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Functional Foods in Health and Disease

Marketability level of potato in Armenia: Potato functional properties

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ABSTRACT

Background: Functional food is becoming more and more important for professionals and also for consumers. On the other hand, it is known that the main factors affecting the sale of agricultural products are the general market dynamics, legislation, product range, seasonal sales dynamics, competitors, pricing, buyers and distribution channels. What's also important is the profile of the company's personnel and the work of personnel in the market, advertising related to the quality of the product, which in recent times is especially based on the "natural" origin and functional value of the product.

Objective: The aim of the current study is to quantify the factors influencing the level of potato marketability through econometric analysis in Armenia. One of the objectives was also to observe whether the population appreciates the functional value of potatoes, which may affect future marketability and yield of potatoes.

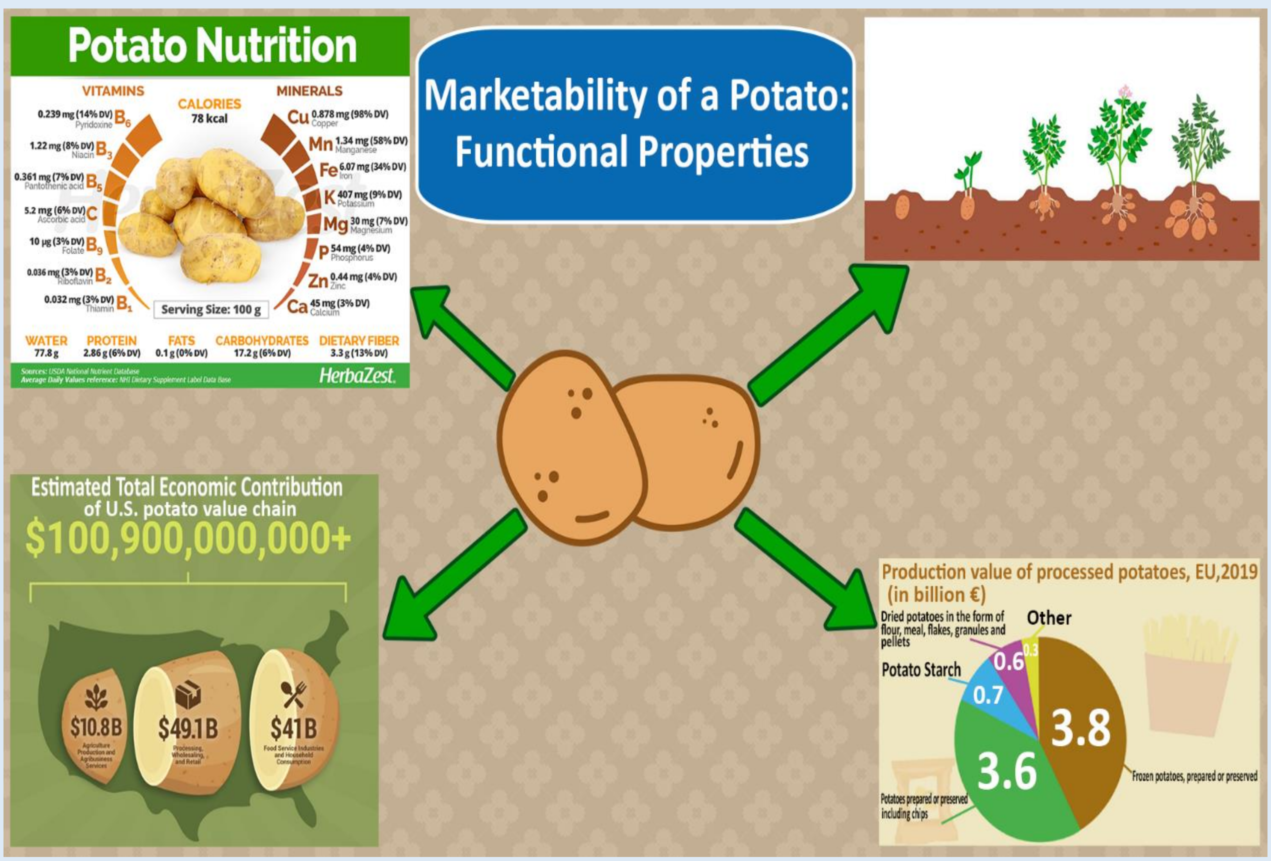
Methods: Quantitative assessment of the factors influencing the level of potato marketability was carried out with a number of indicators: the yield of the sowing area, the gross harvest and the volume of export and import. Observations were carried out during 10 years (2009 - 2018). A seven-item questionnaire was developed to explore consumer preferences for purchasing potatoes.

