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Editorial

Climate change and food security: risks and responses

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Climate change threatens to reverse the progress made so far in the fight against hunger and malnutrition. As highlighted by the latest assessment report of the Intergovernmental Panel on Climate change (IPCC), climate change augments and intensifies risks to food security for the most vulnerable countries and populations. The earliest and the more impacted are the most vulnerable countries and populations in arid and semi-arid areas, landlocked countries and small island developing states. Climate change will also have broader impacts through effects on trade flows, food markets and price stability and could introduce new risks for human health. It is profoundly modifying the conditions under which agricultural activities are conducted and it has both direct and indirect impacts on agricultural production systems.

However, direct impacts include effects caused by a modification of physical characteristics such as temperature levels and rainfall distribution on specific agricultural production systems. While, indirect effects are those that affect production through changes on other species such as pollinators, pests, disease vectors and invasive species. Pests and diseases are likely to move, following climate change, affecting areas previously immune, and thus less prepared, biologically and institutionally, to manage and control them, with potentially higher negative impacts. These changes may also counter-balance direct positive effects of climate change in high-latitude regions. Such indirect effects are much more difficult to assess and project given the high number of interacting parameters and links, many of which are still unknown.

The projected effects of climate change on major crop yields are now well documented based on two decades of research. Studies show that climate change has already negatively affected wheat and maize yields in many regions, as well as globally. According to results from major agricultural model inter-comparison projects, despite remaining uncertainties related to how models account for the representation of combined carbon dioxide fertilization, ozone stress and high temperature effects, there is agreement on the direction of yield changes, with strong negative impacts especially at higher levels of warming and at low latitudes. Potential impacts on other crops than major cereals have been less studied, as well as cli-

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mate change affects animal productivity and health as well as yields of forages and feed crops.

International spotlight on food systems and climate action

International events over the past years have cemented the centrality of food systems transformation in the climate change and Sustainable Development Goals (SDGs) agendas. Global calls for "building back better" after COVID-19 include a push for more sustainable, healthy, and equitable food systems. The chorus of voices for change suggests that now may be the moment. The United Nations convened its first-ever Food Systems Summit (UNFSS) in September 2021, marking an important shift from prior World Food events (1992, 1996, 2002). By moving towards food systems view that encompasses the production, processing, transport, and consumption of food, the UNFSS highlighted the role of global food systems in achieving the SDGs by 2030. The close rings among food security and nutrition goals, climate goals, and many of the other SDGs point to the "the need to confront the realities of balancing food production with climate action, affordable food with healthy diets, and stable food supplies with fair and open trade."

Likewise, the December 2021 Tokyo Nutrition for Growth Summit highlighted the links between food systems and nutrition and climate change. At the close of the UNFSS, the UN Secretary General outlined the need for concrete follow-up at the national level, as countries prepare pathways to transform food systems and achieve their climate commitments. The 2021 commitments required concrete follow-up by national governments to ensure real change. Significant shifts in public and private investment were essential, an issue that was discussed at both UNFCCC and UNFSS. The 2022 UN Conference on Biodiversity and the World Trade Organization ministerial conference, also planned for 2022, provided further opportunities to advance global climate and food systems action. The UNFCCC COP26 held in November 2021 stressed that much more action is required to meet commitments to net zero emissions, and countries were asked to strengthen current targets. In the realm of agriculture and land use (AFOLU), 137 countries pledged to halt and reverse forest and land degradation by 2030, and over 100 countries pledged to reduce methane emissions, including those from the agriculture sector. The Koronivia Joint Work on Agriculture, an important workstream of the UNFCCC, highlighted the key role of soil and nutrient management practices and livestock management systems. While such promises are encouraging, previous commitments have not been met. UNFCCC Cop27 climate talks, which held in November 2022 in Sharm El-Sheikh, Egypt on behalf of Africa to face the challenges of an energy crisis and its effect on climate change which insure on use of green hydrogen in energy production to reduce and mitigate the environmental pollution impacts. These impactful events have dramatically changed the geopolitical context of Cop since Cop26 which held in the UK city of Glasgow last year.

As host country, Egypt's job is to rally other nations in the run-up to and during the conference, to ratchet up their climate action. Egypt must also try to build consensus so that all countries can reach an agreement in the end. Cop stands for Conference of the Parties, referring to governments that have signed the United Nations Framework Convention on Climate Change (UNFCCC). About 90 heads of state have confirmed so far, including US President Joe Biden. A success of Cop26 was countries agreeing on the more ambitious target of limiting global temperature rises to 1.5°C, rather than the much more dangerous 2°C limit. But current policies put the world on course for around 2.4°C warming, with every fraction of a degree fuelling worse impacts.

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The effects of weather factors on titrating acids accumulation in sweet cherry fruits

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During fruit formation, the weather conditions have a decisive influence on the organic acids accumulation. In the context of global climate change, this issue has become new. The study of the titrated acids content in sweet cherry fruits was carried out for 12 years. Cherry fruits of the groups of three terms of ripening were selected for the study. The average and strong correlation between 11 weather factors and the titrated acids content for the sweet cherry cultivars of the early, medium, and late ripening terms were determined. The ranges of the weather factors that have the maximum influence on the formation of the titrated acid found in sweet cherry fruits (Δ_i 10.37-34.06%) were established. The research showed that the rate of maximal titrating acids content has been found in Valeriy Chkalov, Dilema, and Udivitelna cultivars. The optimal values of sugar-acid indices in the fruits of 31 sort samples of sweet cherry in all terms of ripening have been established. Weather conditions, which were during the years of the research, had dominating effects on the formation of titrating acids fund for all groups of cultivars irrespective of the term of fruit ripening. Ranking of weather factors according to the degree of their influence on the titrated acids accumulation in sweet cherry fruits three times of ripening has revealed that for cultivars of early, medium and late ripening terms of sweet cherry fruits the average monthly precipitation in May has a maximal influence and is a rank 1 factor; the average minimum relative humidity in May is essential for the cultivars of a medium-term of ripening.

1. Introduction

Orchards occupy a large area in Ukraine. One of the favourite fruits of consumers is sweet cherry fruits (Dziedzic et al., 2017; Szpadzik et al., 2019; Ivanova et al., 2022). The popularity of this fruit crop is stipulated by attractive cherries, high-taste qualities of fruits (Cao et al., 2015; Pereira et al., 2020; Ivanova et al., 2021), and early term of ripening (Pérez-Sánchez et al., 2008; Savchovska & Nesheva, 2021). But the demand for high-quality sweet cherry fruits still exceeds the supply in the European and World markets (Faniadis et al., 2010; Serra et al., 2011; Liu et al., 2011). Researchers from many countries pay much attention in their studies to the problems and perspectives of growing sweet cherry cultivars of early and late terms of fruits ripening as well as to improving sweet cherry quality (Jänes et al., 2010; Kask et al., 2010; Sîrbu et al., 2012). Under favourable weather conditions, the fruits of sweet cherry cultivars become good shippers, have a marketable state, and have excellent flavor (Einhorn et al., 2013). Many scientists study the biochemical composition and taste of sweet cherry fruits depending on the conditions of the fruit growing area (Borovinova et al., 2008; Radicevic et al., 2019; Szpadzik et al., 2019). The problem of the quality of sweet cherry fruits is widely discussed by scholars in the scientific literature (Usenik et al., 2010; Szpadzik et al., 2019; Antognoni et al., 2020; Ivanova et al., 2022).

The researchers dedicated their studies to determine the optimal set of sweet cherry fruits quality indices by different parameters (Ivanova et al., 2022; Serdiuk et al., 2020a). As many as 53 sweet cherry fruit samples of different cultivars were analyzed by the researchers from the South of Ukraine. In sweet cherry fruits, sweetness is harmoniously combined with palatable sourness, there are some vitamins, enzymes, and mineral salts, that are very beneficial for people's organisms. As many as 35 varieties of Ukrainian selection (Novynka Turovtseva, Bigaro Turovtseva, Chorna Turovtseva, Vypusknutsia, Impuls, Slavianovka, Supernytsia, Vizitka) were selected as the sources of excellent flavor with the highest tasting evaluation (Malyuk et al., 2014). The genetic features of pomological cultivars and weather conditions in a region of sweet cherry trees growing have a significant influence on the formation of biochemical parameters in fruits (Ivanova et al., 2020; Shubenko et al., 2021; Usenik et al., 2008; Picariello et al., 2016). The research by Todd C. Einhorn et al. (2013) established that under the effects of gibberellin acid (25 ppm GA) the content of titrating acids in sweet cherry fruits of a cultivar Swetheart increased at a range of 0,89-0,95%. Sugar-acid index (SAI) points to a harmonious flavor of crop fruits. It is determined as the sugar/acid contents ratio. As some authors state, the fruit with SAI 15-30 n.u. have the most harmonious flavor (Serdyuk & Stepanenko, 2015). Hydroxysuccinic acid makes up 90% of total acidity in fruits of sweet cherry and cherry trees (Radunic et al., 2014). Foreign scientists have established some changes in the biochemical composition of sweet cherry fruits of cultivars with different periods of ripening depending on the region of growing (Basanta et al., 2014). The rate of titrating acid accumulation can change depending on the effects of soil and weather conditions, crop yield, and degree of fruit ripeness. Such stone fruit crops like apricots, peaches, and sweet cherries are standing crops. Insufficient amount of moisture in the soil and in the air has negative effects on the growth of the vegetative organs, yield capacity, as well as on the worsening of the flavour of the fruit (Zeman et al., 2013; Shaaban et al., 2020). Thus, it has been admitted that during the years with a maximal amount of precipitation there are fewer dry substances in fruits. During the period of droughts, there is more sugar but less moisture in fruit cells. Acids accumulation is closely connected with a complex of biochemical transformations of organic acids taken as a whole (Serdyuk & Stepanenko, 2015). A frequent effect of a combination of unfavourable stress factors on sweet cherry trees results in the loss of stress resistance and is manifested in the quality degradation of fruits (Martini & Man, 2014; Dziedzic et al., 2017). To analyze the effects of weather conditions factors on the accumulation of quality indices of fruits (dry soluble substances, sugars, titrating acids) in sweet cherry fruits it was suggested to utilize the Methods of Regressive Correlation Analysis, as well as the Methods of Factor Analysis, in particular – the Method of Principal Component Analysis. The fact, that the amount of test factors exceeds the number of experimental values of a test index within the period of 12 years, is an important problem while developing and analyzing the regressive model. Thus, it is impossible to use the Least Square Method for developing a regressive model. To develop a regressive dependence, the researchers advised in the first stage to develop the system of principal components which will later function as the factors of a regressive model (Kelechi, 2012). The literature sources analysis substantiates the existence of a strong correlation between the taste qualities of sweet cherry fruits and the content of organic acids in them, the amount of which, in its turn, is associated with the weather conditions of the region of plants growing. Under conditions of climate change, the problem of the effects of stress weather factors on the prognostication of titrating

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acids content in sweet cherry fruits, depending on the rate of weather factors effects, has not been highlighted in literature sources, that determine the topicality of the conducted research. The purpose of the research was to develop a mathematical model which will help to improve the forecasting of titrating acids content in sweet cherry fruits under various weather conditions. This mathematical model can be used under conditions of the regions with similar hydrothermal indices to the southern regions of a Steppe zone of Ukraine. The research program is planning to determine the varieties of three terms of ripening with a high titrating acids rate for preserving both fruit quality and biological value.

2. Materials and Methods

The research was conducted during the period of 2008-2019. The everyday meteorological data of Melitopol (Ukraine) Weather Station were used. Fruit farms, where the research was conducted, were located in a Southern Steppe Subzone of Ukraine. The landscape of the area is plain, with an Atlantic-continental climate and high-temperature regime. The annual air temperature range is 9.1-9.9 °C. The average monthly air temperatures in the hottest months were from 20.5 to 23.1 °C. The effective heat sum above 10 °C from April to October totals 3316 °C, and the annual amount of precipitation totals 475 mm. The region, according to the amount of precipitation, belongs to the zone with an insufficient amount of moisture. The average annual relative humidity is within 73%. The average annual air velocity is 3.7 m/s. The climate is dry with eastern and northeastern winds. The readings of the hydrothermal index are in the range of 0.22-0.77.

The agricultural background of the experimental plots during the years of research met the agrotechnology requirements. Moisture accumulation in soil happens preferably in autumn, partly in winter, and in early spring. The crop is grown on southern light loamy soils. Forest is a soil-forming material. This type of soil by its granulometric composition has a large content of physical sand. The fruits of 33 varieties were selected for studying and according to the ripeness stage, they were divided into 3 groups (Table 1).

To estimate the titrating acids content, as many as 100 fruits from 6 trees that were in the fruit-bearing period, were selected for each pomological cultivar. There was threefold repeatability. In 2001 the trees were planted on the pattern 5×3 with weed-free fallow spacings. The trees typical for a separate pomological cultivar, of the same age, with an average fruiting intensity were selected for the study. The fruits were weighed and counted when picking (Serdiuk et al, 2020b; Ivanova et al, 2021). The sweet cherries fruits of each commercial sort were carefully picked on the stage of economic maturity when the fruit pulp is firm, but the flavor and the color are typical for a given pomological cultivar.

The fruits were picked from the trees from four different sides of a crown. The fruits from each pomological cultivar were of the first commercial sort and picked with fruit stalks. The date of picking fruits will be established according to the following quality indices of sweet cherry fruits: visual appearance (fruit analysis in terms of form and colour which must be typical for a given pomological cultivar, fruit-stalk availability, determining the rate of mechanical damages of fruits, their infestation with pests and fungus diseases), the size of the fruits in cross-section diameter. The fruits were kept and transported to the laboratory under favourable conditions so that the fruits had a good visual appearance and flavor typical for a pomological cultivar.

Table 1. The list of varieties taken for studying

1st variety group (early term of ripening)	2nd variety group (medium term of ripening)	3rd variety group (late term of ripening)
Swit Erliz, Merchant, Bigaro Burlat, Rubinova Early, Valeriy Chkalov, Kazka, Zabuta	Kordia, Oktavia, Vynka, Pervistok,Temp, Uliublenytsia Turovtseva, Talisman, Dilema, Melitopolska Chorna,Orion, Chervneva Early, Dachnytsia, Prostir	Karina, Regina, Mirazh, Krupnoplidna, Udivitelna, Zodiak, Ciurpryz, Kolhoznytsia, Prazdnichna, Anons, Temporion, Meotyd

Mass concentration of titrating acids (TA) was defined by a titrimetric method (Serdiuk et al, 2020) – by titrating 0.1 H by solution NaOH. The titrimetric method determined the mass concentration of titrated acids (TA). The essence is to neutralize organic acids in the experimental product with 0.1 n alkali solution. Titrating is carried out before the transition of the solution from an acidic medium to an alkaline one. The moment of transition of the medium to an alkaline one is visually fixed by appearing the pink colour of the solution in the presence of a phenolphthalein indicator. Using formula 1:

$$X = (M \cdot K \cdot Vas \cdot 100) \div (Ms \cdot Vs) \quad (1)$$

X – total acidity, % (100 g); M – the amount of 0.1 H of an alkaline solution used for titrating, cm3; K – conversion factor to apple acid 0.0067; Vas – the volume of an assay sample, ml; MS – assay sample of a tested substance, g; Vs – the volume of the solution which was taken for titrating, ml.

