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PRODUCTION COST AND PERSPECTIVES OF MARTIAN REGOLITH SIMULATION MR-2.2 ON WORLD MARKET

СЕБЕСТОИМОСТЬ ИЗГОТОВЛЕНИЯ СИМУЛЯЦИИ МАРСИАНСКОГО РЕГОЛИТА MR-2.2 И ПЕРСПЕКТИВЫ НА МИРОВОМ РЫНКЕ

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Abstract. *The article discusses the results of cost and profitability calculations of the Martian regolith simulation MR-2.2 production. The simulation has a wide scope of application in scientific research of Mars: from the substrate for plants growing to the research object of applied chemistry and materials science. The calculations were made on the basis of data obtained during the creation of the experimental batch of the product, as well as the rent and wage legislation of Ukraine. Analogues MMS-1 and MMS-2 - produced by the American company "The Martian Garden" using NASA technologies are given as reference items. The comparison is carried out taking into account changes in the cost of the consignment from the lot weight.*

Key words: *production cost, world market, Mars, martian regolith simulation, MR-2.2.*

Introduction. In our time of astronautics and Mars exploration rapid development, one of our main tasks is creation and implementation cheap and accessible martian regolith simulation.

Regolith – is loose material of planets, satellites and small celestial bodies surface [1]. In other words – any finely dispersed material, that differ from stone, rock deposits, cemented sediment independent of presence or absence organic [2].

Martian regolith consisting of rocks volcanic and impact-metamorphic origin. By composition it's related to mafic rocks [1]. Formation of relatively homogenous associated with bedrock destruction and mixing formed products by impact-metamorphic, cryogenic and eolian factors with chemical-air erosion [1].

For solve the problem of this material shortage in Ukraine, was created MR-2.2 simulation.

Materials and methods. MR-2.2 – is artificial mineral model, which created based on martian regolith chemical and mineral analysis data. Simulation consists of a number of minerals, which by chemical and mineral composition similar to rock, which present in surface layer martian regolith.

For mineral processing was used ball mill [3]. In case, total losses of mineral raw, as a result of slipping and sticking of particles on the crushing elements, amounted to 10%.

Standard bulk density of product amount to 1.2172 kg/l. In order to prevent MR-2.2 condensed and lumps formation, optimal tare filled shouldn't exceed 85% for create air cushion and reduction of dust fraction departure upon opening or air flow. As a result, optimal for storage, transportation and using can be considered containers with volume 20 liters, which at 20 kg of MR-2.2 will be filled to 16.43 liters – 82% of the container volume. Consequently, 100 kg of product requires 5 sets of containers of chemically-inert plastic.

Results. Finished product values consist of constant expenses for room and technical equipment and workers salary. Variable expenses include cost of raw materials and containers for finished product. All above expenses shown in Table 1.

Average production capacity, excluding public holidays, amounted to 200 kg off pure product output per month. This output of production are directly determined by the quantity and volume of cylindrical drums, which are used in parallel for components crushing and mixing, and the corresponding elements of crushing and mixing, which are used.

Table 1

Constant and variable expenses for producing MR-2.2

Constant expenses	
Room and technical equipment, USD/month	185.19
Workers salary [3], USD/month	71.15
Variable expenses	
Raw materials cost, USD/100 kg	168.52
Containers cost, USD/100 kg	14.28

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General figures of MR-2.2 production shown in Table 2.

Consequently, the price of 100 kg of finished products without containers – 344.89 USD, 1 kg – 3.45 USD, with taking into account the containers – 100 kg (5 pcs.) of finished products cost – 360.59 USD and 1 pc. (20 kg) of finished products – 90.15 USD.

For comparison, the cost of Martian regolith simulations from "The Martian Garden", created by NASA technology, ranging from 10 to 29.99 USD per 1 kg for MMS-1 (Mojave Mars Simulant) [5], and from 40 to 99.99 USD for MMS-2 (Enhanced Simulant) [6] – depending on the party weight. Cost of 1 kg of MR-2.2 (without container) amount to 3.45 USD (at the rate of 1.00 USD=27.00 UAH) (Fig. 1).

