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EVALUATION OF THE QUALITY OF POTATOES (Solanum Tuberosum L) IN A DIFFERENT GROWING ENVIRONMENT

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Abstract
The purpose of this study is to evaluate the quality and hedonic traits of potatoes grown in a variety of environments. The study was conducted between June and July 2023 in Batu, Bromo, and Nongkojajar. After the harvest, research data was gathered, including the tubers' weight, volume, length, and width. The tubers are steamed after three days to evaluate their taste, smell, colour, texture, and overall physical appearance. Data analysis methods use bivariate, multivariate analysis and PCA biplot with spreadsheets and SAS-JMP v.16. The quality of potato tubers was found to vary significantly between different growing environments in terms of length, width, thickness, volume, and weight per tuber. The superior quality of tubers for all categories is produced in Batu's growing environment, which is markedly different from Bromo and Nongkojajar. The high correlation between length, volume and weight of tubers is more than 0.83. Organoleptically, each growing environment has a position of relative advantage. Stone has advantages in smell and physical appearance. Bromo is superior in texture and colour, with a high correlation of 0.98, and Nongkojajar in taste. Based on the level of consumer preference, it can be concluded that Batu is superior in terms of its physical appearance, Bromo is superior in terms of colour, and Nongkojajar is superior in terms of smell. Even though there was a high correlation of 0.995 between the various growing locations, none of them demonstrated superiority in terms of texture and taste.
Keywords: the potato, organoleptic, hedonic, physical appearance, traits, environment

INTRODUCTION

Potatoes from the Solanaceae family are the world's most important non-cereal crop, providing sustenance to over one billion individuals daily (FAO, 2013). Regarding production, consumption, and area coverage, potatoes are ranked second, third, and fourth globally (FAOSTAT, 2016). Potatoes are the world's fourth most important non-grain food crop, with a global production of approximately 359 million tonnes of tubers (FAO, 2020). Potatoes are becoming more widely acknowledged as one of the world's primary staple crops due to their ability to produce more dry matter and protein per hectare than major cereal crops. The primary factor driving potato cultivation's expansion is the tubers' nutritional value, which also provides economic advantages to developing nations (Buono et al., 2009).

In potato production, the term 'quality' has many aspects that depend largely on the intended use of the final product, as there are specific quality requirements for each use. In potatoes intended for fresh consumption, organoleptic traits related to visual appearances, such as skin colour and absence of external defects, are very important and can greatly influence consumer choice (Fernqvist et al., 2015).

Both for fresh consumption and the french fries and potato chips industry (food processing), the nutritional characteristics of tubers are an important aspect that can influence economic benefits and acceptance by end users (Leo et al., 2008). Edible potatoes contain around 75–84% water and 16–25% dry matter when harvested, which are important because they determine the nutritional value, taste, texture and quality when processed into French fries or chips (Kita et al., 2013). Various types of processed potato products require high-quality potatoes as raw materials in terms of physical and nutritional content. According to Hartuti and Sinaga (2009), potato tuber characteristics significantly impact the quality of the processed product. The quality of potato tubers is influenced by a variety of factors, including shape (round to oval), skin colour (whitish yellow to dark brown), some tuber surfaces (flat and uneven due to buds), and flesh colour (white to yellow). Potatoes are classified as a cold climate vegetable because they require a temperature of 10-180C for growth and development. Potatoes are better suited for planting in highland or mountainous areas with elevations over 700 metres above sea level (Samadi, 2007; Setiadi & Nurulhuda, 2008).

Potato plants are quite sensitive to climate change (Aliche et al., 2018). IPCC (2007) predicts a global temperature increase of more than 5oC until 2100. This increase in temperature is caused by increasing CO2 concentrations in the atmosphere (NOAA, 2018). This phenomenon has the potential to cause drought in the long term (Swann et al., 2016). The growth of cultivated potato plants requires an optimum temperature range of 17 – 20°C (Burton, 1989). The earth's surface temperature increased, including in the highlands, which are currently the centre of Indonesian potato production. In potato plants, temperature is an important factor in growth and development, as well as other environmental factors such as humidity, light, soil type, and nutrition (Jackson, 1999; Fernie & Willmitzer, 2001).