Results: The level of marketability of potatoes had an increasing trend with the certain fluctuations (years: 2010, 2014, 2016 and 2018). The data on the correlation coefficients on the factors influencing the level of potato marketability indicated that the relationship between the marketability level and potato planting area is inverse to the average level (ryx_1 = - 0.615). The correlation between the level of commerciality and yield is direct in the lower middle range (ryx_2 = 0.461). The latter shows that increasing the level of yield contributes to the level of marketability. The effects of gross harvest, export and import volumes have a negative impact on the level of commoditization, but the relationship is extremely weak with ryx_3 = - 0.214 and ryx4 = - 0.0532 and ryx_5 = - 0.105.

Interview studies show that factors affecting potato marketability and productivity are subject to change.

Conclusion: The increase in metabolic/non-communicable diseases, increased consumer awareness of these diseases and their prevention, as well as developments in organic agriculture and functional food production require changes in economic research and calculations, also related to functional foods.

Keywords: potato, market, marketability, organic agriculture, functional food



Graphical abstract: Marketability of a potato: Functional properties.

INTRODUCTION

It is known that the main factors affecting the sale of agricultural products are the general market dynamics, legislation, product range, seasonal sales dynamics, competitors, pricing, buyers and distribution channels. What's also important is the profile of the company's personnel and the effectiveness of the work of personnel in the market, including advertising related to product quality. Brand social media pages are a great way to engage consumers [1], too. Sometimes the characteristics of a product alone can provide positive or negative feedback for the "acceptance" of a product. This may apply to genetically modified organisms(GMOs) [2-3] for example, the public "does not like" such products, but for trading companies, these products seem to be more favorable, including from the point of view of safety and appearance. Another example is the potato; although the potato (Solanum tuberosum) has been recognized by the Food and Agriculture Organization of the United Nations(FAO) as a staple and sustainable food for a growing world population, the potato sometimes also has a negative image, mainly due to the known "poor quality" of potato fries and chips [4].

Agricultural crops are also important to researchers as a source of metabolites other than carbohydrates and amino acids, especially when the human body cannot synthesize these metabolites. In any case, in recent years, agricultural products with functional significance have become increasingly important in various respects. The term Functional Foods has its own history [5]. The concept was created in Japan in the 1980s [6]. Currently, the Functional Food Center (Dr. Danik Martirosyan) [7] defines "functional foods" as "natural or processed foods containing biologically active compounds; which, in defined, effective, non-toxic amounts, provide clinically proven and documented health benefits using specific biomarkers to support optimal health and reduce the risk of chronic/viral diseases and treat their symptoms" [8-10].

Potatoes are characterized not only by their high starch content, but also by the presence of many other nutritional components: proteins, fiber, vitamins and organic acids. Of particular interest are potato proteins with the nutritional value of egg and soy proteins [11-12]. The minerals, proteins and dietary fibers of potatoes are preserved even after cooking, which is not the case for vitamins, which are damaged during cooking. Carotenoids and anthocyanins are regenerated after cooking due to improved release of these antioxidants [13].

As in the case of other agricultural products, when evaluating the "functionality" of potatoes, the consumer, as it were, takes into account the usefulness of "raw" potatoes. However, depending on the variety of potatoes and processing methods, the functional properties of potatoes are also different [14-15]. For example, sweet potato/potato flour is also used to provide desirable nutritional value, antioxidants, and natural color to processed foods [16].

The purpose of the current study is to quantify the factors influencing the level of potato marketability through econometric analysis. One of the goals was also to track whether the population evaluates the functional value of potatoes in the market, which may possibly affect the marketability and yield of potatoes in the future.

METHODS

Assessment of marketability: Quantitative assessment of the factors influencing the level of potato marketability was carried out with a number of indicators: the yield of the sowing area, the gross harvest and the volume of export and import. Observations were carried out during

10 years (2009 - 2018). Excel 2016 was used to analyses regression and correlation.

Assessing the impact of potato "characteristics" on potato "qualification" and sales: Customers rating: A questionnaire consisting of seven questions was created to study consumer preferences regarding the quality of potatoes and identify factors that influence the purchase of "better" potatoes (Table 1).