Measurement instruments, auxiliary equipment, utensil, reagents, and materials: a homogenizer; a blender or a mortar with a pestle; a 25, 50, or 100 cm^3 pipette; an Erlenmeyer flask that can be connected to a reflux condenser; a 250 cm^3 graduated cylinder; a 250 cm^3 beaker with a magnetic or mechanical stirrer; a 50 cm^3 burette; a reflux condenser; analytical scales with weighing accuracy up to 0,01 g; a water bath. Reagents: only reagents of the established analytical purity and distilled or demineralized water or water of equivalent purity were used for the analysis; Sodium hydroxide NaOH with 0.1 mol/dm^3 (0.1N) concentration; phenolphthalein, a solution with 10 g/dm^3 (1%) mass concentration in ethyl alcohol with 95% volume concentration.

Experimental techniques

The dependence of titrating acids on weather factors was studied according to the following patterns:

1. To determine the titrating acids content according to the method mentioned above by conducting experimental research.

2. Systematization of information and organization of structural data concerning weather conditions during the research period. During this period, the following indices were selected: average minimal air temperatures, average air temperatures, average maximal air temperatures, absolute minimal air temperatures, absolute maximal air temperatures, amount of precipitation, average relative humidity, minimal relative humidity, and maximal relative humidity.

3. On the basis of these indices the following indices were counted: hydrothermal coefficient, the difference in temperatures in different periods, the sums of active temperatures, and the sums of effective temperatures.

4. The correlation analysis made it possible to determine the weather factors which have a significant influence on the accumulation of titrating acids of sweet cherry fruits for the fruits of early, medium, and late periods of ripening.

5. The factors, mentioned in paragraph 4, were analyzed by Regressive Analysis Methods in order to determine the degree of impact of each factor on the titrating acids index for the sweet cherry fruits cultivars of three periods of ripening.

As it is known, the analysis of matching correlation coefficients is a primary estimation of the degree of impact of a separate factor on the test index. To compare the degree of the factors' impact on the test index, it is expedient to use another method of statistic analysis, such as Regression Analysis.

But, as the amount of test – factors $X_j,\ j = 1..11$, are one less than the number of observations, (Y_i, for i=1…12 years of investigation), it is not efficient to use a classical pattern of studying the regressive analysis. The factors correlate among themselves, as most of factors matching coefficients are close to k±1. That suggests that there is a multicollinearity effect available.

Thus, it is suggested to develop a regressive model on the basis of the Principal Components Method (principal components analysis, PCA). The Principal Components Method makes it possible to reduce the number of variables by creating artificial factors (principal components). Principal components $(PC_i, i = 1 \dots n)$ represent a linear combination of background factors x_i and don't correlate among themselves. For further analysis is chosen the set of those principal components which takes maximal cumulative dispersion from the variables (Kelechi, 2012; Chen & Ma, 2015).

The creation and the analysis of a regressive model should be done according to the following stages:

1. On the basis of factors values (indices x_{ij}, $i = 1 \ldots n$ – the number of a weather factor, $j = 1 \ldots$ the number of a research year) the set of principal components is created $(PC_i, i = 1..n)$. Then the first principal components are selected $(PC_i, i = 1..k, k < n)$, which ensure the main part of a cumulative dispersion efficiency – more than 90 % (Kelechi, 2012).

2. Develop a regressive dependence of the indices y_1, y_2, y_3 on the developed principal components $(PC_i, i = 1 \ldots k)$:

$$\hat{Y} = b_0 + \sum_{j=1}^{k} b_j \cdot PCA_j \qquad (2)$$

3. Transform the regressive model (2) by replacing the principal components of their formulas through the background factors $(x_i, i = 1 \ldots n)$. After such transformations regressive dependences of titrating acids indices on the background factors can be analyzed:

$$\hat{Y} = a_0 + \sum_{j=1}^{n} a_j \cdot X_j, \qquad (3)$$

where X_j – factors; a_j – model parameters; $\hat{Y}$ – the value of titrating acids content in sweet cherry fruits.

4. On the basis of a developed model (3), the degree of impact of each factor on the resulting indices is analyzed.

The comparative analysis of the degree of impact of each weather factor X_j on the value of titrating acids content in sweet cherry fruits is done on the basis of coefficients Δ_j. These coefficients characterize the relative degree of each factor's impact $(X_j, j = 1..n)$ on the analyzed index Y. Coefficients Δ_j are counted according to the formula:

$$\Delta_i = \left| \frac{\tilde{a}_i \cdot r_{YX_i}}{R^2} \right|, \qquad (4)$$

$\tilde{a}_i$ – parameters of a regressive model in standardized factors values;

Standardized factors values are counted according to the formula:

$\tilde{x}_{ij} = \frac{x_{ij} - \bar{X}_j}{sd(X_j)}$ –, i=1..12, j=1..11; x_{ij} – base value of a factor, i=1..12, j=1..11; $\bar{X}_j$ – average value of a factor, j=1..11; $sd(X_j)$ – standard factors deviations, j=1..11. r_{YX_i} – matching coefficients of correlation; R^2 – determination coefficient.

On the basis of calculated values on the formula (4), factors according to their impact degree were arranged.

Some tools of modern computer technologies of Data Mining – software environment of RStudio – were used to make statistical analysis.

3. Results

Among the most important indicators of sweet cherry fruits for consumers, when they choose fruits, is taste. The formation of taste qualities of fruits depends on a harmonious combination of sugar and organic acid [Hajagos et al., 2012]. But there is not enough information in the available literature about the content of titrating acids in sweet cherry fruits which are grown in Ukraine. The experiment of 2008-2019 established that the average amount of titrating acids in sweet cherry fruits, grown under conditions of fruit farms in the analyzed region of Ukraine, amounted to 0.61% (Table 2-4). Maximal average titrating acids content of 1.00% was registered in sweet cherry fruits of the Udivitelna cultivar in a group of late ripening cultivars. Among the cultivars of two other groups, the fruits of cultivars Valeriy Chkalov and Dilema were characterised by the largest average titrating acids content. They accumulated 0.53% and 0.72% of titrating acids respectively. According to studies by *L. Shubenko et al.* (2021) which were conducted in the conditions of Ukraine, the highest content of titrating acids was recorded in the fruits of a medium-term ripening Alionushka (0.75%), and the lowest one in the fruits of a late-term of ripening Amazonka (0.45%). According to the data of Polish researchers (Bieniek et al., 2011), among the cultivars which were studied for three years a cultivar Agila had the highest content of organic acids in sweet cherry fruits (1.07%), and a cultivar Seda had the lowest content (0.45%). As follows from a 20-year-long study, the cultivars of an early term of ripening (Zabuta, Valeriy Chkalov, Swit

Earlies) accumulated a maximal amount of titrating acids, and the cultivars Merchant, Rubinova Rannia – accumulated the least amount of titrating acids (Table 2).

The fruits of the Chervneva Rannia cultivar, which were picked in 2015 and 2011, were respectively characterised by a minimal and maximal titrating acids content in a group of cultivars of medium-term ripening (Table 3).

A maximal mass portion of titrating acids in a group of cultivars of a late-term of ripening was established in the fruits crop of 2016 of the Udivitelna cultivar (Table 4).

In a group of cultivars of medium-term ripening, a maximal average content of titrating acids was recorded in the fruits of Dilema and Chervneva Rannia cultivars and in the group of late-term ripening – in the fruits of Colhoznitsa and Crupnoplidna cultivars (Table 3, 4). The results of the scientific research show that the sweet cherry cultivars, which were studied, differ in biochemical composition of fruits, in titrating acids content, in particular. This conclusion is proved by the data received by other researchers (Usenik et al., 2008; Antognoni et al., 2020; Corneanu et al., 2020). The estimation of 15 sweet cherry cultivars as to fruit quality was conducted in conditions in Romania (Corneanu et al., 2020). It was found that the titrating acids content fluctuates at a range of 0,39% (cultivar 'Andreiaş') – 0.87% (cultivar 'Cătălina'). It was found by E. Szpadzik et al. (2019) that in conditions of Poland the fruits of sweet cherry cultivars Sylvia and Regina had the lowest acidity (about 0.5%), and the fruits of a cultivar Techlovan had the highest acidity (above 0.7%). As a result of research by A. Hajagos (2012) it was found that there is a significant difference between the cultivars Regina and Kordia as to the accumulation of common acids in sweet cherry fruits. Besides, according to the research data, the content of a test index in fruits of both cultivars depended on the stock and on the stage of ripening of sweet cherry fruits. The analysis of the values of the coefficients of variations showed that the weather factors most affected the titrating acids content in Sweet Earlies and Kazka varieties (Vp=21.6% and 21,4% respectively). Valeriy Chkalov variety had a minimal variation coefficient on the level of 19.7%. From among the cultivars of medium-term ripening the fruits of Vynka, Talisman, Octavia, Prostir were characterised by a minimal variation coefficient (Vp=19.7%). In a group of cultivars of late-term ripening, the most stable TA content was the Karina variety (Vp=17.7%).

Table 2. Titrating acids content (TA) and sugar-acid index (SAI) in the sweet cherry fruits of the varieties of an early term of ripening, % (2008-2019)

Pomological variety	Average titrating acids content, %	Titrating acids content, %		Variation according to years, Vp, %	Sugar-acid index (SAI)
		min	max		
Rubinova Rannia	0.38±0.08	0.25	0.54	20.7	32.5
Valeriy Chkalov	0.53±0.10	0.31	0.72	19.7	23.6
Sweet Erliz	0.53±0.11	0.39	0.73	21.6	24.2
Merchant	0.37±0.07	0.29	0.54	20.1	28.5
Kazka	0.49±0.10	0.29	0.66	21.4	23.7
Bigaro Burlat	0.47±0.09	0.33	0.69	20.5	23.6
Zabuta	0.53±0.11	0.34	0.67	20.3	23.5
Average value	0.47±0.11	0.26	0.73	24.3	25.4
LSD_{05}	0.029	–	–	–	

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Table 3. Titrating acids content (TA) and sugar-acid index (SAI) in sweet cherry fruits of the varieties of a medium term of ripening, % (2008–2019)

Pomological variety	**Average titrating acids content, %**	**Titrating acids content, %**		**Variation according to years, Vp, %**	**Sugar-acid index (SAI)**
		min	max		
Vynka	0.67±0.13	0.50	0.89	19.7	18.3
Pervystok	0.64±0.13	0.47	0.80	20.1	19.4
Temp	0.57±0.12	0.40	0.67	21.3	23.9
Uliublenytsia Turovtseva	0.70±0.15	0.44	0.90	22.0	15.5
Talisman	0.70±0.13	0.47	0.87	19.7	20.8
Dilema	0.72±0.14	0.50	0.91	20.0	17.9
Melitopolska Chorna	0.63±0.13	0.41	0.81	20.6	17.7
Kordia	0.63±0.14	0.39	0.85	22.5	20.9
Oktavia	0.66±0.13	0.41	0.79	19.7	20.9
Orion	0.61±0.13	0.35	0.82	22.6	22.0
Chervneva Rannia	0.71±0.20	0.34	1.01	29.3	15.5
Dachnytsia	0.69±0.14	0.39	0.80	20.3	22.6
Prostir	0.66±0.13	0.43	0.80	19.74	19.2
Average value	0.66±0.14	0.34	1.00	20.7	19.5
LSD_{05}	0.038	–	–	–	

Table 4. Titrating acids content (TA) and sugar-acid index (SAI) in sweet cherry fruits of the varieties of a late term of ripening, % (2008–2019)

Pomological variety	Average titrating acids content, %	Titrating acids content, %		Variation according to years, Vp, %	Sugar-acid index (SAI), relative units
		min	max		
Krupnoplidna	0.72±0.139	0.41	0.86	19.2	19.9
Karina	0.65±0.116	0.39	0.79	17.7	18.9
Regina	0.67±0.134	0.34	0.81	20.1	17.3
Mirazh	0.68±0.132	0.40	0.86	19.3	20.1
Udivitelna	1.00±0.201	0.56	1.30	20.0	13.0
Zodiak	0.65±0.129	0.43	0.84	19.8	20.2
Surpryz	0.62±0.117	0.35	0.76	18.7	21.3
Kolhoznytsia	0.74±0.149	0.46	1.01	20.0	16.9
Kosmichna	0.63±0.123	0.42	0.81	19.4	21.2
Prazdnichna	0.59±0.114	0.37	0.71	19.2	21.6
Anons	0.66±0.138	0.32	0.81	20.7	18.5
Temporion	0.63±0.092	0.43	0.74	14.5	20.4
Meotyda	0.70±0.149	0.39	0.92	21.2	20.1
Average value	0.69±0.163	0.32	1.29	23.6	19.0
LSD_{05}	0.025	–	–	–	

Consumers evaluate the sweet taste of fruits which is emphasized by freshness due to the content of the organic acid (Takácsné Hájos et al., 2011). The best taste depends on harmony between a high sugar content and medium or high acid content. According to the data in tables 2-4, the rate of average values of SAI in the fruits of tested groups is within 13.0-25.4 r.u. As many as 31 sweet cherry cultivars of all terms of ripening with the range of the value within 16.9-28.5 r.u. have been determined by means of optimal SAI parameters. Udivitelna cultivar (SAI – 13.0 r.u.) and Rubinova Rannia cultivar (SAI – 32.5 r.u.) were an exception. There is an opinion that when the SAI value is higher than 30 r.u., the fruit flavour will be too sweet, and when the SAI value is lower than 15 r.u. – it will be too acidic (Serdyuk & Stepanenko, 2015). On the whole, the variation (as to TA content) of the group of cultivars of early, medium, and late-term ripening under the abiotic factors impact was high.

To determine the degree of weather factors impact and cultivar's particular qualities on the formation of titrating acids amount in sweet cherry fruits, a two-way analysis of variance was made (Table 5). The results of the experiment show that for all groups, irrespective of ripening term, the weather conditions which were during the period of 12 years of the experiment (Factor A) had a dominating impact on titrating acids formation. The degree of impact of Factor A for a group of an early term of ripening is 70.3%, for a group of medium-term ripening – 44.5%, and for a group of late-term ripening – 45.8%.

The effects of a cultivar's particular qualities (Factor B) were less substantial. An impact degree of a given factor was from 8.3% to 35.9% for a cultivar group that was analyzed. For a group of cultivars of medium and late terms of ripening the varietal features (Factor B) had a significant impact with a share of influence – 25.1 and 35.9% respectively. The influence of this factor on the fruits of an early term of ripening was low, with a share of influence of 8.3%. Thus, the experiment results show the expediency of titrating acids content prognostication in sweet cherry fruits by the medium values for a particular cultivars group, but not for each pomological cultivar.