This study aims to identify the optimal growing environment to produce Granola potato tubers of the highest possible quality, taking into account not only the physical and sensory (organoleptic) dimensions but also the level of liking (hedonic) in consumer preferences.

MATERIALS AND TOOLS

The research was carried out in three different agroecological locations as growing environmental locations, namely: Ngadas Sukapura Village, Probolinggo at an altitude of 2,329 m above sea level (Gr_Bromo); Jurangkuali, Sumber Brantas Village, Batu, Malang, height 1400 m above sea level (Gr_Batu); and Ngadiredjo Tutur Pasuruan Village at an altitude of 900 m above sea level (Gr_Njr) using Granola potato varieties. On the potato fields of farmers, the research period lasted for two months, beginning at the beginning of June 2023 and ending at the end of July 2023. The parameters of observation include the parametric variables of tuber dimensions (length, width, thickness, volume, and weight of tubers), as well as the non-parametric sensory tests (organoleptic) that include taste, aroma, texture, colour, physical appearance, and preference value (hedonic).

A scoring scale is utilized for organoleptic evaluation, which ranges from very good for organoleptic properties to very poor for the properties observed, including taste, aroma, colour, texture, and physical appearance. Concurrently, the degree of liking (hedonic) is evaluated by assigning a scale ranging from very liking to disliking the observed trait. The tuber harvest results were analyzed using manifest variables for parametric data and latent variables for non-parametric data, with a sample of 32 potato farmers selected from each location. A questionnaire was employed to collect the data.

Primary data from direct observation of the tubers was then collected and analyzed using bivariate analysis (ANOVA) and multivariate analysis (manova) PCA biplot. Secondary data is used to support data analysis, including soil analysis, the biophysical performance of land and climate (agroecology), SOP for potato cultivation, and the level of use of agricultural inputs and profits in potato cultivation.

RESULTS AND DISCUSSION

The Tuber Quality. Tuber quality is measured according to physical dimensions: length, width, thickness, volume and weight of the tuber. The results of the variance analysis showed that the growing locations were significantly different in all tuber dimensional quality parameters. The growing location in Jurangkuali Sumberbrantas Batu (Gr_Batu) gives the best results, which are different from other locations (Student's t, Tukey-Kramer HSD, Dunnet) as shown in table 1, figure 1-5 below.

Table 1
Average Observation Results of Potato Tuber Dimensions at Harvest Time in Three Different Growing Locations.

Treatment Level	Average Tuber Dimensions				
	Length (cm)	Width (cm)	Thickness (cm)	Volume (ml)	Weight (g)
Gr_Bromo	6,484 b	5,373 b	4,579 b	86,818 b	95,818 b
Gr_Batu	10,348 a	6,146 a	5,299 a	161,136 a	176,545 a
Gr_Njr	7,095 b	5,520 b	4,654 b	78,182 b	82,455 b
R^2	0.75	0.20	0.42	0.50	0.61
RMSE	1.02	0.71	0.4	38.88	34.53
SEm (±)	0.13	0.19	0.12	8.98	8.19
CV (%)	12.79	12.57	8.26	35.76	29.19
Sign. Diff.					
Student's t	0,89	0,62	0,35	33,86	30,07
Tukey HSD	1,07	0,75	0,42	40,87	36,30
Dunnet	2.32	2.32	2.32	2.32	2.32
G Mean, Resp.	7,97	5,68	4,84	108,71	118,27

Information: Numbers in the same column accompanied by the same letter are not significantly different (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

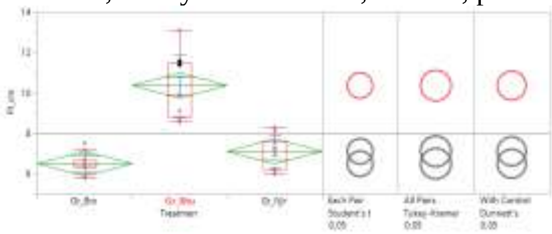

Figure 1
Mean Tuber Length Results, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