The questions used: i. Do you think the price of potatoes is affordable for an Armenian resident with average purchasing power? ii. When choosing potatoes, which characteristics of potatoes are important to you /price, potato size, growing place, cultivar/? iii. Besides firm, well-formed, smooth (with small eyes) and free of large cuts and bruises, what other qualities do you look for when buying a potato? iv. What kind of potato cultivars are there in Armenia? v. What characteristic would you emphasize if you were to choose local potato varieties? vi. What do you know about the import of potatoes in Armenia? and, vii. What are the advantages/disadvantages of potato varieties grown in Armenia compared to imported cultivars?

Table 1. Questionnaire: How do you rate the quality of potatoes?

Aims of these investigations:

- **Study of consumer preferences regarding the quality of potatoes.**
- **Identify factors associated with buying higher quality potatoes.**

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Gender Age Education /secondary, higher/

Number	Question	Answer
1	Do you think the price of potatoes is affordable for an Armenian resident with average purchasing power?	
2	When choosing potatoes, which characteristics of potatoes are important to you /price, potato size, growing place, cultivar/?	
3	Besides firm, well-formed, smooth (with small eyes) and free of large cuts and bruises, what other qualities do you look for when buying a potato?	
4	What kind of potato cultivars are there in Armenia?	
5	What characteristic would you emphasize if you were to choose local potato varieties?	
6	What do you know about the import of potatoes in Armenia?	
7	What are the advantages/disadvantages of potato varieties grown in Armenia compared to imported cultivars?	

Additional questions (8-10) were added to the questionnaires of 97 participants regarding the usefulness and sales of potato chips. In total, 250 consumers (age range - 18-55 years old, gender range (male/female) - 1:1, education: secondary/higher - 4:1) from Yerevan were interviewed. An Excel 2016 t-test was used to determine statistical significance ($P < 0.05$).

