units



a



b



c

Fig. 2. Average values of the influence on the angle of repose of the powder: a – factor A; b – factor B; c – factor C

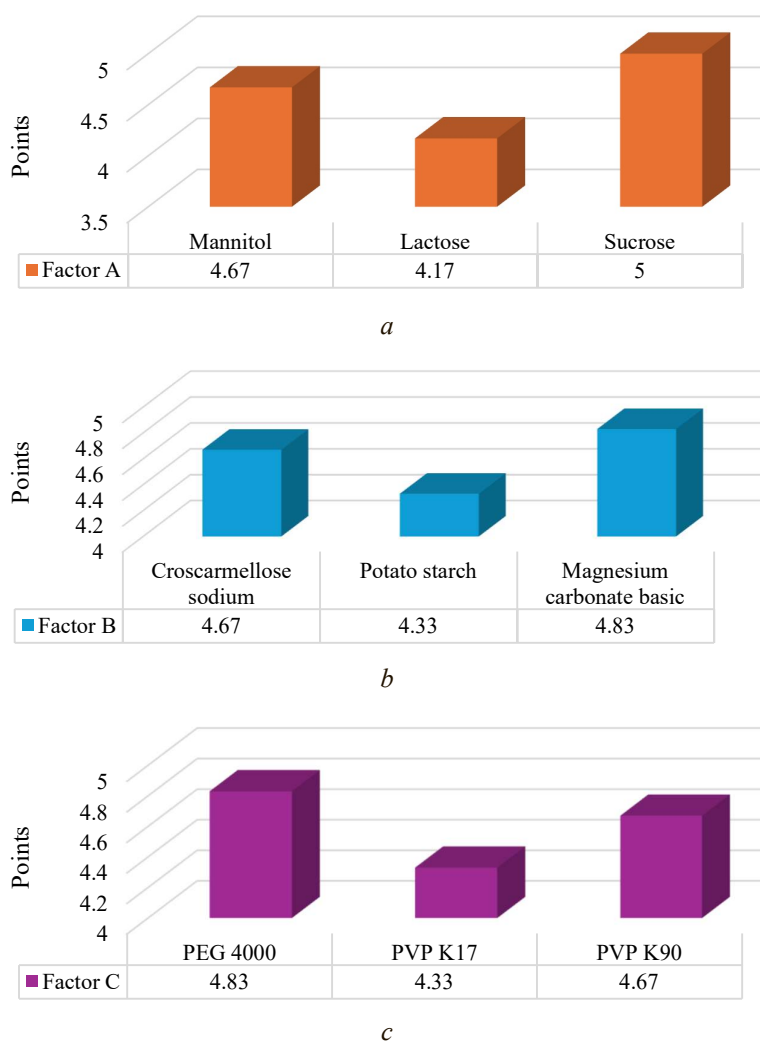


Fig. 3. Average values of the influence on the assessment of the appearance of the powder: *a* – factor A; *b* – factor B; *c* – factor C

The excipients within this functional group are arranged in the following descending order regarding their influence on appearance: magnesium carbonate basic (b_3) > croscarmellose sodium (b_1) > potato starch (b_2).

A comparison of the studied solubilizers revealed that, in terms of their influence on the appearance of the powder, they are positioned in the following order of preference: polyethylene glycol 4000 (c_1) > high-molecular-weight polyvinylpyrrolidone K90 (c_3) > low-molecular-weight polyvinylpyrrolidone K17 (c_2).

The mathematical evaluation revealed that both factor A (the nature of the filler) and factor B (the nature of the disintegrant/anti-caking component) exert a statistically significant impact on the powder's compression index (Carr index). Conversely, the influence of Factor C (the solubilizer type) was found to be statistically negligible. The overall hierarchy of the investigated variables regarding their degree of influence is structured in the sequence: $A > B > C$ (Fig. 4).

Based on the calculated average values, the studied fillers are arranged in the following sequence regarding their effect on the compression index: sucrose (a_3) > mannitol (a_1) > lactose (a_2).

The excipients evaluated within functional category factor B follow a distinct order of influence on the Carr index: magnesium carbonate basic (b_3) > croscarmellose sodium (b_1) > potato starch (b_2).