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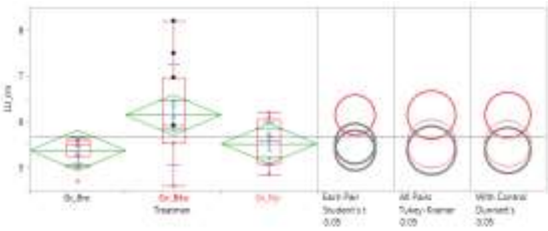

Figure 2
Mean Tuber Width Results, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

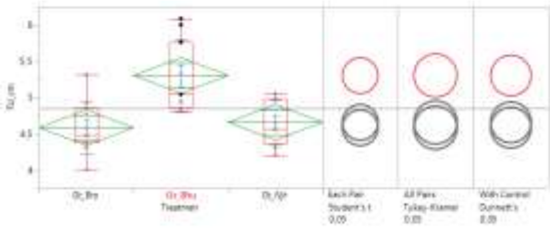

Figure 3
Mean Tuber Thickness Results, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

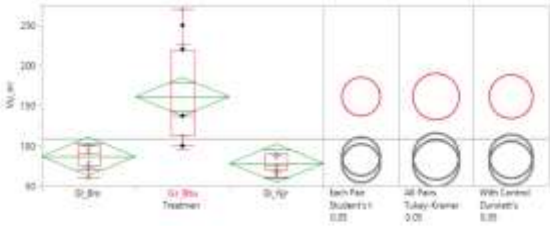

Figure 4
Mean Tuber Volume Results, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

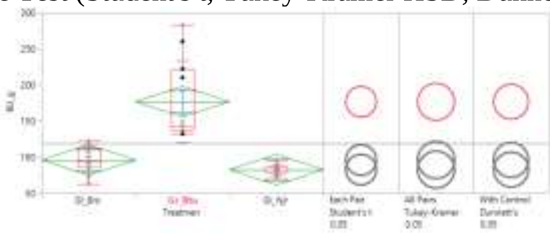

Figure 5
Mean Tuber Volume Results, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

Relative Position of Tuber Quality Advantages

The results of the multivariate PCA biplot analysis were 98.8 per cent, which means that the suitability measure of the main components is high enough to be considered representative enough to describe the correlation and position of relative superiority between variables. The variables are highly correlated at r = 0.96 – 0.99. The growing environmental location of Jurangkuali Sumberbrantas Batu (Gr_Batu) is, on average, superior in all parameters of tuber quality (length, width, thickness) and especially tuber volume and weight) when compared to the other two growing locations, as shown in Figure 6 below.

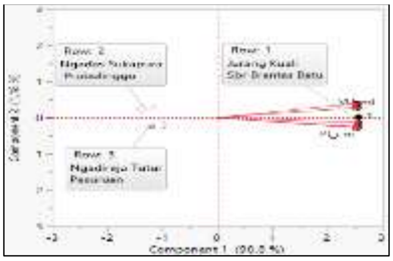

Figure 6
Multivariate PCA Biplot Graph of Tuber Dimensional Quality at Three Growing Environmental Locations (Batu, Probolinggo and Pasuruan).

The growing environmental locations of Ngadirejo Tutur Pasuruan (Gr_Njr) and Ngadas Sukapura Probolinggo (Gr_Bromo) did not have a relative advantage in all observed tuber parameters.

Organoleptic

The results of the analysis of various organoleptic quality parameters (sensory: scores from very good in terms of properties to very poor in terms of observed properties) of potato tubers show that the location of the growing environment has no real effect on aroma and texture but has a significant effect on taste, colour and physical appearance as shown in table 2 and figures 7–10 below.

Table 2
Average Organoleptic Test Results for Potato Tubers at Harvest Time in Three Different Growing Locations.