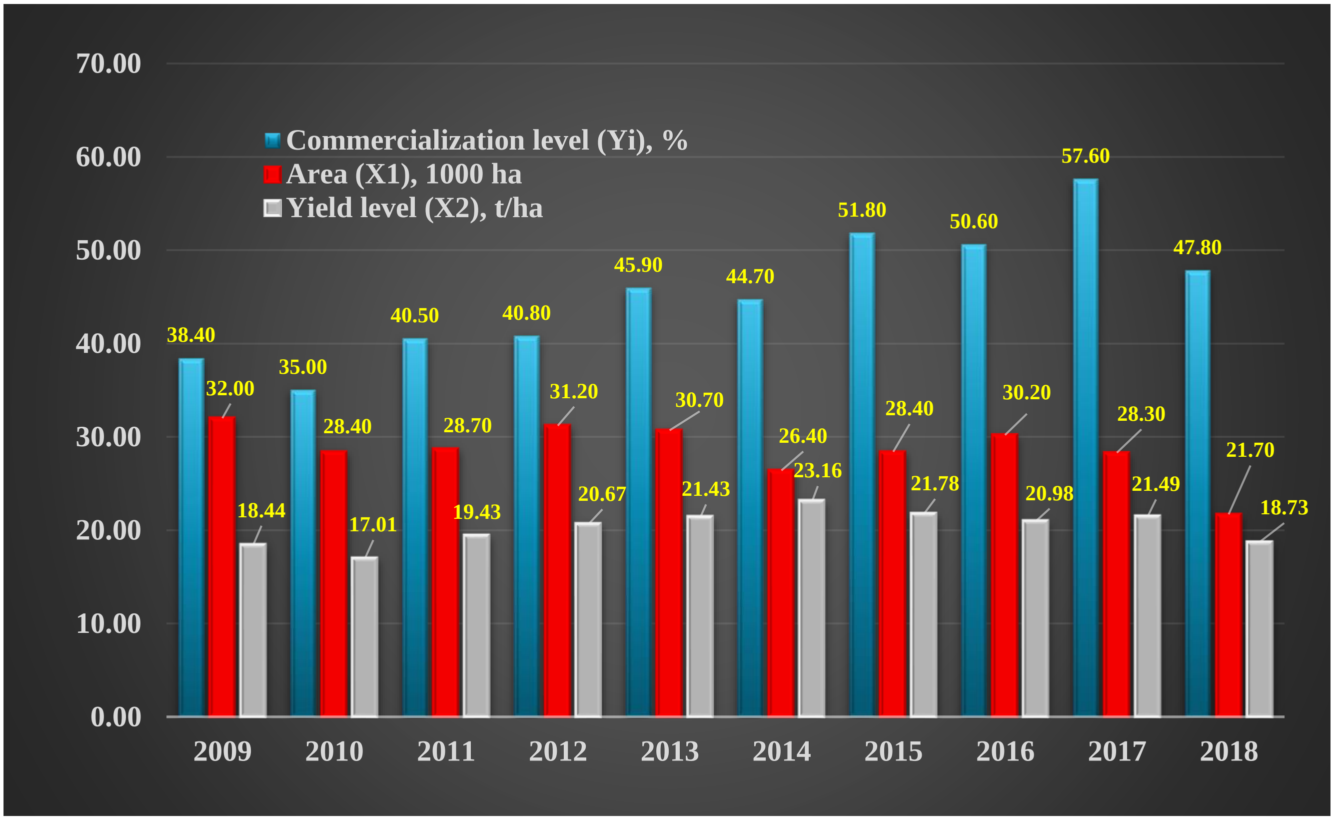

Figure 1. Values of potato marketability indicators: commercialization level, area and yield level (2009—2018).

RESULTS

Assessment of marketability: The indicators of the level of marketability of potatoes and factors affecting it are presented in Figures 1-2 and Tables 2-3.

As can be seen from the data in Figure 1-2, in 2009-2017, the level of commercialization of potatoes had an increasing trend with the certain fluctuations (years: 2010, 2014, 2016 and 2018). In 2018, compared to the previous year, the value of the indicator decreased and made 47.8 % (47.8 % vs. 57.6 %). The corresponding areas are: 21.7 and 28.4 (1000 ha) (Figure 1-2). During the considered period, the maximum area was in 2009, and the maximum value of the commerciality level indicator was recorded in 2017 (Figure 1). In parallel with this, the yield level fluctuated within 17.01 - 23.16 t/ha, the maximum indicator was recorded in 2014.The gross harvest for the period under review also fluctuated significantly, the maximum level was recorded in 2014, the lowest – in 2018 (Figure 2). As for the volumes of export/import, the volumes of export and import of potatoes fluctuated widely, amounting to 841.3 - 23502.8 tons and 857.3 - 9365.0 tons, respectively (Figure 2). The data on the correlation coefficients on the factors influencing the level of potato marketability are presented in the Table 2. According to these data (Table

2), the relationship between the commercialization level and potato planting area is inverse to the average level (ryx_1 = - 0.615). The correlation between the level of commerciality and yield is direct in the lower middle range (ryx_1 = 0.461). The latter shows that increasing the level of yield contributes to the level of commercialization.