Table 5. Results of two-factors dispersion analysis under titrating acids content fund formation in sweet cherry fruits

Source of variation	Sum of squares	Degree of freedom	Dispersion	F_{fact}	$F_{table\ 095}$	Impact, %
Sweet cherry varieties group of an early period of ripening						
Factor A (year)	2.020	11	0.184	594.0	1.8	70.3
Factor B (variety)	1.070	6	0.178	576.8	2.2	8.3
Interaction AB	0.253	66	0.004	12.4	1.4	19.5
Sweet cherry varieties group of a medium period of ripening						
Factor A (year)	6.955	11	0.632	1159.9	1.8	44.5
Factor B (variety)	0.823	12	0.069	125.8	1.8	25.1
Interaction AB	1.934	132	0.015	26.9	1.3	27.9
Sweet cherry varieties group of a late period of ripening						
Factor A (year)	5.738	11	0.522	2129.7	1.8	45.8
Factor B (variety)	4.504	12	0.375	1532.3	1.8	35.9
Interaction AB	2.166	132	0.016	66.9	1.3	17.3

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Weather factors ranking according to the degree of their impact on titrating acids accumulation in sweet cherry fruits cultivars of three terms of ripening has established that average monthly precipitation in May (X1) has a maximal impact and belongs to the 1st rank; for the cultivars of the medium term of ripening the average minimal relative air humidity in May (X3) are of the same importance. The analysis of weather conditions (factors) X_i impact on titrating acids index Y in sweet cherry fruits of early, medium and late ripening terms was done on the basis of calculated matching coefficients of correlation r_{YX_i} and on testing the meaningfulness of these correlation coefficients. In order to receive this target, Student's criteria were used and tested a statistical hypothesis $H_0: \rho = 0$ (ρ – correlation coefficient of entire assembly) when using an alternative hypothesis $H_1: \rho \neq 0$ under significance value $\alpha = 0,05$. As the calculations showed, significant correlation coefficients under the significant value $\alpha = 0,05$ and under the number of degrees of freedom $k = 10$ are within an interval [-0.55;0.55].

As a result, 11 factors that in a specified growing period may affect the titrating acids accumulation in sweet cherry fruits of the early, medium, and late ripening terms, were selected. These thermal air parameters (°C) are the difference between average, maximal, and minimal temperature in May (X_6), June (X_7), and during the period of fruit picking (X_9). Humidity indices (%, мм) are the average monthly precipitation amount in May (X_1); average monthly air humidity in May (X_2), the average minimal relative air humidity in May (X_3), in June (X_4), and during the period of fruits picking (X_{10}); a total amount of days with precipitation more than 1 mm in May (X_5); precipitation amount during the period of blooming and fruits ripening (X_8); average relative air humidity during the period of fruits picking (X_{11}). Further study is conducted according to the research design given above.

First step. Five principal components were selected by the Principal Components Method $(PC_i, i = 1..5)$. These 5 components ensured more than 95% of cumulative dispersion (Cumulative Proportion of Variance).

Second step. Regressive models of titrating acids index dependence on the principle components were designed for each cultivars group $(PC_i, i = 1..5)$ of a variety (2).

The regression equation for early cultivars looked like this:

$$\hat{Y}_1 = 0,4760 + 0,0288PC_1 + 0,0051PC_2 - 0,0195PC_3$$
$$-0,0467PC_4 + 0,0527PC_5$$

The regression equation for the medium cultivars group looked like this:

$$\hat{Y}_2 = 0,6664 + 0,0405PC_1 - 0.0186PC_2 - 0.0451PC_3$$
$$-0.0456PC_4 + 0.0057PC_5$$

The regression equation for the late cultivars group looked like this:

$$\hat{Y}_3 = 0,6918 + 0,0338PC_1 + 0,0132PC_2 - 0.0006PC_3$$
$$-0.0193PC_4 - 0.0807PC_5$$

The value of the determination coefficient (R – squared) for early cultivars amounted to 0.9181, for medium cultivars – 0.9199, and for late cultivars – 0.7156, which indicates a strong impact of independent variables on dependent variables. The values p-value < 0.05 for all regressive models indicate the validity of the models on the basis of Fisher criteria under the level of significance – 0.05.

Third step. After passing to base factors, the model looks like (3). This regressive model characterizes the dependence of the accumulation index of titrating acids (for $\hat{Y}_1, \hat{Y}_2, \hat{Y}_3$) on weather factors (in a standard form).

The regressive model of dependence of accumulation index of titrating acids on weather factors, expressed in a standard form is:

– for early cultivars it looks like this:

$$\hat{Y}_1 = 0,62875\tilde{X}_1 + 0,1820\tilde{X}_2 + 0,2612\tilde{X}_3 + 0,13290\tilde{X}_4$$
$$+0,490352\tilde{X}_5 - 0,17954\tilde{X}_6 - 0,0456\tilde{X}_7 + 0,19142\tilde{X}_8$$
$$+0,062705\tilde{X}_9 + 0,267523\tilde{X}_{10} + 0,12964\tilde{X}_{11}$$

– for medium cultivars it looks like this:

$$\hat{Y}_2 = 0,489599\tilde{X}_1 + 0,312162\tilde{X}_2 + 0,335628\tilde{X}_3$$
$$-0,0361\tilde{X}_4 + 0,335628\tilde{X}_5 - 0,19027\tilde{X}_6 + 0,066303\tilde{X}_7$$
$$+0,2263\tilde{X}_8 - 0,22744\tilde{X}_9 + 0,347166\tilde{X}_{10} + 0,30343\tilde{X}_{11}$$

– for late cultivars it looks like this:

$$\hat{Y}_3 = 0{,}445998\tilde{X}_1 + 0{,}121565\tilde{X}_2 + 0{,}217837\tilde{X}_3$$
$$+0{,}28610\tilde{X}_4 + 0{,}428744\tilde{X}_5 - 0{,}26322\tilde{X}_6 - 0{,}26471\tilde{X}_7$$
$$+0{,}099087\tilde{X}_8 + 0{,}063256\tilde{X}_9 + 0{,}180767\tilde{X}_{10} + 0{,}053937\tilde{X}_{11}$$

On the basis of designed models, for each factor coefficients $\Delta_i, i = 1..14$ are calculated by the formula (3). Coefficients Δ_i determine the degree of each factor in total dispersion of the value of titrating acids content in sweet cherry fruits. On the basis of calculated indices $\Delta_i, i = 1.14$, all factors were ranked depending on the rate of their impact from the most significant (rank 1) to the least important (rank 14). Table 1 shows the indicator values $\Delta_i, \%$ and the rank of factors.

The varieties of the early, medium, and late periods of ripening Δ_i vary within 0.75-34.06 % (Table 6). For further analysis of research results all factors, depending on coefficient values $\Delta_i (i=1…11)$ were divided into 3 groups. The first group- factors that have a strong impact on titrating acids accumulation ($\Delta_i \geq 10{,}37\ \%$); second group – factors that have a medium impact on titrating acids accumulation (Δ_i from 3.00 to 9.31%); the third group – other factors which have little impact on titrating acids accumulation ($\Delta_i \leq 2{,}56\%$).

The first group of factors includes three factors that have a significant impact on titrating acids accumulation in sweet cherry fruits in an early term of ripening. They have a valuation Δ_i in the range of 10.44-34.06%. The factors which have a valuation Δ_i in the range of 11.52-18.33% belong to the first group of factors but are typical for sweet cherry fruits in the medium term of ripening. The experiment has detected some common impacts of three weather factors on titrating acids accumulation in sweet cherry fruits of early and medium terms of ripening. They are humidity indices in May: the average monthly precipitation (X_1), the average minimal relative air humidity (X_3), and the number of days with precipitation more than 1 mm (X_5). The humidity index in May (the average monthly humidity (X_2) also had a significant impact on titrating acids accumulation in sweet cherry fruits of a medium-term ripening.

The factors which have a valuation Δ_i in the range of 10.37-23.99 % belong to the first group of factors and are typical for the sweet cherry fruits of late-term ripening. They are – humidity indices and thermal parameters in May: the average monthly precipitation (X_1), the number of days with precipitation more than 1 mm (X_5), and the difference between average maximal and minimal air temperatures (X_6). The weather parameters in June also have an impact on titrating acids accumulation in sweet cherry fruits of a late-term of ripening: the average minimal relative air humidity (X_4) and the difference between average maximal and minimal air temperatures (X_7).

According to Table 6, the factors that have an average impact on titrating acids accumulation in sweet cherry fruits of early, medium and late terms of ripening with valuations Δ_i from 3.26 to 9.31% belong to the second group. To weather factors, which have an average impact on titrating acids, accumulation belongs:

– for cultivars groups of an early term of ripening: the average monthly relative air humidity (X_2) and the difference between average maximal and minimal air temperatures (X_6) in May; the average minimal relative air humidity (X_4) in June; the amount of precipitation in the period after blooming and before fruits ripening (X_8); the average minimal relative air humidity in the period of fruits picking (X_{10});

– for cultivars groups of medium-term ripening: the average minimal relative air humidity (X_4) and the difference between average maximal and minimal air temperatures (X_7) in June, the amount of precipitation in the period after blooming and before fruits ripening (X_8), the average minimal air humidity (X_{10}) and the average relative (X_{11}) air humidity in the period of fruits picking.

– for cultivars groups of late-term ripening: the average monthly relative air humidity (X_2) and the average minimal relative air humidity (X_3) in May, the amount of precipitation in the period after blooming and before fruits ripening (X_8), the average minimal relative air humidity (X_{10}) in the period of fruits picking.

In the second group of factors for sweet cherry fruits of three terms of ripening, there are two common weather factors, which have a significant impact on titrating acids accumulation in fruits of the early, medium, and late-term storage. They are the amount of precipitation after blooming before fruits ripening (X_8) and average minimal relative air humidity (X_{10}) in

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Table 6. Table of matching coefficients correlation , impact degree indices), ranks of weather factors (X_i,) on titrating acids content in sweet cherry fruits of early, medium, and late terms of ripening.

Factors (X_i)	Relative factors term (X_i)	Matching coefficients of correlation (), coefficients of factors' degree of impact (and indices of a rank of factors for the cultivars of early, medium, and late groups								
		early			medium			late		
		$r_{y_1x_i}$	Δ_i, %	rank	$r_{y_1x_i}$	Δ_i, %	rank	$r_{y_1x_i}$	Δ_i, %	rank
X_1	Average monthly amount of precipitation in May, mm	0.962	34.06	1	0.856	11.52	4	0.802	23.99	1
X_2	Average monthly relative air humidity in May, %	0.677	6.94	5	0.702	18.33	2	0.635	5.18	7
X_3	Average minimal relative air humidity in May, %	0.710	10.44	3	0.760	19.12	1	0.636	9.31	6
X_4	Average minimal relative air humidity in June, %	0.435	3.26	8	0.305	5.91	8	0.569	10.93	4
X_5	Total amount of days with precipitation more than 1 mm in May, %	0.797	22.02	2	0.724	15.07	3	0.672	19.33	2
X_6	Difference between average maximal and minimal temperatures in May, °C	-0.551	5.57	7	-0.609	0.85	10	-0.587	10.37	5
X_7	Difference between average maximal and minimal temperatures in June, °C	-0.430	1.11	10	-0.284	5.48	9	-0.649	11.54	3
X_8	Amount of precipitation in blooming period and in picking fruits period, %	0.569	6.13	6	0.524	7.15	7	0.503	3.35	9
X_9	Difference between average maximal and minimal temperatures in the period of fruit picking, °C	-0.255	0.90	11	-0.571	0.75	11	-0.207	0.88	11
X_{10}	Average minimal relative air humidity in the period of fruits picking, %	0.464	7.00	4	0.656	7.42	6	0.349	4.24	8
X_{11}	Average relative air humidity in the period of fruits picking, %	0.351	2.56	9	0.620	8.40	5	0.243	0.88	10

the period of fruit picking. The analysis of the ranking of weather factors, which belong to the second group as to their impact on the test index, confirms a mild impact of these factors on titrating acids accumulation in sweet cherry fruits.

Thus, in a cultivars group of an early term of fruits ripening factors (X_2, X_4, X_6X_8, X_{10}) take the fourth – eighth ranks; in a cultivars group of a medium-term of fruits ripening factors (X_2, X_4, X_6X_8, X_{10}) take the fifth – ninth ranks; in a cultivars group of a late-term of ripening factors (X_2, X_4, X_6X_8, X_{10}) take the third – ninth ranks in terms of the degree of their impact.

Other weather factors, which have an insignificant impact on titrating acids accumulation, belong to the third group. According to Table 6, valuations Δ_i for the cultivars of an early term of ripening are from 0.90 to 2.56%; for the cultivars of a medium-term of ripening Δ_i $0.75\% - 0.85\%$; for the cultivars of a late-term of ripening – 0.88%. A cumulative percentage of the impact of this group of factors for a cultivars group of an early term of ripening amounted to 4.57%, for a cultivars group of a medium-term of ripening it amounted to 1.60%, and for a cultivars group of a late-term of ripening – 1.76%. For all cultivars groups, there is a common weather factor which is 11th as to ranking and, according to the received data, it has an insignificant impact on titrating acids accumulation in fruits of the cultivars of three periods of ripening, This factor is the difference between average maximal and minimal temperatures in the period of fruits picking (X_9). Thus, weather conditions in May have the most significant impact on titrating acid accumulation in sweet cherry fruits irrespective of the period of ripening. These weather conditions are average monthly precipitation amounts (rank 1). For the cultivars of an early term of ripening, the most important are the weather conditions in May, and for the fruits of medium and late terms of ripening the most significant are weather conditions in May and June. It should provide a concise and precise description of the experimental results. All sections and subsections must be numbered.

4. Conclusions

Maximal values of titrating acids content have been established in Valeriy Chkalov, Dilema, and Udivitelna cultivars (0.53, 0.72, and 1.00% respectively) under Vp=19.7-20.0%.

Optimal parameters of the sugar-acid index were also established in the fruits of 31 sweet cherry cultivar samples with the range of the value within 16.9-28.5 r.u. For all groups of cultivars, irrespective of the term of ripening, the weather conditions during the period of research had dominating effects on the formation of titrating acids fund. The correlative analysis of weather conditions' impact on titrating acids amount in sweet cherry fruits of the early, medium, and late terms of ripening has been made. Medium and strong correlative dependences between 11 weather factors (X_i, i=1..11) and the amount of titrating acids for sweet cherry cultivars of early, medium, and late terms of ripening have been established ($\left|r_{Y_j X_i}\right| \geq 0.55$, $i = 1..11, j = 1..3$). The models of dependence of titrating acids accumulation on weather factors impact for cultivars groups of early, medium and late terms of ripening were developed on the basis of Principle Components Method and the Least Squares Method. The analysis of the degree of impact of each weather factor on the titrating acids accumulation index has been made. The calculated coefficients as to the impact of factors $\Delta_i, \%$ showed, that the group of temperature parameters and humidity indices had the most significant impact on the titrating acids accumulation in sweet cherry fruits with a maximal $\Delta_i \geq 10.37\%$ in the total factors impact. The ranges of the degrees of weather factors impact, which have the maximal effects on titrating acids accumulation in sweet cherry fruits (Δ_i 10.37% to 34,06%), have been established. The weather parameters which have the maximal impact on titrating acids accumulation in sweet cherry fruits have been established for the cultivars of three terms of ripening. Early and medium cultivars depend on three weather factors: average monthly precipitation, average minimal relative air humidity, and the total number of days with precipitation more than 1 mm in May. Late cultivars depend on average monthly precipitation, the total number of days with precipitation more than 1 mm, the difference between average maximal and minimal air temperatures in May, average minimal relative air humidity, and the difference between average maximal and minimal air temperatures in June. The weather factors ranking according to the degree of their impact on titrating acids accumulation in sweet cherry fruits of three terms of ripening showed, that average monthly precipitation in May (X_1) has the most significant impact and belongs to the first rank; for the cultivars of medium-term of ripening the average minimal relative air humidity in May (X_3) is the most important. On the basis of Regressive Analysis, it has been substantiated that the weather conditions in May have the most significant impact on titrating acids

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accumulation in sweet cherry fruits irrespective of the terms of ripening, in particular – the average monthly precipitation (rank 1); the weather conditions in May are the most significant for the cultivars of an early term of ripening; for the cultivars of medium and late terms of ripening the most important are the weather conditions in May and June.