Treatment	Average Score Results of Organoleptic Characteristics of Tubers				
	Flavor	Aroma	Texture	Colour	Physical appearance
Gr_Bromo	73.63ab	71.6a	81.87a	81.1a	83.03ab
Gr_Batu	68.8b	83.1a	75.16a	73.08ab	88.38a
Gr_Njr	79.33a	72.33a	74.33a	69.67b	73.67b
R^2	0.5	0.4	0.39	0.57	0.65
RMSE	5.27	7.8	5.19	5.13	5.51
SEm (±)	2.70	3.87	2.73	2.59	3.11
CV (%)	7.13	10.30	6.73	6.88	6.75
Sign. Diff.					
Student's t	10,524	15,582	10,365	10,252	11,021
Tukey HSD	13,196	19,539	12,997	12,855	13,819
Dunnet	12,313	18,200	12,00	12,00	12,900
G Mean, Resp.	73.92	75.69	77.12	74.62	81.69

Information: Numbers in the same column accompanied by the same letter are not significantly different (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

The highest average results for physical appearance and colour organoleptic variables were found in Gr_Batu, although they were not significant for Gr_Bromo.

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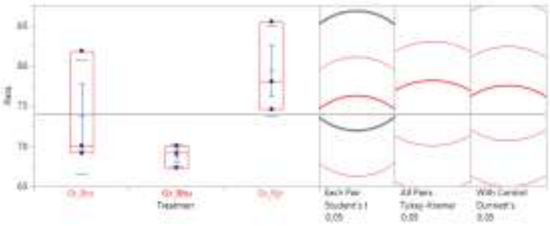

Figure 7
Mean Organoleptic Test Results for Tuber Taste, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

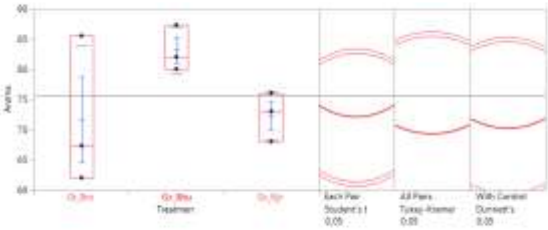

Figure 8
Mean Organoleptic Test Results for Tuber Aroma, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

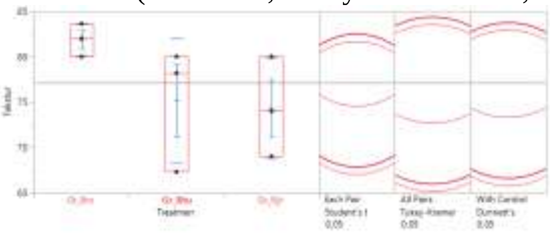

Figure 9
Mean Organoleptic Test Results for Tuber Texture, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

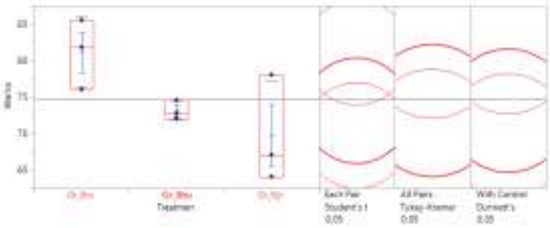

Figure 10
Mean Organoleptic Test Results for Tuber Color, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

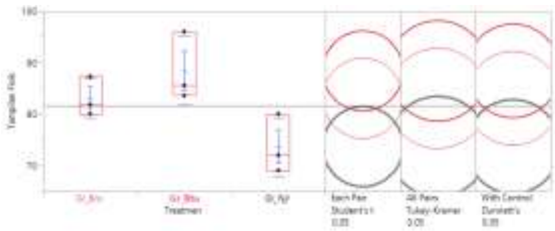

Figure 11
Mean Organoleptic Test Results for Physical Appearance of Tubers, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

Meanwhile, the multivariate analysis (manova) results show that the organoleptic properties have various correlations, as shown in Table 3 below.