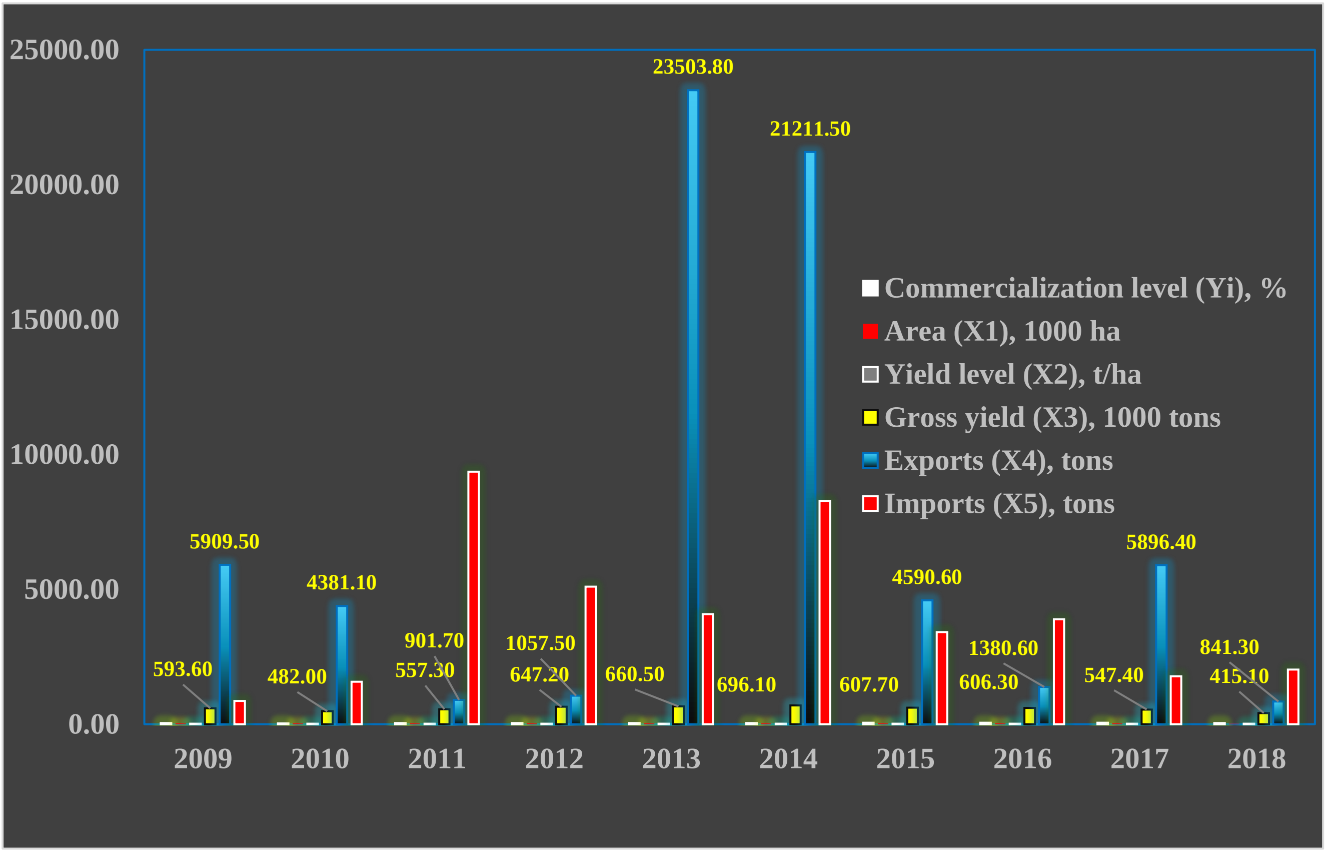

Figure 2. Values of potato marketability indicators and factors influencing it in 2009 - 2018.

Table 2. Correlation coefficients between the level of marketability of potatoes and the area occupied, yield, gross harvest, export and import indicators (2009-2018).

	Y_i	X_1	X_2	X_3	X_4	X_5
Yi	1					
X_1	-0.245794	1				
X_2	0.626282777	0.051908	1			
X_3	0.039485	0.596073	0.73612	1		
X_4	0.033712	0.083249	0.52764	0.59507	1	
X_5	-0.131495	-0.023812	0.44802	0.47358	0.22925	1
Y_i - Commercialization level, %						
X_1 - Area, 1000 ha						
X_2 - Yield level, centner/ha						
X_3 - Gross yield, 1000 tons						
X_4 - Exports, tons						
X_5 - Imports, tons.						

The effects of gross harvest, export and import volumes have a negative impact on the level of commoditization, but the relationship is extremely weak with ryx_3 = - 0.214 and ryx_4 = - 0.0532 and ryx_5 = - 0.105 (Table 3).

The data on the factors affecting the marketability of potatoes in Armenia in 2009-2018 (regression statistics) are presented in the Table 3. The regression equation looks like this:

$$y_i = -57.083 + 1.404\ X_1 + 0.685\ X_2 - 0.129\ X_3 - 0.000\ X_4 - 0.00047\ X_5 \quad (1)$$

Table 3. Factors affecting the marketability of potatoes in Armenia in 2009-2018 (regression statistics)

Multiple R	**0.9881**							
Adjusted R Square	0.9469	Regression	5	415.5443	83.1089	33.0957	0.0024	
Standard Error	1.5847	Residual	4	10.04478	2.5112			
Observations	10	Total	9	425.5890				
	Coefficients	**Standard Error**	**T Stat**	**P- value**	**Lower 95%**	**Upper 95%**	**Lower 95.0%**	**Upper 95.0%**
Intercept*	-57.0833	12.2213	-4.6709	0.0095	-91.0152	-23.1514	-91.0152	-23.1514
X_1	1.4044	0.4271	3.2884	0.0303	0.2187	2.5903	0.2187	2.5903
X_2	0.6853	0.0643	10.6530	0.0004	0.5067	0.8639	0.5067	0.8639
X_3	-0.1291	0.0242	-5.3317	0.0059	-0.1963	-0.0619	-0.1963	-0.0619
X_4	0.0000	0.0001	-0.0394	0.9705	-0.0003	0.0003	-0.0003	0.0003
X_5	-0.0005	0.0003	-1.8127	0.1441	-0.0012	0.0002	-0.0012	0.0002
X_1	Area, 1000 ha							
X_2	Yield level, centner/ha							
X_3	Gross yield, 1000 tons							
X_4	Exports, tons							
X_5	Imports, tons.							