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Conflict of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Income and price elasticities of animal food demand and welfare in Indonesian urban: an application of the LA-AIDS

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Protein consumption can be a measure of the welfare of society. Developed countries consume more protein than developing countries. This study analyzes rising prices and income on demand and welfare in urban Indonesia. The research data use the 2018 Household National Socio-Economic Survey (Susenas) data in household consumption and expenditure data collected by the Central Statistics Agency (BPS). The number of samples is 133,873 households. The demand systems approach uses the Almost Ideal Demand System (LA-AIDS). The welfare change approach uses Compensating Variation (CV) and Equivalent Variation (EV). The results showed that the meat group was the most elastic animal food with a demand elasticity of 13,936%, followed by milk (0.991%), sea fish (0.649%), eggs (0.284%), and chicken meat (0.057%). Beef is a substitute for sea fish and eggs. Beef with chicken and milk is complimentary. All animal food is a luxury item except sea fish, a normal item. In the long term, the highest marginal expenditure share is marine fish at 0.592%, followed by milk (0.123%), beef (0.102%), eggs (0.078%), and the lowest is chicken meat at 0.012%. Considering the substitution, the price increase simultaneously requires CV compensation of Rp. 244,830/HH/month, EV of Rp.231,858/HH/month. Especially for the animal food group, the biggest compensation for eggs needs CV compensation of Rp. 10,083/HH/month, and EV of Rp. 9,493/HH/month. In general, EV compensation is more effective than CV compensation.

1. Introduction

A country's food consumption, especially protein, is often a measure of a nation's welfare. People in developed countries consume more stable protein food than developing countries (Umaroh & Pangaribowo, 2020, Sa'diyah 2019). The world's commitment to food sufficiency is contained in the 17 goals of Sustainable Development Goals (SDGs). The number one and two SDGs goals are without hunger and poverty (Horne et al., 2020), (Naidoo & Fisher, 2020). To realize the second goal of the SDGs food sufficiency, including protein adequacy, is very important (Robert et al., 2005). Indonesia, as a developing country, is also strongly committed to achieving the SDG's goals. Data from the Indonesian Central Bureau of Statistics (BPS) states that the proportion of daily consumption of protein per capita by food commodity groups and urban and rural classification, September 2018 for fish/shrimp/squid/clams is 12.89 (urban), 14.55

(rural), and 13.59 (urban + rural). For the meat group, it was 8.08 (urban), 5.24 (rural), and 6.89 (urban + rural). Household consumption of eggs and milk is 6.09 (urban), 4.23 (rural), and 5.31 (urban + rural). This protein consumption is still much smaller than in developed countries(McCarthy, 2020), (Khonje et al., 2020).

Indonesians' food consumption habits are diverse and vary depending on the season and region. Food consumption patterns may range from one area to the next depending on the environment, including local resources and culture, the dynamics of Indonesian food consumption, tastes, and incomes. Similarly, food consumption patterns will alter over time as a result of changes in income, price changes, and public awareness of food and nutrition, and lifestyle changes. As a result of these changes, both between regions and over time, how much food must be provided and how it will be distributed will decide how much food must be provided and how it will be divided so that the community can afford to buy it. As a result, one of the entrance points and sub-systems for strengthening food security is the usage or consumption of food. Food supply policies, both from domestic production and imports, can be established by understanding people's food consumption patterns. The food production policy considers the amount and type of food that can be produced, as well as land, air, technology, and other supporting infrastructure. It can be established how much and what kind of food should be produced domestically or imported by taking into consideration the potential for food production and demand. Furthermore, by understanding changes in people's food consumption, policies on food prices and distribution may be developed to ensure that people have access to the food that is available. As a result, society's well-being improves.

In the last five years, the price of animal protein food, especially beef, has increased quite rapidly (Nendissa et al., 2019). Food prices and income greatly influence demand, especially animal food. This decrease in order causes a reduction in consumption (Zhang et al., 2020), (Gouel & Guimbard, 2019), (Bairagi et al., 2020). Apart from prices and income, household socio-economic factors, including the number of household members and settlement type, also influence food demand. Urban households consume more protein food than rural households (Kharisma et al., 2020) (Khoiriyah et al., 2020), and (Nikmatul et al., 2020).

Research on food demand systems has been carried out in several countries, i.e., Switzerland (Abdulai, 2002), Germany (Bronnmann et al., 2019), (Beznoska, 2019), Saudi (Alnafissa & Alderiny, 2019), Brazil (Coelho & Aguiar, 2007), and several countries (Dong et al., 2003), (Pereda, 2008), (Elijah Obayelu et al., 2009). In general, these studies analyze limited food demand. This research not only discusses the demand for animal food but also explores changes in welfare. The research data use the 2018 National Social Economic Survey (Susenas) data collected by the BPS. Research data is in the form of data on consumption and expenditure of all food and non-food items. Food data discussed in detail in this study is animal food consisting of five animal food groups, namely sea fish, chicken, beef, eggs, and milk. The demand systems approach uses LA-AIDS. Analysis of changes in welfare is done using Compensating Variation (CV) and Equivalent Variation (EV), and estimating parameters using Seemingly Unrelated Regression (SUR). The results showed the price elasticity and income of each animal's food. Price elasticity consists of price elasticity itself and cross prices. Price elasticity can infer whether animal food is elastic, inelastic, or unitary elastic. Cross-price elasticity can conclude whether animal foods are substitutes or complementary. Income elasticity concludes whether animal food is a normal good, a luxury good, or an inferior good. On the welfare aspect, supposed whether the price increases simultaneously or partially impact increasing welfare (better-off) or decreasing welfare (worse-off). All research results are expected to be valuable input for food policy formulation to accelerate the fulfilment of protein consumption according to national protein adequacy.

2. Materials and Methods

2.1. Price and income elasticities: Almost Ideal Demand System (AIDS)

The analytical model used in this study is the Almost Ideal Demand System (AIDS) model. This AIDS model is used to provide estimates of own-price elasticity, cross-price elasticity, and expenditure elasticity. Although AIDS is a nonlinear model, using the stone price index can solve nonlinear problems making it easy to estimate. Mathematically, the AIDS model used is as follows:

$$W_i = \alpha_0 + \sum_i \gamma_{ii} log p_i + \beta_i \log (X/P) \quad (1)$$

P is the price index, defined as:

$$\log P = \alpha_0 + \sum_i \alpha_i \log P_i + \frac{1}{2} \sum_i \sum_j \gamma^*_{ij} \log P_i \log P_j \quad (2)$$

To prevent non-linearity and reduce the effects of multicollinearity in the model, equation (2) is usually approximated by Stone's Price Index: $\log P^* = \sum_i W_i \log P_i$. Thus, AIDS changed to Linear Approximation AIDS (LA/AIDS). And this LA/AIDS model will be used in research.

The following form of the AIDS model was used in the present analysis to estimate the system of demand functions for food items like sea fish, chicken meat, beef, eggs, and milk. From the estimated demand function, price and income, elasticities were derived. Following (Bronnmann et al., 2019), the LA/AIDS was used:

$$W_i = \alpha_0 + \sum_j \gamma_{ij} log p_j + \beta_i \log (X/P*) \qquad (3)$$

W_i is the average budget share of the i[th] commodity, P_j is the price of the j[th] item, X is expenditure on food commodities (sea fish, chicken meat, eggs, beef, and milk), Ln P* is a price index, and α_0, γ_{ij}, and β_i are the parameters that need to be estimated.

The demand elasticities are calculated as functions of the estimated parameters, and they have legal implications. The specific form of expenditure elasticity (η_i), which measures the sensitivity of demand in response to changes in consumption expenditure, is as:

$$\eta_i = 1 + \frac{\beta_i}{w_i} \qquad (4)$$

The uncompensated (l) own-price elasticity (ϵ_{ii}^M) and cross-price elasticity (ϵ_{ij}^M) measure how a change in the price of one product affects the demand for this product and other products with the total expenditure, and other prices held constant. The form of uncompensated own and cross-price elasticities are as, respectively:

$$\epsilon_{ii}^M = -1 + \frac{\gamma_i}{w_i} - \beta_i \qquad (5)$$

$$\epsilon_{ij}^M = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \qquad (6)$$

The compensated (Hicksian) price elasticities own and cross (ϵ_{ii}^H and ϵ_{ij}^H)

Which measures the price effects on the demand assuming the real expenditure $X/P*$ is constant, is described as:

$$\epsilon_{ii}^H = -1 + \frac{\gamma_i}{w_i} + w_i \qquad (7)$$

$$\epsilon_{ij}^H = \frac{\gamma_{ij}}{w_i} + w_j \qquad (8)$$

To ensure that the assumption of maximizing satisfaction is not violated, three restrictions must be inserted into the model:

1. Adding-up:

   $\sum_i \alpha_i = 1$, $\sum_i \alpha_{ij}\ households = 0$, $\sum_i b_i = 0$, allows an expenditure share of a single value.

2. Symmetry:

   $C_{ij} = C_{ji}$ shows the consistency of consumer's choices

3. Homogeneity

   $\sum_j C_{ij} = 0$, which is based on the assumption that 'changes' are proportional to all prices and expenditures, that do not affect the number of purchased items.

2.2 Measuring Welfare: Compensating Variation and Equivalent Variation

Compensating Variation (CV) is a paid amount of money that must be given to households to return to their original satisfaction. In contrast, Equivalent Variation (EV) is the amount of money compensated to families to return for their actual income (Bellemare et al., 2013). The exact measure of the change in welfare can be described in terms of the cost function based on price differences. To measure changes in interest related to price changes, a measure of CV can be used (CV_1), with the formula:

$$CV_1 = C(U_i^0, P_i^1) - C(U_i^0, P_i^0) \qquad i = 1, \dots, 4. \qquad (9)$$

Where U is utility and P is a vector of prices, the superscript 0 and 1 refer to before and after price changes, respectively.

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$$CV = -\int_{P_1}^{P^0} \sum_i X_i(P, U^0) dP_i + \Delta m \quad (10)$$

$$U_0 = \left[\ln C - \left(\alpha_0 + \sum_{j=1}^{8} \alpha_j \ln p_j + \frac{1}{2} \sum_{j=1} \sum_{k=1} \gamma_{jk} \ln P_j \ln P_k\right)\right] / \beta_0 \pi P_i^{\beta_i} \quad (11)$$

According to Huffman & Johnson (2002), the procedure for calculating CV and EV using the AIDS model as in the AIDS model, the expenditure function, e (u, p), is stated in the formula as follows:

$$log\{e(p,u)\} = (1-u) log\{a(p)\} + u \log\{b(p)\} \quad (12)$$

Where p is the price, a (p) and b (p) a positive linear homogeneous functions at p;u as a utility level that has a value between 0 and 1.

The form of specific functions that are given in log {a (p)} and log {b (p)} (Deaton & Muellbauer, 1980) are expenditure functions that can be written as a percentage change in welfare based on the following formula:

$$log\{e(p,u)\} = \alpha_0 + \sum \alpha_k \log p_k + (1/2) \sum\sum \gamma_{kj} log p_k log p_j + \mu \beta_0 \pi (p_k)^{\beta k} \quad (13)$$

Where p_k is an animal food price consumed by the household; $\alpha_k, \beta_k, \gamma_{kj}$ is a parameter. To meet that requirement a(p), b(p), and e(p,u) are linear and homogenous to p, parameter must fulfil: $\sum \alpha_k = 1$, $\sum \gamma_{kj} = \sum \gamma_{jk}$ $\sum \beta_k = 0$. Also, symmetry in the second order from $log\{e(p,u)\}$ concerning pk and pj requires $\sum \gamma_{kj} = \sum \gamma_{jk}$.

By using the theory of duality, the Marshallian demand function in the form of a budget share can be derived as

$$w_i = \alpha_i + \sum \gamma_{ij} log p_j + \beta_i \log(\frac{m}{p^*}) \quad (14)$$

Where is the budget share of animal food; m represents total household expenditure; p* price index is determined using the Stone price index (Deaton & Muellbauer, 1980).

The utility function can indirectly be determined based on the equation (11):

For calculating CV and EV, we can use the estimation results of equation (14). Where $\alpha_i, \beta_i, \gamma_{ij}$, which is estimated based on data w_i, p_i, and m.

By using the starting point (P^0, m^0) dan endpoint (p^1, m^1) of price changes and income changes, then equation (31) can be used to calculate $u^0 = V(p^0, m^0)$ dan $u^1 = V(p^1, m^1)$. Then equation (11) can be used to calculate $\log e(p^0, u^0)$, $\log e(p^1, u^0)$, $\log e(p^0, u^1)$, and $\log e(p^1, u^1)$, where we know $m^0 = e(p^0, u^0)$ dan $m^1 = e(p^1, u^1)$. Finally, CV and EV can be calculated as follows:

$$CV = m^1 - e(p^1, u^0)$$

$$CV = m^1 - exp\{\log e(p^1, u^0)\} \quad (16)$$

$$EV = e(p^0, u^1) - m^0$$

$$EV = \exp\{\log e(p^0, u^1)\} - m^0 \quad (17)$$

We can also calculate the starting point for total expenditure as follows:

$$pcv = CV/m^0 \quad (18)$$

Where pcv is the percentage change in welfare with CV and also called the welfare price elasticity as follows:

$$e_{iw} = pcv/(\frac{\Delta p_i}{p_i}) \quad (19)$$

$$\text{Ande}_{gw} = pcv/(\Delta p_g/p_g) \quad (20)$$

We can also calculate the starting point for total expenditure as follows:

Where e_{iw} or e_{gw} is the price elasticity of welfare due to the percentage change in commodity price i (Δp_i / p_i) or commodity bundle price i $(\Delta p_i/p_i)$ or commodity bundle price g $(\Delta p_g/p_g)$, generally, e_{iw} or e_{gw} are negative, which means that welfare will decrease if there is a price increase, nevertheless, if the positive sign shows a powerful substitution effect.

$$u = V(p,m) = \{\log m - \alpha_0 - \sum \alpha_k log p_k - (1/2) \sum\sum \gamma_{kj} log p_k log p_j\} / \{\beta_0 \pi (p_k)^{\beta k}\} \quad (15)$$

2.3 Analysis of the impact of changes in food prices on welfare

In principle, there are five methods for measuring welfare (Araar & Verme, 2016): 1) Consumer's Surplus variation (CS for short); 2) Compensating Variation (CV); 3) Equivalent Variation (EV); 4) Laspeyer Variation (LV); dan 5) Paasche Variation (PV). In this study, the impact of price changes on welfare is analyzed using the concept of CV and EV approaches (Alem, 2011; Friedman & Levinsohn, 2002; Jansen, 2000; Vu & Glewwe, 2011, 2011) Using observations of the household budget share after price changes and price elasticity are estimated as derived from the LA/AIDS model. A CV is the amount of money needed to compensate households after a price change and restore utility levels after a change. With the LA-AIDS model, the CV can be estimated using a second-order Taylor expansion of the expenditure function as an equation formula as follows:

$$\Delta \ln e = \sum_{i=1} W\_kel_i \, \Delta lnP_i + \frac{1}{2}\sum_{i=1}\sum_{j=1} W\_kel_i \, \epsilon^*_{ij} \, \Delta lnP_i \Delta lnP_j \quad (21)$$

Where ϵ^*_{ij} is the compensated price elasticity of good *i* concerning the price of good *j*.