The statistical assessment demonstrated that only factor A (the nature of the filler) exerts a statistically significant influence on the taste profile of the prepared solution. Impacts of factor B (the disintegrant/anti-caking component) and factor C (the solubilizer) were not statistically verified for this specific parameter (Fig. 5).

Based on the calculated average scores, the investigated fillers are arranged in the following descending sequence concerning their effect on the taste of the resulting solution: sucrose (a_3) > mannitol (a_1) > lactose (a_2).

Table 1

Results of studies of powder for the oral solution when studying the nature of excipients

N	A	B	C	y_1	y'_1	y_2	y'_2	y_3	y'_3	y_4	y'_4	y_5	y'_5
1	a_1	b_1	c_1	94.45	95.06	41	43	5	5	10.4	10.7	3	4
2	a_1	b_2	c_2	95.54	95.97	46	45	4	4	12.0	11.7	3	3
3	a_1	b_3	c_3	96.29	96.54	38	39	5	5	8.6	9.4	4	4
4	a_2	b_1	c_2	95.67	96.54	42	41	4	4	14.8	13.5	3	3
5	a_2	b_2	c_3	95.57	95.14	45	45	4	4	16.6	15.7	3	3
6	a_2	b_3	c_1	96.21	97.55	37	38	4	5	13.5	13.1	3	3
7	a_3	b_1	c_3	95.41	95.95	43	44	5	5	9.2	9.5	5	4
8	a_3	b_2	c_1	94.95	95.15	43	42	5	5	11.0	11.8	5	5
9	a_3	b_3	c_2	96.86	97.39	35	36	5	5	9.9	9.3	5	5

Note: y_1 and y'_1 – uniformity of the dosed units of powder of the first and second series of the experiment, respectively, $\pm\%$; y_2 and y'_2 – angle of repose of the powder of the first and second series of the experiment, respectively, degrees; y_3 and y'_3 – assessment of the appearance of the powder (organoleptic assessment) of the first and second series of the experiment, respectively, points; y_4 and y'_4 – compression index (Carr index) of the powder for the first and second series of the experiment, respectively, points; y_5 and y'_5 – taste of the resulting powder solution (organoleptic assessment) for the first and second series of the experiment, respectively, points.

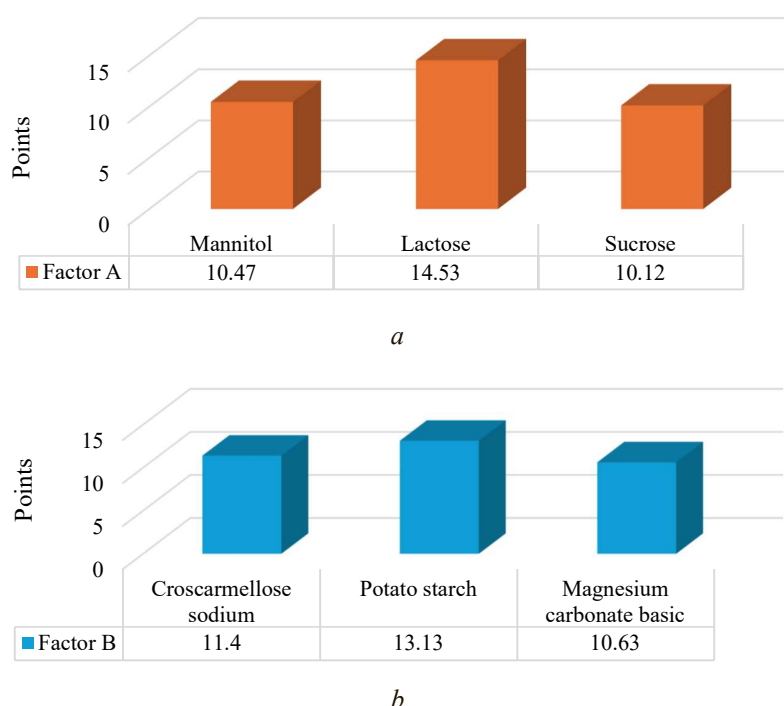


Fig. 4. Average values of the influence on the assessment of the appearance of the powder: *a* – factor A; *b* – factor B