Assessing the impact of potato "characteristics" on potato "qualification" and sales: Customers rating: One of the main tasks in creating the questionnaire (Table 1) was, first of all, to find out the opinion of consumers about the purchasing power of the population of the Republic of Armenia in order to neutralize the influence of purchasing power on the choice (questions ##1-2). Regardless of age and gender, as well as education, the majority of the RA population, 62.5 %, found that, despite the constant increase in potato prices, the population has the opportunity to buy potatoes of their choice. At the same price, the consumer generally considered good quality potatoes with the following characteristics: firm, regular shape, smooth (with small eyes), without large cuts and bruises. The consumer avoided green, poorly germinated, or shriveled potatoes. Approximately the same number of consumers - 62.7 % - stated that they choose Armenian and/or Russian potato varieties. 70.0 % of these consumers did not explain the reason, the rest cited the quality of the potatoes, their cultivation in "clean" soil and / or the absence of GMO/living modified organism (LMO) nature.

A small percentage of consumers knew the names of Armenian potato varieties. Almost all questionnaires mentioned starch content. 34.5% of participants stated that varieties differ in "functional value"/"functional importance". The answers to questions 8-10 of the questionnaire of 97 participants were also interesting. All participants over 30 noted the danger of chips. They were sure that the sales of chips would increase if they used "qualitative" potatoes and did not use various harmful additives in chips. Most would buy Armenian products, despite the "less attractive" appearance of the product.

DISCUSSION

According to the FAO, potatoes of South American origin are now cultivated in 150 countries. In 2020 alone, total global production reached 359 million tons [30]. Figure 4 shows the total harvest of grain and leguminous crops in Armenia by region in 2021. The Potato is one of the most important food products consumed by the population of the Republic of Armenia, and over 70 % of potato sowing areas are in Gegharkunik, Lori and Shirak regions.