In this study, a CV will be calculated only for households in rural areas. Based on the formula above, a positive CV represents an increase in the level of interest (welfare gain), and vice versa if a negative value means a decrease in welfare (welfare loss) due to changes in prices (Varian, 2010). In addition to using a CV, EV is also used to see the impact of price increases on welfare, with the following equation:

$$EV = -\sum_k xk\Delta pk - \frac{1}{2\sum_{kj}\frac{\partial xk}{\partial pj}}\Delta pk\Delta pj + 1/2\sum_k xk\Delta pk \sum \frac{\partial xk}{\partial m}\Delta pk \quad (22)$$

EV rules are the same as the CV if positive, EV means an increase in interest (welfare gain/better off), whereas if negative, there is a decrease in welfare (welfare loss/worse off) due to price increases (Varian, 2010).

2.4. Data

The data used in this research is secondary data conducted by the Central Bureau of Statistics in the form of a household survey, called Susenas (Survai Sosial Ekonomi Nasional/National Socio-economics Survey) data (March 2018). The data analyzed were socio-demographic data (household residence status, total household member (HHsize), household consumption and spending, and total expenditure. The animal foods observed in this study were eggs (chicken eggs, local chicken eggs, and duck eggs), chicken meat (local chicken meat and chicken meat), beef, fresh fish (fresh fish and shrimp including fish, shrimp, squid, and shellfish) as well as milk powdered (milk powder and infant milk). The sample of this research is 133,873 households.

3. Results and Discussion

3.1 Parameter estimates of animal food demand in urban Indonesia

It is crucial to estimate the parameters of all animal food prices, income, and household size (HH). These parameters serve as the basis for calculating price and income elasticity. Price elasticity includes the price elasticity of the goods themselves and the costs of other goods. The calculated price elasticity includes Marshallian and Hicksian price elasticities. Table 1 is the result of estimating animal food parameters using the LA-AIDS approach. These parameters have also met the three restriction tests and the demand system restrictions. The three restrictions are adding up, homogeneity, and symmetry.

All parameters of animal food prices, namely sea fish price, chicken meat price, beef price, egg price, and milk price, are very significant to demand. It can be interpreted that an increase in animal food prices reduces demand. This is to the economic theory that there is a negative relationship between price and need for a good. Household income, as measured by total household expenditure, is only significant for milk. At the same time, for other animal foods, it is not substantial. The parameters for the number of household members were important for chicken, beef, and eggs. At the same time, sea fish and milk were not substantial. In general, it can be concluded that the AIDS model for animal food in urban households in Indonesia can explain the animal food demand model in almost all of them. Virtually all parameters of price, income and household size members are very significant.

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Table 1: AIDS estimated parameters for animal food in the urban of Indonesia

Variable	Sea fish	Chicken meat	Beef	Eggs	Milk
Intercept	2,598*	1.297*	1.487*	1.460*	1.289
Price of sea fish	-0.052*	-0.0002*	-0.002	-0.0029	-0.00005
Price of chicken meat	-0.026*	-0.0001*	-0.0007	-0.0008	0.00002
Price of beef	-0.024*	0.0002	-0.0024*	-0.0009	-0.00002
Price of eggs	-0.009*	-0.00002	-0.00007	-0.0003*	-0.00003*
Price of milk	0.007*	-0.00004	-0.00019	-0.0002	-0.00001*
Total expenditure	0.028	0.00003	0.00067	-0.0001	-0.00001*
Household size	-0.081	-0.00003*	-0.0002*	-0.0005*	-0.00003
β	-1.880*	-0.00001*	-0.0005*	-0.0005*	-0.00002*
R^2	0.014*	-1.627	-0.055*	0.081*	-1.616
Intercept	0.998				

Source: Author's computations based on Susenas, 2018

*) significant 99%

3.2 Marshallian (uncompensated): own and cross-price elasticity

Price elasticity describes the relationship between the percentage change in the number of goods ordered due to the price change. Price elasticity consists of Marshallian and Hicksian price elasticities. Price elasticity includes own-price elasticity and cross-price elasticity. The own-price elasticity of animal food is the percentage change in the amount of animal food demanded due to the percentage change in the price of the animal food item. Meanwhile, cross-price elasticity is the percentage change in the quantity of animal food demanded due to changes in the price of other animal foods. Table 2 results from calculating the own-price elasticity and the cross-price elasticity of the Marshallian. All animal food self-price elasticities are negative. This is in line with the economic theory that price and market have a negative relationship. Alternatively, in other words, if the price goes up, the market goes down.

In urban Indonesia, all animal foods are inelastic except beef, which are highly elastic. This is indicated by all the elasticities of demand for animal food less than one, except beef more than one (absolute). The meat group is the most elastic animal food with a demand elasticity of 13,936%, followed by milk (0.991%), sea fish (0.649%), eggs (0.284%), and chicken (0.057%). The 1% increase in beef prices reduced demand by 13,936%. Chicken meat is an animal food with the most minor demand elasticity. It can be interpreted that changes in demand for chicken meat are more minor than changes in chicken prices. This confirms with the findings of Mwenjeri et al. (2016), who found that food spending elasticity in Laikipia City, Kenya, is positive. Marshallian price elasticity is greater (absolute) than Hicksian because in Marshallian price elasticity, besides there is a substitution effect, there is also an income effect. In contrast, in Hicksian, there is only a substitution effect.

Table 2 also shows the cross-price elasticity of animal foods. It can be seen that almost all animal foods have substitute or complementary goods. This is indicated by the analysis results that part of the cross elasticity is positive, and part of the cross elasticity is negative. Positive cross-price elasticity means that animal food is a substitution. Meanwhile, negative cross-price elasticity means that animal food is complimentary. Substitution is an increase in the price of animal food to increase the demand for other animal foods. Complementary is that the rise in animal food prices reduces the need for other animal foods. Sea fish is a substitute for chicken, eggs, and milk. Sea fish was complementary to beef. Indonesian urban households consume seafood and beef at the same time. In other words, beef and sea fish complement each other.

Sea fish is substituted for chicken, eggs, and milk, while with beef, sea fish is a substitute. Chicken meat substitutes sea fish and eggs, while beef and milk are complimentary. Beef is a substitute for sea fish and eggs. Beef with chicken and milk is complimentary. Eggs with sea fish and chicken are substitutes. Eggs with beef and milk are complimentary. Milk with beef is complimentary. Milk with sea fish, chicken, and eggs is a substitute. An increase followed the 1% increase in milk prices in demand for marine fish, chicken meat, and eggs by 0.277%, 0.053%, and 0.733%. Indonesian urban households consume milk along with beef. This is indicated by the negative sign in the cross-price elasticity of beef and milk. In other words, beef and milk are complimentary. An exciting finding on the animal food consumption of urban Indonesian households is the increase in beef prices a decrease in chicken meat consumption and the rise in demand for eggs. This means that the rise in beef prices decreases the consumption of animal food directly to eggs instead of chicken. Therefore, beef price stability is essential to prevent a drastic decrease in beef consumption. This reduction in protein consumption can be one of the drivers of increased stunting both in Indonesia (Sari et al., 2017), (Hoddinott et al., 2013), (Mahmudiono et al., 2016), as well as in other countries (Headey & Martin, 2016), (Jain, 2018), (Béné et al., 2015).

3.3 Hicksian (compensated): own and cross-price elasticity

Hicksian price elasticity reflects the percentage change in the quantity of animal food demanded due to the percentage change in the price of animal food. Table 3 presents the own-price elasticities and the Hicksian cross-price elasticities. All animal foods are inelastic, meaning that a 1% price increase causes a decrease in less than 1% demand unless beef is very elastic. The 1% increase in beef prices caused demand to fall by 4,145%. Compared to other animal foods, the 1% price increase for sea fish, chicken meat, eggs, and decrease in milk demand are by 0.058%, 0.387%, 0.902%, and 0.384%, respectively.

Table 3 also presents the cross-price elasticity of Hicksian animal food in urban households in Indonesia. The finding is that all animal foods are substitutes, as indicated by the positive cross-price elasticity. This means that an increase in the price of one animal food causes a decrease in animal food itself and an increase in demand for other animal food. Beef is a substitute for chicken, milk, sea fish, and eggs. The 1% increase in beef price increases the demand for chicken meat by 0.632%, milk by 0.538%, sea fish by 0.293%, and eggs by 0.053%.

Referring to the results of the analysis of own and cross-price Marshallian and Hicksian elasticity as in Tables 2 and 3, it can be concluded that the difference in the value of the two elasticities is slight. This means that the substitution effect is much more significant

Table 2: Marshallian (uncompensated) own and cross-price elasticities

Animal food groups	Sea fish	Chicken meat	Beef	Eggs	Milk
	Uncompensated				
Sea fish	-0.649	0.265	0.267	0.273	0.277
Chicken meat	0.029	-0.057	-0.944	0.055	0.053
Beef	-2.464	-15.277	-13.936	-13.145	-12.567
Eggs	0.590	0.729	0.725	-0.284	0.733
Milk	0.013	-0.009	-0.008	-0.007	-0.991

Source: Author's computations based on Susenas, 2018

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than the income impact. Price changes have a profound effect on the consumption of animal foods. A price increase in price reduces the consumption of animal foods (all price elasticities were negative). In Hicksian terms, all animal foods are substitutes. It can be concluded that the consumption of animal food in Indonesian urban households is a mutual substitution.

3.4 Income elasticity and marginal expenditure share

Income elasticity often uses the household expenditure elasticity approach. Income elasticity describes the percentage change in animal food demanded due to a percentage change in household income. Meanwhile, the Marginal Expenditure Share (MES) shows the additional demand for animal food due to extra income in the long run. Table 4 is the result of calculating income elasticity and MES of Indonesian urban households. Beef is very elastic with an income elasticity of 3,418%, followed by milk, chicken, eggs, and sea fish with income elasticities of 1,145%, 1,122%, 1,017%, and 0.872%, respectively. The 1% increase in income increased the demand for beef by 3,418%. The rise in revenue has been responded to very well by Indonesian urban households by increasing beef consumption.

On the other hand, the decrease in income has also been responded to very strongly because beef demand has been significantly reduced. Milk is an animal food with the second-largest income elasticity after beef. The 1% rise in income increased the demand for milk by 1,145%. Likewise, for chicken and eggs, the rise in demand was also more significant than the increase in prices. Beef is the most luxurious animal food, followed by milk, chicken, and eggs. This is indicated by an income elasticity of more than one. The findings of this study are consistent with those of several other studies conducted in various countries. The income elasticity value is positive, according to Abdulai & Aubert (2004), who used cross-sectional data on six food groups. In addition, Erhabor & Ojogho (2011) conducted a study in Nigeria, and the findings revealed that as income climbed, so did food spending. Similarly, Mwenjeri et al. (2016) found that a rise in household income increased consumption in Kenya.'

Table 3. Hicksian (compensated) own and cross-price elasticities

Animal food groups	Sea fish	Chicken meat	Beef	Eggs	Milk
	Compensated				
Sea fish	-0.058	0.274	0.293	0.338	0.371
Chicken meat	1.281	-0.387	0.632	0.677	0.709
Beef	5.791	5.123	-4.145	5.187	5.219
Eggs	0.701	0.034	0.053	-0.902	0.130
Milk	1.187	0.519	0.538	0.583	-0.384

Source: Author's computations based on Susenas, 2018

Table 4. Expenditure elasticity and marginal expenditure share

Animal food group	Expenditure elasticity	Marginal expenditure share
Ikan Laut	0.872	0.592
Ayam	1.122	0.012
Daging Sapi	3.418	0.102
Telur	1.017	0.078
Susu	1.145	0.123

Source: Author's computations based on Susenas, 2018

Meanwhile, sea fish are everyday goods because the income elasticity is less than one. All animal food is a luxury item except sea fish, an everyday item. This is evidenced by the income elasticity of more for luxury goods and less than one for standard items.

MES shows the effect of changes in income on changes in demand in the long run. The highest MES was sea fish at 0.592%, followed by milk (0.123%), beef (0.102%), and eggs (0.078%), and the lowest was chicken meat at 0.012%. Beef has MES number three, but it is pretty big too. This means that the increase in income has a significant enough effect on the demand for meat. Following the research of Nendissa et al. (2019), the rise in beef prices in the last five years is relatively high. The increase in beef prices should be followed by an increase in income to impact increasing demand for beef and increasing household consumption of beef.

3.5 Welfare analysis

3.5.1 Compensating Variation

Scenarios of increasing prices, either simultaneously or partially, have been carried out to analyse welfare changes due to price changes. The scenario for an increase in food prices for this analysis includes a 10% increase in the price of marine fish, 10% chicken, 10% beef, 20% eggs, 5% milk, 5% other protein, 5% other food, and 5% non-food. The results of the data analysis show that the increase in prices causes households to experience worse off. This is shown by CV. Mostly negative. The increase in all prices for both food and non-food items simultaneously requires a total variation of compensation (CV) that must be given to households of Rp. 244,830/HH/month (Table 5). The partial price increase for one food shows that the largest CV is the price increase in the non-food group, namely Rp. 129,138. The price increase in this non-food group was only 5%. A 5% increase in food prices other than protein requires a CV of Rp.90,545/HH/month. Meanwhile, a 5% increase in the price of protein food in addition to animal protein requires a CV of Rp.1,724/HH/month.