Table 3
Correlation Coefficient Between Organoleptic Characteristics of Potato Tubers. Influence of Three Growing Environmental Locations

	Flavor	Aroma	Texture	Colour	Perf_physical
Flavor	**1.00**	-0.82	-0.11	-0.30	-0.99
Aroma	-0.82	**1.00**	-0.48	-0.30	0.73
Texture	-0.11	-0.48	**1.00**	0.98	0.25
Colour	-0.30	-0.30	0.98	**1.00**	0.43
Perf_physical	-0.99	0.73	0.25	0.43	**1.00**

The table above shows texture variables are highly correlated (r = 0.98), as is physical appearance with aroma (r = 0.73). Most of the other variables are negatively correlated and uncorrelated.

Regarding the location of the growing environment, it can be seen that Gr_Batu produces a very aromatic aroma, Gr_Bromo provides a very delicious taste, and Gr_Njr does not have any superior organoleptic properties as in Figure 12 below.

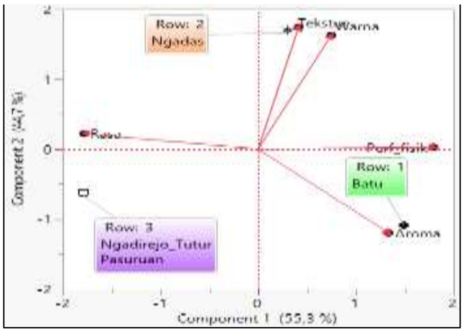

Figure 12
Biplot graph of organoleptic characteristics of tubers at three growing environmental locations (Batu, Probolinggo and Pasuruan).

The biplot graph above shows that the suitability measure for the main components is quite high at 55.3 per cent, so it is considered representative enough to describe the correlation between variables. The location of the growing environment for Batu is superior for aroma properties, Ngadas for texture and colour characteristics, while Ngadirejo does not have the observed superior properties. Texture and colour properties have a positive correlation of r = 0.98, while taste characteristics of aroma and physical appearance have a high negative correlation of r = 0.82 – 0.99.

Level of Likes (Hedonic)

The analysis of various hedonic parameters (assessed with a score from very like to dislike very) of potato tuber properties (taste, aroma, texture and colour) shows that the location of the growing environment has no significant effect on all parameters except physical appearance. The growing location in Jurangkuali Sumber Brantas Batu (Gr_Batu) produces the best mean physical appearance preference (highest/most liked), which is not significantly different from Ngadas Sukapura Probolinggo (Gr_Bromo) but significantly different from Ngadirejo Tutur Pasuruan (Gr_Njr) as in table 3 and figure 13 below.

Table 4
Average Hedonic Test Results for Potato Tubers at Harvest Time in Three Different Growing Locations.

Treatment	Average Hedonic Characteristics Scoring Results of Tubers				
Levels	Flavor	Aroma	Texture	Colour	Physical appearance
Gr_Bromo	67.83a	62.3a	76.17a	77.33a	74.83a
Gr_Batu	59.8a	69.23a	71.9a	75.7a	80.73a
Gr_Njr	74.5a	72.3a	80.13a	66.13a	64.43b
R²					0.76
RMSE					4.67
SEm (±)					2.61
CV (%)					6.37
Significant Different Threshold (.05)					
Student's t LSD					9,33
Tukey-Kramer HSD					11,70
Dunnet					10,9
Grand mean, Mean Respon					73.33

Information: Numbers in the same column accompanied by the same letter are not significantly different (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

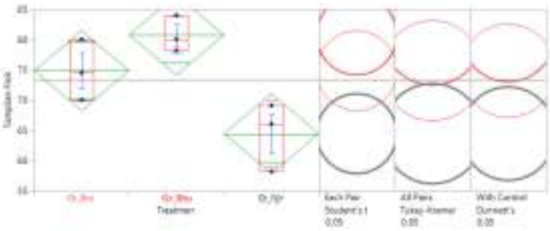

Figure 13
Mean Hedonic Test Results for Physical Appearance of Tubers, Treatment Variance, Standard Deviation, Standard Error, and Difference Test (Student's t, Tukey-Kramer HSD, Dunnet, p =.05).

Meanwhile, the results of the MANOVA test show that the hedonic variables between traits have various correlations, as in Table 4 below.