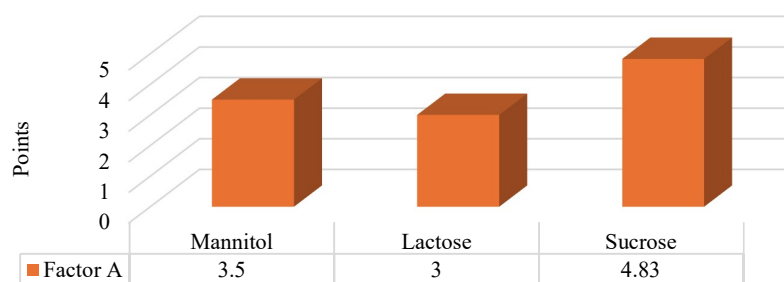


Fig. 5. Average values of the influence of factor A on the taste of the resulting powder solution

5. Discussion

The mathematical analysis of the experimental data facilitated a rational and data-driven selection of the optimal components for the oral powder formulation.

For Factor A, sucrose proved to be the most versatile choice by perfectly balancing technological and consumer requirements, providing the best flowability via the lowest angle of natural inclination and Carr index, while yielding the highest scores for both the dry powder's appearance and the reconstituted solution's taste.

Regarding factor B, magnesium carbonate basic emerged as the most successful technological modifier because it effectively minimized the Carr index and angle of natural slope, indicating vastly improved powder fluidity, a reduced tendency toward compaction, and a positive influence on the structural uniformity and visual appearance of the mass.

For factor C, polyethylene glycol 4000 emerged as the most balanced option across multiple indicators, optimizing angle of natural slope and appearance, thereby stabilizing the mixture's structure without worsening its free-flowing properties.

Ultimately, the combination of sucrose, basic magnesium carbonate, and polyethylene glycol 4000 maximizes both manufacturing efficiency and patient acceptability.

To additionally characterize the optimized formulation, particle size distribution was determined by analytical sieve analysis. The powder was divided into fractions employing sieves with nominal aperture sizes of 710, 500, 355, 250, 180, and 125 μm . The corresponding mass fractions were as follows: 1.2% for particles exceeding 710 μm , 8.7% for the range of 500–710 μm , 32.4% for 355–500 μm , 27.8% for 250–355 μm , 17.5% for 180–250 μm , 8.9% for 125–180 μm , and 3.5% for particles smaller than 125 μm . Consequently, the most prevalent particle size fraction was identified as 355–500 μm , constituting 32.4% of the total mass of the powder.

The obtained results are consistent with the Quality by Design approach reported for the development of combined powders for oral solution in sachets, where the selection of the optimal formulation was based on the simultaneous evaluation of flowability, angle of repose, content uniformity and organoleptic characteristics [22]. Similar to our study, a comprehensive assessment of multiple critical quality attributes enabled the identification of an optimized formulation with promising technological characteristics.

Practical significance. The practical importance of this study is evidenced by the successful creation of a scientifically validated,

multi-factorially optimized powder formulation intended for oral administration. By departing from a trial-and-error approach and instead utilizing a stable, systematic dataset – which includes variables such as dosing uniformity, flowability and organoleptic characteristics – a stable technological framework has been established. This optimal formulation guarantees a high degree of uniformity in dosing units and exceptional content homogeneity throughout the manufacturing process.

The outstanding flow properties achieved, characterized by a low Carr index and minimized angle of repose, result in enhanced manufacturing efficiency by reducing stickiness and improving flow control during the filling of individual sachets. Additionally, the proposed sequence of technological operations, which including mixing durations, sieving requirements, and the meticulous stepwise incorporation of components, provides a basis for further development and optimization of the manufacturing process for the combined active formulation.

Limitations of the study. It is essential to acknowledge several limitations that may have influenced the outcomes of these experiments. The physical properties of the powder were assessed on a 5,000 g laboratory scale,

suggesting that the transition to industrial-scale equipment will introduce varying mechanical and shear forces that could alter the physical dynamics of the powder.

Since the processing was performed exclusively under controlled conditions of 18 to 22°C and a relative humidity not exceeding 40%, any environmental variations during large-scale handling may adversely affect the bulk volume and flow stability of the ingredients that may be hygroscopic.

Prospects for further research. Future research endeavours should prioritize the translation of these laboratory findings into a dependable and commercially viable pharmaceutical product. A key objective is to perform comprehensive scale-up studies that enable the transition of the established technological framework from laboratory-scale batches to industrial manufacturing processes, while ensuring the preservation of flowability and dosing uniformity under high-speed mechanical filling conditions. In addition, in further studies, it is advisable to provide for the determination of the powder dissolution time as an additional indicator, which will allow quantitatively assessing the kinetics of the transition of the components of the developed dosage form into the solution.