Regardless of the substitution, the compensation required for CV and EV is the same, namely Rp. 245,532/HH/month (Table 4 and 5). The compensation needs to be given so that households return to their welfare level with a 5% increase in non-food prices

Table 5. Compensating Variation of animal food, other food and non-food

Food & Non-food Items	W/O Subst*	Subst Only**	W/ Subst***	Price changes (%)
	Rp/Household/month			
ALL Items	-245,532	**702.45**	**-244,830**	
Sea fish	-858	-1.05	-859	10
Chicken meat	-7,014	161.7	-6,852	10
Beef	-2,381	54.6	-2,328	10
Eggs	-10,876	792.75	-10,083	20
Milk	-3,296	-4	-3,301	5
Other Protein	-1,721	-3	-1,724	5
Other Food	-90,411	-127	-90,545	5
Non Food	-128,975	-156	-129,138	5
TOTAL (Household)	**-245,532**	**702.45**	**-244,830**	

Source: Author's computations based on Susenas 2018
Note: *W/O subts = without substitution
**Subst Only = substitution only
***W/ subts = with substitution

is Rp.128,975 / HH/month. Compensation for food other than all protein is Rp.90,411/HH/month and for other proteins Rp.1,721 / HH/month. Particularly for the five animal food groups, the largest compensation was the increase in egg prices by 20%, requiring Rp's compensation are 10,876/HH/month, followed by chicken, milk, beef, and sea fish with Rp's consecutive compensation are Rp.7,014. Rp. 3,296, Rp. 2,381 and Rp. 858 per HH (household) per month.

Considering the substitution, the price increase simultaneously requires CV compensation of Rp. 244,830/HH/month. This CV compensation is smaller than without considering substitution. The largest CV compensation remains at the 5% increase in non-food prices, requiring Rp's CV compensation by Rp.129,138/HH/month. The second-largest compensation is the increase in other food prices by 5%, requiring CV compensation of Rp. 90,545/HH/month. Meanwhile, specifically in the animal food group, the largest compensation was for eggs, which increased by 20%, so it requires Rp's CV compensation is Rp. 10,083/HH/month. Then chicken meat, which has experienced a price increase of 10%, requires Rp's CV compensation is Rp.6,852/HH/month. The 5% increase in milk prices requires CV compensation of Rp. 3,301/HH/month. Beef requires compensation of Rp. 6,852/HH/month and the smallest compensation is for sea fish. The 10% increase in the price of sea fish requires CV compensation of Rp. 859/HH/month.

3.5.2 Equivalent Variation

Table 6 results from the analysis of changes in welfare using the Equivalent Variation (EV) approach. The scenario of a price increase is the same as an analysis of changes in CV welfare. Regardless of substitution, the amount of compensation given to households is the same between CV and EV, as presented in Tables 4 and 5. Without substitution, the amount of compensation that must be given if all food and non-food items simultaneously increase is Rp. 245,532/HH/month. An increase in egg price of 20% requires the highest compensation, namely Rp. 10,876/HH/month (without substitution), Rp. 9,493 (with substitution), and Rp 1,384 (substitution only). Chicken meat is the animal food that requires the second-largest compensation after eggs, followed by milk, beef, and sea fish.

With the substitution, the EV compensation required if the price increases simultaneously are Rp. 231,858/HH/month. This amount of EV compensation is smaller than CV compensation. A 20% increase in egg prices requires EV compensation of Rp. 9,493/HH/month. A 10% increase in chicken meat price requires compensation of Rp. 6,473/HH/month and a 5% increase in milk price require compensation of 3,127/HH/month. The animal food that requires the lowest EV compensation is marine fish. An increase in the price of marine fish by 10% requires an EV compensation of Rp.815/HH/month.

Other food is food that requires the largest EV compensation, namely Rp. 122,362 / HH/month. This is following the research results by Khoiriyah (2019) expenditure on other food is the second largest after grains if there is a 5% increase in other food prices. A large EV compensation is needed because the calculation of welfare changes refers to the share of household expenditure. They were judging from the results of data analysis, between CV and EV results in different values. CV is more than EV in absolute terms. So it can be concluded that EV compensation is more efficient for urban households in Indonesia than CV compensation. The smaller EV compensation indicates this compared to CV. One example of an EV policy is direct cash assistance (BLT). BLT is direct cash assistance provided to households. Through BLT, it is hoped that the target will be more accurate because the animal protein food aid is received directly by households. EV compensation helps households to return to their original income. This EV compensation replaces the income that is reduced as a result of an increase in price.

4. Conclusion

This research describes the impact of animal food prices on demand and consumer welfare in Indonesia's urban. The total sample is 133,873 households. The research data used the 2016 Household National Socio-Economic Survey (Susenas) data on household consumption and expenditure data collected by the Central Statistics Agency (BPS). Data analysis for the demand system uses the Linear-Approximation: Almost Ideal Demand System (LA-AIDS) approach and the study of changes in prices for changes in household welfare uses the Compensating Variation (CV) and Equivalent Variation (EV) approaches. The

Table 6: Equivalent Variation of animal food, other food and non-food

Food & Non-food Items	W/O Subst*	Subst Only**	W/ Subst***	Price changes (%)
	Rp/household/month			
ALL Items	**-245,532**	**13,676**	**-231,858**	
Sea fish	-858	44	-815	10
Chicken meat	-7,015	540	-6,473	10
Beef	-2,382	184	-2,198	10
Eggs	-10,876	1,384	-9,493	20
Milk	-3,296	169	-3,127	5
Other Protein	-1,721	90	-1,633	5
Other Food	-90,411	4,654	-85,759	5
Non Food	-128,974	6,614	-122,362	5
TOTAL (household)	**-245,532**	**13,676**	**-231,858**	

Source: Author's computations based on Susenas 2018
Note: *=w/o subts = without substitution
**=Subst Only = substitution only
***=w/ subts = with substitution

results showed that the meat group was the most elastic animal food with a demand elasticity of 13,936%, followed by milk (0.991%), sea fish (0.649%), eggs (0.284%), and chicken meat (0.057%) in Indonesian urban households. Beef is a substitute for sea fish and eggs. Beef with chicken and milk is complimentary. In the substitution effect shown by the Hicksian price elasticity, the result shows that all animal food is inelastic, meaning that a 1% price increase causes a decrease in demand of less than 1% unless beef is very elastic. The 1% increase in beef prices caused demand to fall by 4.145%. Compared to other animal foods, the 1% price increase for marine fish, chicken meat, eggs, and milk causes a decrease in demand by 0.058%, 0.387%, 0.902%, and 0.384%, respectively. All animal food is a luxury item except sea fish, a standard item. In the long term, the highest marginal expenditure share is sea fish at 0.592%, followed by milk (0.123%), beef (0.102%), eggs (0.078%), and the lowest is chicken meat at 0.012%. Beef has MES number three, but it is pretty big too.

Considering the substitution, the price increase simultaneously requires CV compensation of Rp. 244,830/HH/month. This CV compensation is smaller than without considering substitution. The largest CV compensation remains at the 5% increase in non-food prices, requiring Rp's CV compensation is Rp.129,138/HH/month. The second-largest compensation is the increase in other food prices by 5%, requiring CV compensation of Rp. 90,545/HH/month. Meanwhile, specifically in the animal food group, the largest compensation was for eggs, which increased by 20%, requiring Rp's CV compensation. 10,083 / HH / month. Then chicken meat, which has experienced a price increase of 10%, requires Rp's CV compensation is Rp. 6,852/HH/month. The 5% increase in milk prices requires CV compensation of Rp. 3,301/HH/month. Beef requires compensation of Rp. 6,852/HH/month and the smallest compensation is for marine fish. The 10% increase in the price of marine fish requires CV compensation of Rp. 859/HH/month.

In EV compensation, considering the substitution, the EV compensation required if the price increases simultaneously are Rp.231,858/HH/month. This amount of EV compensation is smaller than CV compensation. A 20% increase in egg prices requires an EV compensation of Rp.9,493/HH/month. A 10% increase in chicken meat price requires payment of Rp.6,473/HH/month, and a 5% increase in milk price requires payment of Rp.3,127/HH/month. The animal food that requires the lowest EV compensation is

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sea fish. An increase in the price of marine fish by 10% requires an EV compensation of Rp. 815/HH/month. EV compensation is more effective than CV compensation.

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Author contributions

Ratya Anindita was responsible for data collection, literature review, forecasting analysis, and drafting the manuscript. Ana Arifatus Sa'diyah was responsible for translating the manuscript. Nikmatul Khoiriyah was responsible for editing the manuscript.

Conflict of interest:

The authors declare no conflict of interest.

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Physiological response of some canola genotypes to proline concentration under saltwater irrigation conditions

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A pot experiment was conducted in split-split plot design with four replications to study proline foliar application with 0, 50, and 100 ppm and four canola genotypes cultivated under irrigation of tap water and salinity irrigation water at 4500 ppm and their interactive effects on growth characters, yield, and yield components and some chemical composition of the canola plants. Results indicated that a higher salinity level at 4500 ppm reduced growth, photosynthetic pigments, yield, and yield attributes as well as the chemical composition of seeds as compared with tap water. Results also indicated that Serw 6 cultivar had the greatest values of most characters under study. Trapper cultivar came in the second rank. Meanwhile, proline treatment at 100 ppm was the optimum treatment. Results indicated that there was an interaction between salinity x cultivars x proline concentration. Pots irrigated tap water secured the highest values of most characters with Serw 6 or Trapper cultivar x 100 ppm proline treatment. It could be concluded that proline especially at 100 ppm partially alleviated the harmful effects of salinity stress on the growth, yield, and yield components as well as the chemical composition of seeds of Serw 6 or Trapper cultivar of canola plants and nutritive value of the yielded seeds.

1. Introduction

Canola (*Brassica napus L.*) is the third most important oilseed crop worldwide and accounts for 12% of the total annual global oil production (FAOSTAT 2014). Seeds of canola have an oil content of more than 40% and produce post-crushing meals with 35% to 40% protein which is used mainly for animal feed (Snowdon *et al*., 2007). Canola is important due to the low Erucic acid in its oil which makes it good quality edible oil, but it also has high Erucic acid containing varieties that are used for manufacturing purposes. Seed oils are an important source of fatty acids for human nutrition and hydrocarbon chains for industrial products such as oleochemistry or as a replacement for petroleum products for combustion engines (Friedt and Lühs, 1998). It is the preferred oil seed crop under Egyptian conditions, especially where salinity and drought are commonplace and in newly reclaimed soil (Weiss, 1983). Canola oil contains a suitable profile of saturated fatty acids (7%), high levels of unsaturated fatty acids such as oleic acids (61%), and medium levels of linoleic acid (21%) and linolenic acid (11%). (El-Sabagh *et al.*, 2018). As a result, it is a healthy edible oil.

Abiotic stress that limits plant growth and development is largely confined to salinity and drought in the realm of agriculture (Chandrasekaran *et al.*, 2014; Augé *et al.*, 2015). Osmotic factors owing to salinity and drought create rampage adversities upon plant production and productivity due to water constraints. Various biotic and abiotic stresses limit the successful cultivation of canola, with salinity being one of the major abiotic factors limiting production (Ashraf, 2001 and Qasim *et al.*, 2003). Over 800 million ha of land is under salinity stress, accounting for 6% of the total cultivated land on earth (Arzani, 2008 and Munns and Tester, 2008). It has been reported that 20% of cultivated and 50% of croplands all over the world are affected by salinity (Kaya *et al.*, 2002). Salinity can cause an assortment of changes in the metabolisms of plants including suppression of photosynthesis and respiratory, osmotic stress, ion toxicity, oxidative stress, and nutrient paucity (Tuteja, 2007 and Bandehagh *et al.*, 2011). A surfeit of NaCl in soil solution, obstructs mineral nutrition and water uptake thus causing to accumulation of toxic ions in plants. Several authors, who have studied the effects of salinity on Brassicas report reductions in plant height, shoot and root dry weight, leaf number, leaf area, pod number/plant, seed number/pod, 100-seed weight, seed yield/plant, oil and protein content in the seeds (Ashrafijou *et al.*, 2010; Saadia Sakr *et al.*, 2012 and El Habbasha and Mekki, 2014) on canola. Currently, there is intensive work by many researchers to study the responses of plants to salt stress in order to try to overcome salt injury.

One approach is the exogenous application of substances that have been identified at a cellular level to be involved in resistance to stresses such as glycine betaines, proline, and antioxidants (Lopez and Satti, 1996). Proline is an amino acid and is one of the most commonly occurring compatible solutes, it plays a crucial major role in osmoregulation and osmotolerance (Hasegawa *et al.*, 2000). It protects membranes and proteins against the destabilizing effects of dehydration during abiotic stress. In addition, it has some ability to scavenge free radicals generated under stress conditions (Ashraf and Foolad, 2007). Exogenous application of proline counteracted the adverse effects of salt stress by stimulating the growth of cells and plants (Ali *et al.* 2008) improving metabolism (Rai and Rana, 1996) and reducing oxidation of membrane lipids (Okuma *et al.*, 2004; Yazici *et al.*, 2007) under stress conditions. Athar and Ashraf (2009) also showed that exogenously applied proline at the germination and seedling stages alleviated the adverse effects of salt stress on canola cultivars and Okuma *et al.* (2004) illustrated that proline induced alleviation of the adverse effects of salt stress on growth. The work reported in this paper is the result of trying to determine whether proline can applied exogenously in the field to alleviate field-induced salt stress under Egyptian conditions. This may then provide an agronomic option for the alleviation of stress which could be used whilst plant breeders and biotechnologists search for genetic and physiological solutions to this problem. Therefore, the objective of this research studying the effect of different proline concentrations on growth parameters, yield and yield attributes, and some chemical analysis of canola varieties under saline conditions.

2. Material and Methods

2.1. Experimental site layout

A pot experiment was conducted at the wire-house of the National Research Centre, Dokky, Cairo, Egypt, where the cultivation process for canola seeds were done in the middle of November (15 November) during the growing season (2019/2020). The temperature ranged from 10–27 °C and relative humidity ranged from 21–87 %. The chemical analysis of the experimental soil was determined according to Chapman and Pratt (1978) and included the following characteristics: pH 7.8, organic matter 0.21%, CaCo3 1.0%, E.C. 0.5 mhos cm-3 and available total N, P, K were 0.10, 3.20, 20.0 ppm, respectively. To reduce compaction and improve drainage, the soil was mixed with sand granules in a proportion of 2:1 (v:v). Nitrogen fertilizer was applied at the rate of 72 units of (N) ha^{-1}

and Phosphorus fertilizer was applied at a rate of 24 units of (P2O5) ha^{-1} to each pot. The fertilizer was divided into three doses, the first dose mixed with the soil before sowing, the second dose after three weeks of sowing, and the third dose after six weeks of sowing. The experimental design was a split-split plot design with six replicates. The main plots included two salinity levels (tap water (600 ppm) and 4500 ppm) were prepared by dissolving sea salt with tap water. Sub-plots were assigned to four canola varieties (two genotypes imported from Germany (Agamax and Trapper) and two Egyptian genotypes (Serw 4 and Serw 6). Sub-subplot was divided into the foliar application of proline (0 as (control), 50 and 100 ppm) at 30 and 45 days from sowing.

2.2. Data recorded

2.2.1. Growth characters

Plants were sampled during vegetative stages (60 and 90 days after sowing) for measurement of some growth parameters (plant height, number of leaves/ plants, number of branches/ plant, fresh and dry weights of plant), fresh leaves were used for determination of photosynthetic pigments, where chlorophyll (A and B) and carotenoids contents in canola leaves were determined according to Witham *et al.* (1971).

2.2.2. Yield and yield attributes

At harvest, five plants were sampled randomly to estimate, plant height, number of siliqua $plant^{-1}$, 1000-seed weight (g), and seed, straw, and biological yields $plant^{-1}$ (g).