Table 5
Correlation Coefficient Between Hedonic Variables of Potato Tuber Characteristics. Influence of Three Growing Environmental Locations

Correlation Matrix	Flavor	Aroma	Texture	Colour	Perf. Physique
Flavor	**1.00**	0.17	***1.00***	-0.73	-0.97
Aroma	0.17	**1.00**	0.20	-0.80	-0.41
Texture	***1.00***	0.20	**1.00**	-0.75	-0.98
Colour	-0.73	-0.80	-0.75	**1.00**	0.88
Perf_physical	-0.97	-0.41	-0.98	0.88	**1.00**

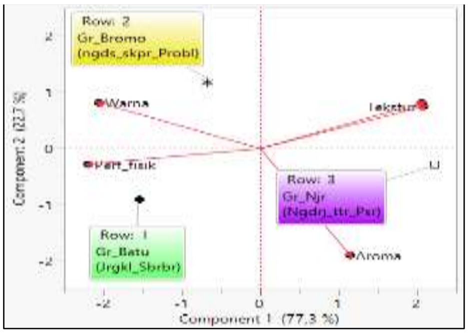

Figure 14
Biplot graph of organoleptic characteristics of tubers at three growing environmental locations (Batu, Probolinggo and Pasuruan).

The correlation matrix table shows that the hedonic trait variables have varying correlation values , most negatively correlated. Texture and taste variables are highly positively correlated (r=1.0), then physical appearance and colour (r=1.0). Meanwhile, physical appearance, taste, and texture had a high negative correlation (r = -0.97 and r = -0.98).

The results of the multivariate PCA biplot analysis showed 77.3 per cent, which means that the suitability measure of the main components is high enough to be considered representative enough to describe the correlation and position of relative superiority between variables. Each growing environmental location has a relative advantageous position. Gr_Batu excels in physical appearance characteristics, Gr_Bromo in colour, and Gr_Njr in aroma. At the same time, all locations in the growing environment do not share the texture and taste properties, even though the two are perfectly correlated very strongly (high) at r = 1.0.

Viewed from the production side, quality is a characteristic that has many facets and is very dependent on the intended use of the final product (Talburt & Smith, 1987; Hiltrop, 1999; Gerendás & Führs, 2013). External quality parameters such as mealiness, waxy coating, and cooking heat are important for potatoes used for fresh consumption. Internal quality parameters are influenced by starch content, which is positively correlated with the specific gravity and dry matter content of tubers (Smith, 1977; Talburt & Smith 1987; Feltran et al., 2004).

The growing environment influences the external quality of potato tubers. This type of soil, with all the physical, chemical and biological fertility attributes, can provide optimal growth space, nutrition and environmental suitability for the growth and development of potato tubers in physical and non-physical dimensions (nutrition). Details of the agroclimate for each growing environmental location are shown in Table 5 below.

Table 6. Agro-climatic details of three growing environmental locations

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Agroclimatic	Gr_Stone	Gr_Bromo	Gr_Njr
Province	East Java	East Java	East Java
Kokab	Rock	Probolinggo	Pasuruan
Subdistrict	Bumiaji	Sukapura	Speak
Village	Sbr. Brantas	Nadas	Ngadirejo
Climate (SF)	C	D	C
Type of soil	Andisol	Inceptisol	Latosol, Regosol
pH	5.5 - 6.5	5.6 – 7.0	6.5 – 7.0
Texture	Sandy loam	Dusty clay sand	Clay sand
C-organic	5.8	1.96	1.75
Solum (cm)	80-95 (87.5)	(75-85 (80)	60-70 (65)
Altitude(mpl)	1700	2750	1000
CH (mm)	2500	2400	2300
Max temp	18 0C	270C	29 0C
Templin	11 0C	140C	21 0C
Productivity (t/ha)	25	15	25
Fertilizer kg/Ha	ZA 415, SP36 549, NPK 702	Urea 143, ZA 286 SP36 286, Ponska 286	Urea 125, ZA 200, SP36 75, Ponska 250
Seed (G)	G2-G3	G2-G5	G2-G5
P.Org. (t/ha)	3.7	5.5	5
Agrotechnology	Independent, Forward	Currently	Currently