Furthermore, it is essential to conduct both long-term and accelerated stability studies of the proposed optimal formulation in accordance with established regulatory standards. This approach will ascertain the shelf-life of the powder, assess its susceptibility to environmental moisture over time, and assist in the selection of the most appropriate moisture.

6. Conclusions

The current study has successfully developed and optimized a multi-component powder formulation intended for oral administration, utilizing a 1 : 1 mixture of dimethylaminoethanol and sodium succinate. By employing a systematic three-factor experimental design and subsequent analysis of variance, this research assessed various fillers, disintegrants, anti-caking agents, and solubilizers to ascertain their specific influence on the pharmaco-technological and organoleptic characteristics of the formulation. This comprehensive, data-driven methodology facilitated the informed selection of excipients that collaboratively improve flowability, stability, and consumer acceptability, advancing beyond individual parameter evaluations to encompass a thorough assessment of the overall dosage form.

The mathematical analysis determined a precisely defined optimal formulation for an individual portion of the powder. The active pharmaceutical ingredients, dimethylaminoethanol and sodium succinate, each constitute 5.0% of the mixture, equating to 0.0250 g per portion. To provide optimal support for these active components, sucrose was identified as the most effective filler, making up the majority of the mixture at 86.0% (4.3000 g) of the formulation. Sucrose was unequivocally chosen due to its superior efficacy in enhancing the angle of natural slope, reducing the Carr index, and offering the most favourable visual appearance and

taste profile. Magnesium carbonate basic was selected as the preferred anti-caking agent at a concentration of 2.0% (0.1000 g) because it consistently exhibited optimal technological parameters concerning powder mass quality, improved fluidity, and reduced compactability. Additionally, polyethylene glycol 4000 was incorporated as the solubilizer at 2.0% (0.1000 g) to effectively stabilize the structural characteristics of the powder while maintaining its essential free-flowing attributes.

The effective optimization of these variables resulted in the formulation of a finalized, high-quality powder composition and the creation of a specialized scheme for producing the preparation in individual sachet dosage forms. This standardized formulation framework ensures optimal dosage uniformity and a highly satisfactory final administration experience for the consumer.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, academic or other circumstances that could affect the objectivity of the results obtained and the conclusions drawn.

Funding

The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence tools

During the preparation of this study, artificial intelligence tools were used. Their utilization was restricted to the grammatical verification of Ukrainian and English texts, clarifying certain terms to maintain linguistic precision, and identifying minor linguistic discrepancies, such as repetitions or punctuation errors. For these purposes, the ChatGPT model (OpenAI, GPT-5.5, 2026) was utilized.

All scientific statements, interpretations, analyses, and conclusions presented in this study are the product of the authors' independent efforts and are solely based on experimental results. Any recommendations provided by the AI were thoroughly evaluated by the authors for accuracy, relevance, and consistency with the experimental data. No text generated by the AI was incorporated, either directly or indirectly, into the manuscript.

The application of artificial intelligence tools did not affect the research process, data analysis, interpretation of results, or the development of conclusions. The manuscript is a complete representation of the authors' scientific judgment and the results of their experimental endeavors.

Authors' contributions

Liudmyla Kucherenko: Conceptualization, Supervision, Project administration, Writing – review & editing; **Vladyslav Slobodanyk:** Investigation, Formal analysis, Writing – original draft, Visualization; **Serhii Borsuk:** Methodology, Investigation, Validation, Writing – review & editing; **Olha Khromylova:** Investi-

gation, Resources, Formal analysis, Writing – original draft, Visualization; **Oleksii Bihdan**: Data curation, Validation, Writing – review & editing, Funding acquisition; **Konstantin Kandybey**: Formal analysis, Validation, Writing – review & editing, Funding acquisition; **Olena Portna**: Methodology, Data curation, Funding

acquisition; **Hanna Nimenko**: Methodology, Formal analysis, Data curation, Funding acquisition.

All authors have read and agreed to the published version of the article and are jointly responsible for the reliability, accuracy, and integrity of the data and research results presented in the article.

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