2.2.3. Chemical analysis

Macronutrients (N, P, and K) and micronutrients (Fe, Mn, and Zn) of canola seeds were determined according to Cottenie *et al.* (1982). The percentages of oil and total protein in canola seeds were determined according to (Helrich K., 1990). Seed protein content will calculate by multiplying N (%) by 5.75. Seed oil content will estimate by using the Soxhlet apparatus and petroleum ether at 60-80°C as a solvent.

2.3. Statistical analyses

The combined analysis of variance for the data of the two seasons was performed after testing the error homogeneity and Fisher's Least Significant Difference (LSD) test at 0.05 level obtained data from each season were subjected to the proper statistical analysis of variance of significance was used for the comparison between means according to Gomez and Gomez (1984).

3. Results and Discussion

3.1. Morphological characters and photosynthetic pigments after 60 days from sowing

3.1.1 Effect of salinity levels on some morphological characters and photosynthetic pigments after 60 days from sowing

The mean values for growth parameters (plant height, number of leaves/ plants, number of branches/plant, fresh and dry weights of plant) and photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids, and total pigments) after 60 days from sowing are presented in Table (1). The salinity level (4500 ppm) significantly affected the studied growth parameters and photosynthetic pigments compared with the tap water treatment, where it reduced the aforementioned characteristics. Farouk, (2011) stated that such reduction may be due to the inhibiting effect of salinity on cell division and cell enlargement; increase energy required for mineral and water absorption; accumulation of some poisonous compounds in the plants; high respiration rate; inhibition of protein turnover and nucleic acid synthesis. These results are in accordance with those recorded by Ashrafijou *et al.*, 2010 and Saadia *et al.*, 2012.

3.1.2. Effect of varietal differences on some morphological characters and photosynthetic pigments after 60 days from sowing

Average of plant height, number of leaves/ plants, number of branches/ plant, fresh and dry weights of plant, chlorophyll a, chlorophyll b, carotenoids, and total pigments affected by canola cultivars are shown in Table (1). The four tested cultivars were significantly different in most of the aforementioned characters. The results indicated that Serw 6 cultivar had the greatest plant height, number of leaves /plant, fresh and dry weights of plant, and chlorophyll b compared with other cultivars after 60 days from sowing. In this connection, the Trapper cultivar had the maximum values of the number of branches/plants, chlorophyll a, carotenoids, and total pigments compared with the other tested cultivars after 60 days from sowing. Serw 4 cultivar had the greatest number of branches/plant and chlorophyll after 60 days from sowing. While it gave the lowest values of plant height, the number of branches/plants, and chlorophyll b. In this regard, the Agamax cultivar gave the minimum values of the number of leaves /plants, chlorophyll a, carotenoids, and total pigments. Moreover, the Trapper cultivar gave the lowest values of fresh and dry weights of plants. These results may be due to the superiority of Serw 6 cultivar in traits under study to increase vegetative growth and plant height compared to the rest of the varieties. The results of the present investigation are in trend with those obtained by Bybordi and Tabatabaei (2009) and El-Habbasha and Mekki, (2014).

3.1.3. Effect of proline concentration on some morphological characters and photosynthetic pigments after 60 days from sowing

Proline treatments caused significant increases in most of the growth parameters and photosynthetic pigments relative to the corresponding control (0 of proline concentration) (Table 1). Increasing the proline concentration from 0 to 100 ppm increased most of the studied characters, this increment reached a significant level with the characters, plant height, and fresh weight/ plant. Application of proline increased growth parameters under saline conditions as compared with the control plant (0 proline) with both varieties. The protein organic amino acid-proline functions as an osmolyte, radical scavenger, electron sink, stabilizer of macromolecules, and a cell wall component (Matysik *et al*., 2002). Increased accumulation of proline leads to the increase of enzyme activity of glutamate kinase and therefore increases proline biosynthesis (Vašáková and Štefl, 1982). Plants utilize increased content of proline to protein biosynthesis that has specific properties. Proline and hydroxyproline are found in specific compounds. Many of these compounds have specific characteristics and these proteins help to overcome plant stress. This reason for such stress may be soil salinity. For some stress proteins rich proline content is typical (Jofre and Becker, 2009; Roshandel and Flowers, 2009). This is consistent with the general argument that proline is one of the major organic osmolytes. Therefore, the rapid accumulation of free proline in plants is a typical response to a wide range of environmental stresses (Pavlíková *et al*., 2008). The positive effect of proline on growth parameters of photosynthetic pigments may be attributed to an important variable amino acid in determining protein and membrane structures and scavenging reactive oxygen species (ROS) under drought stress (Ashraf and Foolad, 2007). Proline not only acts as an osmotolerant but also acts as a nutritional source.

3.1.4. Effect of Interactions

3.1.4.1. Effect of interaction between salinity levels and proline concentration on some morphological characters and photosynthetic pigments after 60 days from sowing

Results indicate that irrigation of tap water treatment with application of 100 ppm proline gave the highest values of plant height, number of leaves/ plants, number of branches/ plants, and fresh and dry weights of the plant) and photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids, and total pigments as compared to other treatments (Table 2). In the contrast, salinity 4500 ppm with 0 proline concentration treatment produced the lowest values of previous characters.

3.1.4.2. Effect of interaction between varietal differences and proline concentration on some morphological characters and photosynthetic pigments after 60 days from sowing

The obtained results verified that 100 ppm proline treatments with Agamax cultivar were highly efficient in increasing plant height as compared with other treatments (Table 3). Also, 50 ppm proline treatments with the Trapper cultivar were highly efficient in increasing chlorophyll a, chlorophyll b, carotenoids, and total pigments as compared to other treatments. On the other side, 0 proline concentration with the Trapper cultivar gave the lowest values of plant height, chlorophyll a, chlorophyll b, carotenoids, and total pigments.

Table 1. Effect of salinity levels, cultivars, and proline concentration on some growth characters of canola genotypes after 60 days from sowing

Treatments	Plant height	No. of leaves/ plant	No. of branches/ plant	Fresh weight/ plant	Dry weight/ plant	Chlorophyll A	Chlorophyll B	Carotenoids	Total pigments
Salinity	-	-	-	-	-	-	-	-	-
4500 ppm	36.99	6.51	4.63	40.36	7.65	0.69	0.81	0.46	2.14
Tap water	41.78	7.34	5.18	45.70	8.65	0.78	0.92	0.52	2.41
F.test	*	*	*	*	*	*	*	*	*
Cultivars	-	-	-	-	-	-	-	-	-
Agamax	41.14	6.65	4.21	42.92	8.44	0.35	0.93	0.23	1.63
Serw 4	36.35	6.67	4.95	40.81	7.70	0.60	0.81	0.40	1.95
Serw 6	42.47	7.03	4.63	43.96	8.51	0.41	0.97	0.27	1.79
Trapper	36.11	6.64	5.06	40.70	7.48	1.27	0.74	0.86	3.14
LSD 0.05	0.17	NS	0.21	0.29	0.10	0.11	NS	0.17	NS
Proline con.	-	-	-	-	-	-	-	-	-
0	37.63	6.89	4.88	42.88	8.17	0.74	0.87	0.49	2.29
50	38.43	6.94	4.91	42.97	8.11	0.74	0.87	0.49	2.27
100	42.10	6.94	4.94	43.24	8.17	0.72	0.87	0.48	2.26
LSD 0.05	0.30	NS	NS	0.15	NS	NS	NS	NS	NS

Table 2. Effect of interaction between salinity levels and spraying by proline concentrations on some growth characters of canola genotypes after 60 days from sowing

Treatments		Plant height	No. of leaves/ plant	No. of branches/ plant	Fresh weight/ plant	Dry weight/ plant	Chlorophyll A	Chlorophyll B	Carotenoids	Total pigments
4500ppm	0	34.21	6.52	4.64	40.35	7.65	0.69	0.81	0.46	2.14
	50	36.19	6.47	4.61	40.14	7.61	0.69	0.81	0.46	2.13
	100	40.56	6.54	4.66	40.58	7.68	0.69	0.82	0.46	2.15
Tap water	0	41.04	7.37	5.24	45.59	8.69	0.79	0.92	0.53	2.44
	50	40.67	7.31	5.22	45.61	8.61	0.78	0.92	0.52	2.41
	100	43.64	7.35	5.10	45.89	8.66	0.76	0.92	0.50	2.37
LSD 0.05		0.43	NS	NS	0.11	0.15	NS	NS	NS	NS

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Table 3. Effect of interaction between varietal differences and spraying by proline concentrations on some growth characters of canola genotypes after 60 days from sowing

Treatments		Plant height	No. of leaves/ plant	No. of branches/ plant	Fresh weight/ plant	Dry weight/ plant	Chlorophyll A	Chlorophyll B	Carotenoids	Total pigments
Agamax	0	37.53	7.16	4.41	44.97	8.76	0.38	0.98	0.25	1.75
	50	40.46	6.51	4.21	42.96	8.54	0.36	0.97	0.24	1.70
	100	45.43	6.28	4.01	40.83	8.01	0.31	0.84	0.20	1.45
Serw 4	0	34.06	6.57	5.30	39.15	7.09	0.93	0.74	0.62	2.49
	50	36.35	6.41	4.47	40.71	7.90	0.41	0.81	0.27	1.61
	100	38.65	7.03	5.08	42.58	8.12	0.46	0.87	0.30	1.76
Serw 6	0	40.53	7.50	5.32	44.45	8.31	0.49	0.98	0.33	1.95
	50	42.88	7.11	4.38	44.70	8.73	0.38	0.97	0.25	1.74
	100	44.00	6.47	4.20	42.72	8.49	0.36	0.97	0.24	1.70
Trapper	0	31.09	6.82	4.38	39.68	8.29	0.97	0.72	0.65	2.55
	50	34.69	6.65	5.19	41.21	7.59	1.53	0.78	1.03	3.66
	100	42.53	6.46	5.63	41.19	6.56	1.33	0.73	0.89	3.22
LSD0.05		0.95	NS	0.45	0.26	NS	0.14	NS	0.21	0.30

3.1.4.3. Effect of interaction between salinity levels and varietal differences on some morphological characters and photosynthetic pigments after 60 days from sowing

Data presented in Table (4) illustrated the effect of interaction between salinity levels and varietal differences on some morphological characters and photosynthetic pigments after 60 days from sowing, where the interaction between salinity levels and varietal differences significantly affected most of the studied characters except, number of leaves/ plants, Chb, and carotenoids. Where the treatments tap water + Serw 6 and tap water + Agamax records the highest values of plant height, number of leaves/ plants, number of branches/ plant, fresh weight/ plant, and Chb, while the treatments saline water (4500 ppm) + Serw 6 and saline water + Trapper recorded the lowest values of plant height, number of leaves/ plant and fresh weight/ plant. Also, the treatment saline water (4500 ppm) + Serw 6 recorded the lowest values of dry weight/ plant, Cha, Chb, Car, and total pigments.

3.1.4.4. Effect of interaction among salinity levels, varietal differences, and proline concentration on some morphological characters and photosynthetic pigments after 60 days from sowing

The second-order interaction among the three tested factors clearly showed the beneficial effects of salinity and proline growth parameters and photosynthetic pigments under canola cultivars (Figs 1, 2, 3, and 4). Pots irrigated with tap water secured the highest values of plant height with Agamax genotype and 100 ppm proline, while the lowest value of the plant height was recorded by the treatment salinity level of 4500 ppm with Trapper and 0 proline concentration (Fig 1). Pots irrigated with tap water recorded the highest values of fresh weight/ plant with Agamax genotype and 0 ppm proline as well as tap water with Serw 6 and 50 ppm proline concentration with no significant differences between both treatments (Fig 2), while the treatment of 4500 ppm salinity level with Serw 4 genotype and 0 proline concentration recorded the lowest value for fresh weight/ plant character. Dry weight/ plant showed the highest value with the treatment of tap water with the Agamax genotype and 50 ppm proline concentration while the treatment 4500 ppm salinity water with Trapper genotype and 50 ppm proline concentration showed the lowest value of dry weight/ plant (Fig 3). The pots sowing by Trapper genotype and irrigated with tap water and sprayed by 50 or 100 ppm proline showed the highest total pigments as illustrated in (Fig 4).

Table 4. Effect of interaction between salinity levels and varietal differences on some morphological characters and photosynthetic pigments after 60 days from sowing

		Plant height	No. of leaves/ plant	No. of branches/ plant	Fresh weight/ plant	Dry weight/ plant	Chlorophyll A	Chlorophyll B	Carotenoids	Total pigments
4500 Ppm	Agamax	38.88	6.56	3.91	40.37	7.06	0.30	0.84	0.30	1.57
	Serw 4	34.58	6.52	4.76	39.79	7.65	0.45	0.82	0.29	1.69
	Serw 6	41.62	6.75	4.32	43.61	6.45	0.31	0.77	0.27	1.35
	Trapper	34.20	6.53	5.29	39.56	7.07	0.91	0.72	0.75	2.38
Tap water	Agamax	43.39	7.04	4.50	44.47	8.83	0.39	1.01	0.25	1.79
	Serw 4	39.12	6.81	5.13	41.82	8.73	0.74	0.79	0.49	2.21
	Serw 6	43.37	7.29	5.94	44.29	8.56	0.45	0.97	0.30	1.86
	Trapper	38.01	6.73	5.84	43.83	8.91	1.12	0.77	0.75	2.90
L S D 0.05		1.12	NS	0.45	0.84	0.64	0.21	NS	NS	0.67

Fig (1): Effect of interaction between salinity levels, cultivar and spraying by proline concentrations on plant height of canola after 60 DAS

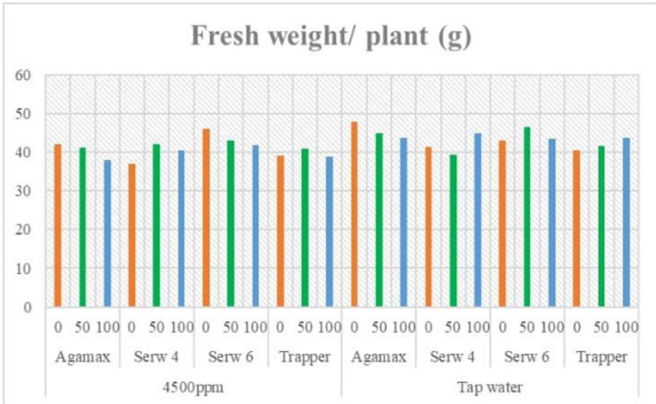

Fig (2): Effect of interaction between salinity levels, cultivar and spraying by proline concentrations on fresh weight/plant of canola after 60 DAS