Table 2

General figures of MR-2.2 production

Production figures	
Raw materials cost, USD/100 kg	168.52
Production loss, %	10.00
Cost of 100kh of MR-2.2 with adjusted for losses, USD	185.37
Room and technical equipment, USD/month	185.19
Workers salary [4], USD/month	71.15
Production capacity, 100 kg/month	2.00
Contribution to sustainable development, %	10.00
Cost of 1 kg of product without container, USD	3.45
Cost of 100 kg of product without container, USD	344.89
Bulk volume of 100 kg of MR-2.2, liters	82.16
Cost of 1 set of containers, USD	2.86
Containers volume, liters	20.00
Tare filled, %	82.00
Requirement in container for 100 kg of finished products, pcs.	5.00
Total cost of 100 kg (5 pcs.) of finished products, USD	360.59
Cost 1 pc. (20 kg) of finished products, USD	90.15
Cost-effectiveness of production, %	**153.36**

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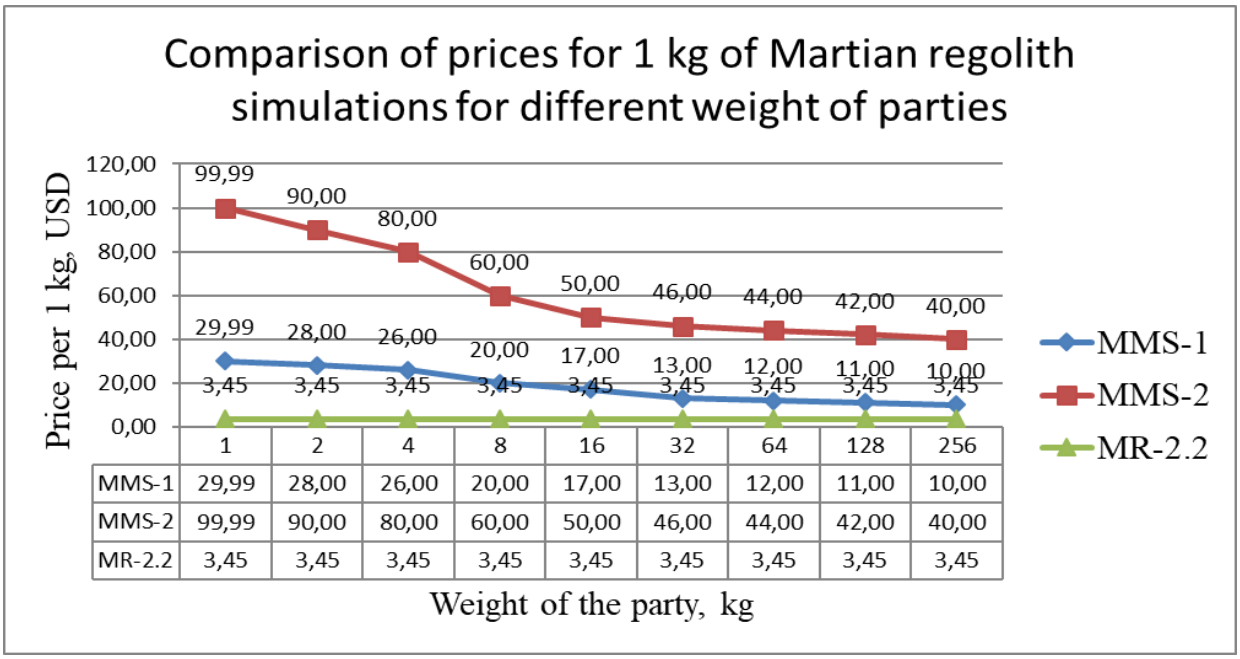

	1	2	4	8	16	32	64	128	256
MMS-1	29,99	28,00	26,00	20,00	17,00	13,00	12,00	11,00	10,00
MMS-2	99,99	90,00	80,00	60,00	50,00	46,00	44,00	42,00	40,00
MR-2.2	3,45	3,45	3,45	3,45	3,45	3,45	3,45	3,45	3,45

Fig. 1. Comparison of prices for 1 kg of Martian regolith simulations for different weight of parties

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Conclusion.

Therefore, Martian regolith simulation MR-2.2 is an affordable and competitive analogue of American products. Difference in final price for 1 kg ranges between 6.55 and 26.54 USD for MMS-1 and between 36.55 and 96.54 USD for MMS-2. MR-2.2 simulation has wide scope of use as a part of Mars exploration: from substrate for plants growing to object for chemistry and material science research. And with activation of NASA and Space-X Mars programs requirements in product will be increase.

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Аннотация. *В статье рассматриваются результаты расчётов себестоимости и рентабельности производства симуляции марсианского реголита MR-2.2. Симуляция имеет широкую сферу применения в рамках исследования Марса: от субстрата для выращивания*

растений до объекта исследования прикладной химии и материаловеденья. Расчёты производились на основе данных, полученных во время создания экспериментальной партии продукта, а также, законодательных норм об аренде и заработной плате. В качестве предметов сравнения приводятся аналоги: MMS-1 и MMS-2 – производства американской компании "The Martian Garden" по технологиям NASA. Сравнение проводится с учётом изменения стоимости партии товара от массы партии.

Ключевые слова: *себестоимость изготовления, мировой рынок, Марс, симуляция марсианского реголита, MR-2.2.*

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