Source: data analysis processed from various sources, 2023

Referring to the optimal growth requirements for potato plants, the Gr_Batu growing environment meets the criteria for optimal agro-climatic suitability as a condition for growth and development. The Andisol soil of the location (Gr_Batu) has a high content of organic matter and C-organic to provide the soil humus needed for the qualitative growth and development of potato tubers. Resman (2010) states that Andisol tends to have a large amount of humus (containing 7-12% of organic carbon in the soil). Andisol has quite a high nutrient content, 2-5% organic C, and pH 5-7 (Saridevi et al., 2016). USDA (2015), Andisol is soil that comes from volcanic material and is rich in organic material. Good physical fertility and according to plant needs, especially sandy loam texture, crumb structure, deep solum, good effective depth, and fast permeability are also the main keys to plant growth and development to produce quality tubers. The agroclimatic conditions of Andisol in Jurangkuali Sumberbrantas have a rural climate, namely that the land never experiences drought for 90 days, but there is leaching throughout the Juarti year (2016). This condition ensures that Andisol soil moisture is maintained. Andisol soil is one of the most productive soils if managed well.

In the inceptisol (inceptum or beginning), Gr_Bromo grows as young soil because its formation is quite fast due to the weathering of the parent material. Low clay content, namely <8% at a 20-50 cm depth. Inceptisol soil is classified as moderately weathered and leached soil (Sanchez, 1992).

The tuber quality results were quite good on Latosol and Regosol soils at the Gr_Njr growing location. It is suspected that this type of soil has quite good fertility. Latosol soil comes from the weathering of sedimentary and metamorphic rocks. This soil has the characteristics of a brick-red colour because of the iron and aluminium content. The soil pH is close to neutral, so its fertility can be regulated with a little fertilizer added. Meanwhile, Regosol soil is formed from material released by volcanic eruptions that has yet to undergo perfect development, has low organic matter the rough texture, and cannot properly hold the water and minerals plants need.

The level of nitrogen fertilization, which tends to be higher at the two locations Gr_Bromo and Gr_Njr, along with the soil types Inceptisol and Latosol and Regosol, will also affect organoleptic quality. Naumann (2020) states that N supply can negatively affect many quality traits.

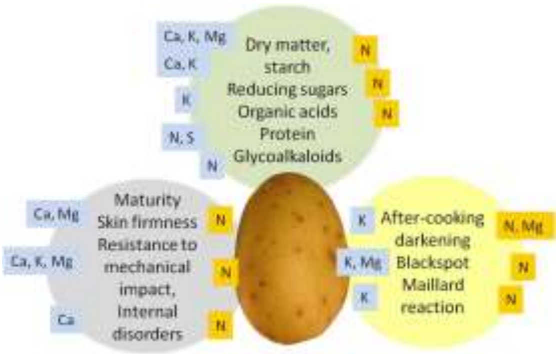

Figure 15
Quality characteristics of potato tubers are influenced by the provision of macronutrients: properties (grey), main compounds (green), and susceptibility to discolouration (yellow) in tubers and food. Blue: positive effect, orange: negative impact of the mineral. (Source: Naumann, M. 2020. Potato Research).

CONCLUSION

This study found significant differences in potato quality across environments, even though the "ideal" environment for potato cultivation is heavily influenced by desired and preferred quality characteristics. Using multivar biplot analysis, which is highly qualitatively capable of determining the relative position of various organoleptic and hedonic properties of potatoes, is a method highlighted as being important by the study's findings. This approach contributes to a better understanding of the variations in potato quality caused by the environment and offers a solid scientific foundation for constructing protected geographical identifications. Protected geographical identification is critical in potato cultivation because it allows farmers to optimize environmental conditions and produce potatoes of high quality that meet consumer expectations.

As a result, this approach promotes the development of effective, scientific, data-driven cultivation strategies, ensuring that the potatoes produced meet the desired quality criteria. Overall, the findings of this study highlight the significance of multivar biplot analysis in improving understanding of environmental influences on potato quality and enabling more precise and targeted cultivation based on consumer preferences.

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