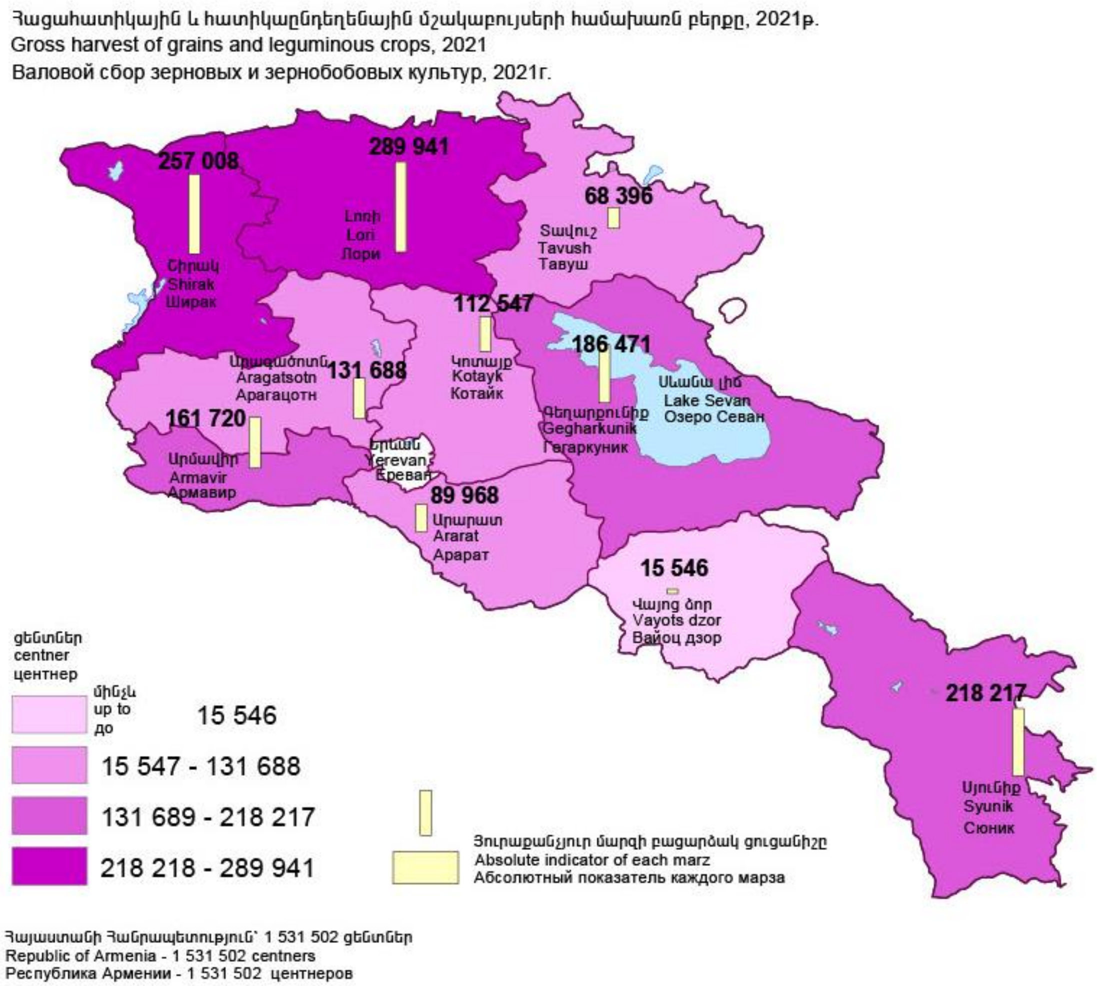

Figure 4. Gross harvest of grain and leguminous crops, 2021, Statistical Committee of the Republic of Armenia (ARMSTAT), Atlas the Republic of Armenia by the regions and Yerevan City, 2022 https://www.armstat.am/file/doc/99533933.pdf.

According to the data of Statistical Committee of the Republic in 2021, 65.8 kg of potatoes were consumed per capita, which is 5.2 % of the consumed energy value (https://armstat.am) (accessed on 14 May 2023). Based on the importance of the indicator of the level of marketability, we tried to assess the joint quantitative impact of a number of factors on the level of marketability. A wide range of factors was taken into account, but calculations showed that there is a statistical relationship between not all possible factors and the level of marketability of potatoes. The econometric calculations performed show that among the observed indicators, the indicators of area, yield, gross harvest and imports have statistical significance (Figure 1-2). The regression equation (1) shows that a decrease in the sown area of potatoes by 1000.0 ha in the Republic of Armenia leads to an increase in the level of marketability by 1.404 %, an increase in the level of yield by 1 centner/ha leads to an increase in the level of marketability by 0.68 %. As for the gross harvest, an increase of 1000 tons leads to a decrease in the level of marketability by 0.12 %. The increase in imports does not have a significant impact on the product. However, the demands of the population are changing quite quickly. On the one hand, this is facilitated by the nature of rapidly growing non-communicable disease(NDC)/metabolic diseases [17] and the number of patients [18-20]. At the same time, interest in organic farming is growing [21-24]. This is indirectly evidenced by the results of the survey of the current study. Sometimes the "vague" answers of the questionnaires also indicated the need to clarify the questions of the questionnaire. In addition, unfortunately, in these potato studies, surveys were carried out only in 2018, there is no dynamic picture of the survey analysis.

Climatic and socio-economic changes are the cause of the spread of various infectious diseases of humans, animals and plants [25-28]. Along with crop diseases, the intensive circulation of goods between continents also increases the problems related to food safety. Crop diseases can pose a huge threat to production, causing shortages in food demand [29–30], which is becoming more relevant due to climate change [31–33]. In addition, the use of pesticides is a concern from the point of view of food safety [34-44], too. The demand for solutions to above-mentioned problems causes the rapid development of biotechnologies [45-53]. These refer both to the development of various "genetic" biotechnologies aimed at increasing the resistance of organisms [54], and to the "indirect" increase of resistance of organisms based on, for example, the use of pre- [55] and probiotic therapies [56-61]. Various biotechnological methods are also used to increase potato resistance and protect potato products from various pathogens [62-72]. In connection with the growth of NCDs/metabolic diseases [73-85], "between" the development of organic agriculture [86-88] and biotechnologies [50-53; 89-91], the use and production of functional food [92-102] is gaining momentum.

Although scientific information on the content and profile of bioactive lipids in potato cultivars is very limited, the data indicate that different potato cultivars might have interesting levels of bioactive lipids, fatty acids, phytosterols, tocopherols and carotenoids. Different potato cultivars also contain significant amounts of potassium, iron and other phytonutrients (proteins, fibers, complex carbohydrates, carotenoids, B vitamins (thiamin, pyridoxine, folate, L-ascorbic acid, etc.) [4, 11-13]. Potato is a major source of dietary polyphenols. Thus, "red" and "purple" potatoes are a source of phenylpropanoids, including of chlorogenic acid and anthocyanin. It is known that the "new"/"baby" potatoes with their immature tubers are a richer source of phytonutrients than "elder" potatoes. Interestingly, in recent times, the number of potential health benefits of glycoalkaloids in the composition of potato tubers have also been increasingly described. This also applies to their anti-cancer effects [4, 11-12, 103]. The studies on Andean potato extract show that the anti-cancer activities of potato extracts are the result of a combination of different compounds (hydroxycinnamic acids (mainly chlorogenic acid isomers) and polyamines) [103]. Given the potassium/sodium content, potatoes can be an important food for hypertension control diets [104]. The iron biofortified potatoes by CIP, might have significant contribution to reducing anemia/malnutrition [13]. Regarding the antioxidant properties of potatoes, the above already shows that the potato tuber does not consist of just starch, but actually has many secondary metabolites and storage proteins that have beneficial effects on health, also due to the antioxidant properties of several of these metabolites [4]. Hellmann and co-authors described in detail the antioxidant properties of B vitamins (thiamin, pyridoxine, folate and L-ascorbic acid) of potatoes [4]. The data on the RDAs for B vitamins [4] are presented in the Table 4. These investigations as well as other scientific investigations in this area [102] allows potato to be evaluated as sources for a functional food(s).

Thus, the level of marketability of potatoes is an important performance indicator, the value of which can significantly depend on the awareness of the population about the functional significance of potatoes. The results of the current preliminary studies show that in the near future, the influence of indicators related to organic agriculture and functional food will be of great importance for the assessment of the marketability of crops.

Table 4. Recommended Dietary Allowances of B vitamins: Medium size potatoes*

Vitamins	RDAs; mg/day	Provision of RDA by the medium size potato (148 g); %
Thiamin (Vitamin B1)	1.2 (men) and 1.1 (women)	8
Pyridoxine (Vitamin B6)	1.3 (adults: 19–51 years) 1.7 (men) and 1.5 (women) (adults: above 51 years)	17.76
Folate (Vitamin B9)	0.4 (adults) and 0.6 (pregnant women)	6
L-ascorbic acid (Vitamin C)	90 (men) and 75 (women)	30-40

***Provision of RDA by medium size potatoes (this might be different for the potato varieties). This table is created on data from the study by Hellman and co-authors [4].

CONCLUSION

NCDs kill 41 million people annually. This number, equivalent to 74% of deaths worldwide, is increasing annually (https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases) (accessed on 16 September 2022). Along with metabolic factors, behavioral risk factors are the most common NCDs causes. The most important risk factors related to smoking, blood pressure, sedentary lifestyle, overweight/obesity are also related to unhealthy diet. Currently, probably depending also on the increase in the number of NCD patients, there is a high tendency for the development of organic agriculture. In this regard, it is important to evaluate the effectiveness of organic and current farming. Estimates of the productivity and marketability of organic and conventional potatoes by different authors show that the transition to organic farming is a complex and multi-stage process. During this "transitional" stage, the productivity and yield of conventional potatoes is often significantly higher than that of organic potatoes. However, the development of organic agriculture, as well as the increase in the volume of functional food production, is inevitable. It implies the introduction of new indicators in economic calculations and research.

Abbreviations: non-communicable disease: NCD; genetically modified organisms: GMOs; living modified organisms: LMOs; hectare: ha; Food and Agriculture Organization of the United Nations: FAO; Recommended

Dietary Allowances: RDAs; International Potato Center: IPC.

Conflicts of Interest: The authors declare that the study was conducted without a potential conflict of interest.

Author Contributions: HT and AP designed this study, SA and EP carried out the experimental part. All participants read and agreed with the final version of the manuscript.

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