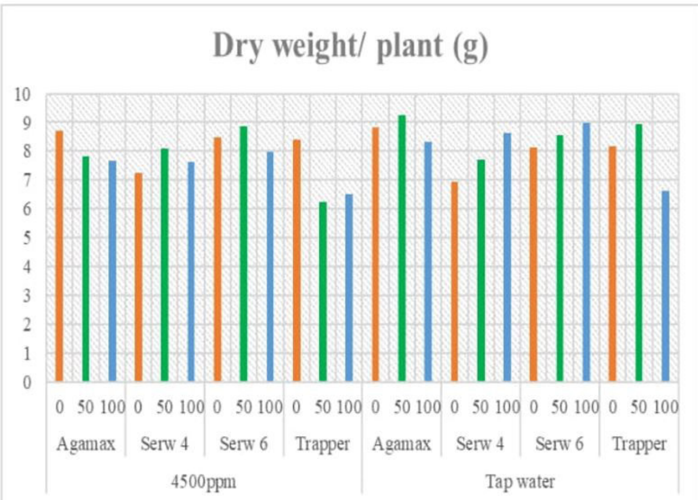

Fig (3): Effect of interaction between salinity levels, cultivar and spraying by proline concentrations on dry weight/plant of canola after 60 DAS

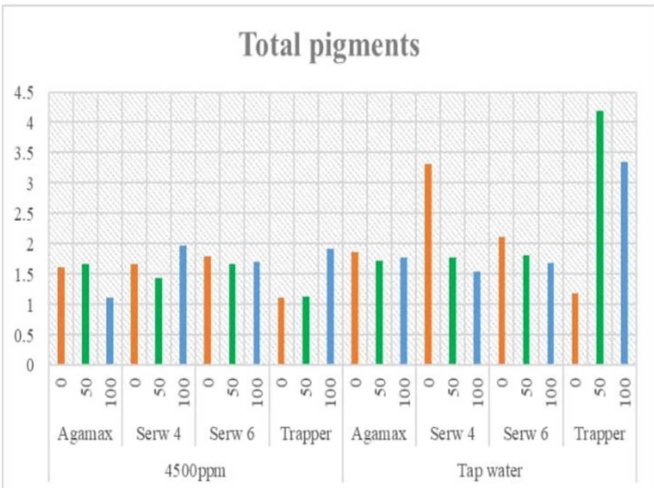

Fig (4): Effect of interaction between salinity levels, cultivar and spraying by proline concentrations on total pigments of canola after 60 DAS

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3.2. Yield and yield attributes of some canola genotypes

3.2.1. Effect of salinity levels on some yield and yield attributes of some canola genotypes

The results illustrated in (Table 5) shows the effect of saline water (4500 ppm) and tap water on some yield and yield attributes characters, where, salinity stress caused decreases in 1000 seed weight, seed yield/plant, pod yield/plant, straw yield/plant, and biological yield/plant. Farouk *et al.* (2011) stated that such reduction in yield and yield attributes result from the reduction in the supply of carbon assimilation due to decreasing the net photosynthetic rate and biomass accumulation. Van Hoorn *et al*., (2001) mentioned that the reduction in yield of soybean plants under salinity stress was attributed to the decrease in photosynthetic rate, carbohydrate accumulation, nitrogenase activity, and consequently seed yield. The results of the present investigation are in trend with those obtained by Eyvazlou *et al*., 2019.

3.2.2. Effect of varietal differences on some yield and yield attributes of some canola genotypes

The results in (Table 5) indicated that the effect of four canola cultivars on yield and yield attributes were significantly pod yield/plant, straw yield/plant, and biological yield/plant. Agamax cultivars gave better values to the previous characters as compared to other cultivars. This increase in pod yield/plant, straw yield/plant, and biological yield/plant amounted to 11.52, 10.19, and 10.48 % more than Serw 4 cultivar. In this regard, the increase in Agamax yield may be due to increasing vegetative growth, which led to an increase in yield component resulting in increased plant seed yield compared to the rest of the varieties. These results are in coinciding with those detected by El-Habbasha and Mekki (2014).

3.2.3. Effect of proline concentration on some yield and yield attributes of some canola genotypes

Data presented in Table (5) showed that increasing proline concentration from 0 to 100 ppm tended to significantly increment 1000 seed weight, seed yield/plant, pod yield/plant, straw yield/plant, and biological yield/plant. While, increasing proline concentration from 50 to 100 ppm tended to no significant increment in most of the studied characters except, pod yield/plant and biological yield/plant.

Table 5. Effect of salinity levels, cultivars, and proline concentration on yield and yield attributes of canola plants

Treatments	1000 seed weight	Seed yield/plant	Pod yield/plant	Straw yield/plant	Biological yield/plant
Salinity	-	-	-	-	-
4500 ppm	3.08	4.31	8.66	14.11	27.08
Tap water	3.56	4.93	9.89	16.17	30.99
F. test	*	*	*	*	*
Cultivars	-	-	-	-	-
Agamax	3.40	4.65	9.49	15.25	29.39
Serw 4	3.08	4.25	8.51	13.84	26.60
Serw 6	3.34	4.61	9.24	15.03	28.88
Trapper	3.30	4.56	9.03	15.02	28.61
LSD 0.05	NS	NS	0.54	0.84	0.64
Proline con.	-	-	-	-	-
0	2.90	4.40	8.23	14.11	26.74
50	3.32	4.51	9.24	15.07	28.82
100	3.34	4.64	9.86	15.94	30.44
LSD 0.05	0.21	0.15	0.42	1.05	1.14

3.2.4. Effect of interactions

3.2.4.1. Effect of interaction between salinity levels and proline concentration on some yield and yield attributes of some canola genotypes

The interactive effects between salinity and proline concentration significantly affected significantly of pod yield/plant, straw yield/plant, and biological yield/plant (Table 6). Pots that received an application of salinity at the rate of 4500 ppm and untreated proline treatments produced the lowest pod yield/plant, straw yield/plant, and biological yield/plant. Meanwhile, the maximum values of the previous characters were reported with tap water treatment and foliar application of 100 ppm proline treatment. El-Moukhtari *et al.* (2020) reported that under high-salt conditions, proline application enhances plant growth with increases in seed germination, biomass, photosynthesis, gas exchange, and grain yield. These positive effects are mainly driven by better nutrient acquisition, water uptake, and biological nitrogen fixation. Exogenous proline also alleviates salt stress by improving antioxidant activities and reducing Na+ and Cl– uptake and translocation while enhancing K+ assimilation by plants. These results are in general agreement with those recorded by Gyawali *et al.*, 2019 and Sadak *et al.*, 2020.

3.2.4.2. Effect of interaction between varietal differences and proline concentration on some yield and yield attributes of some canola genotypes

Concerning the interaction effect between varietal differences and proline concentration, where the studied characters were significantly affected by the interaction between treatments, except, for 1000-seed weight and seed yield/ plant. The maximum values of pod yield/plant, straw yield/plant, and biological yield/plant were recorded with Serw 6 and spraying of 100 ppm proline treatment (Table 7). In contrast, the lowest values of the aforementioned characters were obtained by Serw 4 cultivars and untreated proline combination.

Table 6. Effect of interaction between salinity levels and spraying by proline concentrations on yield and yield attributes of canola plants.

		1000 seed weight	Seed yield/ plant	Pod yield/ plant	Straw yield/ plant	Biological yield/ plant
4500 Ppm	0	3.10	4.29	8.60	14.02	26.91
	50	3.09	4.34	8.70	14.15	27.19
	100	3.07	4.29	8.68	14.17	27.14
Tap water	0	3.51	4.91	9.82	16.10	30.83
	50	3.56	4.88	9.79	15.99	30.66
	100	3.61	4.99	10.07	16.40	31.46
LSD 0.05		NS	NS	0.64	1.05	1.25

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Table 7. Effect of interaction between varietal differences and spraying by proline concentrations on some yield and yield components of canola genotypes

		1000 seed weight	Seed yield/ plant	Pod yield/ plant	Straw yield/plant	Biological yield/plant
Agamax	0	3.39	4.57	9.64	15.03	29.24
	50	3.48	4.89	9.58	15.20	29.67
	100	3.34	4.48	9.25	14.51	28.24
Serw 4	0	3.06	4.21	8.36	13.43	26.00
	50	3.28	4.45	8.45	14.58	27.48
	100	2.91	4.09	8.74	13.52	26.35
Serw 6	0	3.13	4.35	8.49	14.14	26.98
	50	3.40	4.61	9.52	15.13	29.26
	100	3.48	4.85	9.71	16.83	31.39

3.2.4.3. Effect of interaction between salinity levels and varietal differences on some yield and yield attributes of some canola genotypes

The results in (Table 8) showed that there were significant interactions between salinity levels and varietal differences in straw yield/plant and biological yield/ plant. The highest values were obtained from irrigation of tap water integrated with Agamax cultivars. On the other hand, the lowest values were recorded from the irrigated with 4500 ppm salt treatment integrated with Serw 4 cultivar. These results are in accordance with those recorded by Bybordi and Tabatabaei (2009) and El-Habbasha and Mekki (2014).

3.2.4.4. Effect of interaction among salinity levels, varietal differences, and proline concentration on some yield attributes of some canola genotypes

Data presented in Figs 5, 6, 7, and 8 clear that, the third interaction among salinity levels, varietal differences, and proline concentration on seed yield/ plant, pod yield/plant, straw yield/plant, and biological yield/ plant, where these characters significantly affected by the interactions among salinity levels, varietal differences and proline concentration where the treatment tap water with the cultivar Agamax and spraying with 50 ppm proline concentration recorded the highest values of the studied characters. While, the lowest values of the studied characters were recorded by the treatment 4500 ppm saline water with the cultivar Serw 4 and without sparing proline for the characters seed yield/ plant, straw yield/plant, and biological yield/plant, also the treatment of 4500 ppm saline water with the cultivar Serw 6 and without sparing proline for the character pod yield/plant.

Table 8. Effect of interaction between salinity levels and varietal differences on some yield and yield components of canola genotypes

IRRI	TRT	1000 seed weight	Seed yield/plant	Pod yield/plant	Straw yield/ plant	Biological yield/ plant
4500 ppm	Agamax	3.29	4.48	9.23	14.76	28.47
	Serw 4	2.94	4.12	8.24	13.31	25.67
	Serw 6	3.23	4.53	9.07	14.80	28.4
	Trapper	3.13	4.41	8.74	14.55	27.7
Tap water	Agamax	3.51	4.81	9.75	15.73	30.29
	Serw 4	3.22	4.37	8.77	14.38	27.52
	Serw 6	3.44	4.68	9.41	15.26	29.35
	Trapper	3.46	4.70	9.31	15.50	29.51
LSD0.05		NS	NS	NS	0.94	1.14

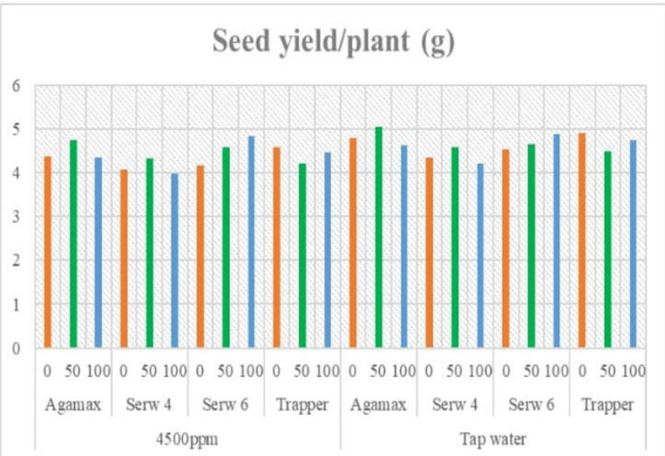

Fig (5): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on seed yield/plant of canola genotypes

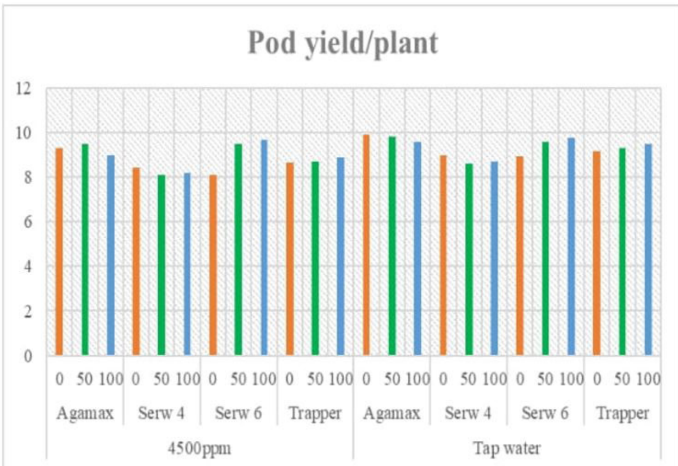

Fig (6): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on pod yield/plant of canola genotypes

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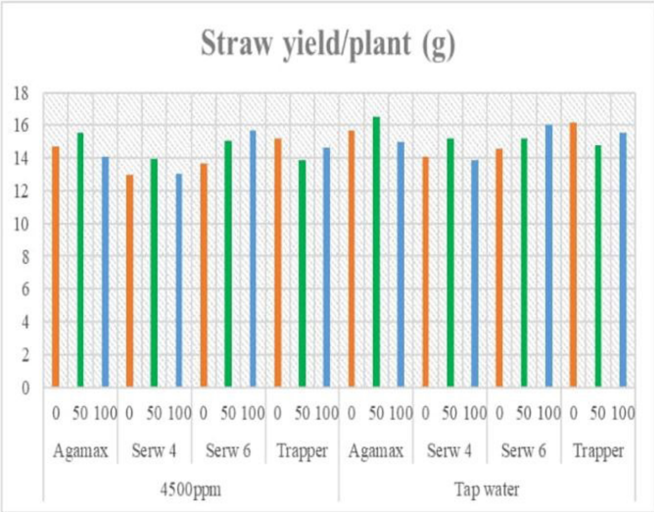

Fig (7): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on straw yield/plant of canola genotypes

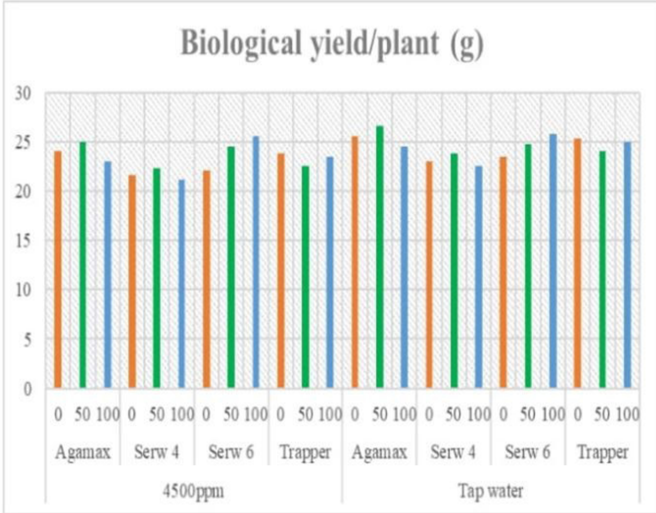

Fig (8): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on biological yield/plant of canola genotypes

3.3. Seed chemical composition of some canola genotypes

3.3.1. Effect of salinity levels on seed chemical composition of some canola genotypes

Results in (Table 8) show that protein %, N%, P%, K%, Fe ppm, Mn ppm, and Zn ppm concentrations were significantly decreased by increasing salinity level relative to a corresponding control, while oil% was significantly decreased by increasing salinity. These results may be due to the reduction in the growth of canola plants under salinity stress was attributed to the decrease in photosynthetic rate, protein and carbohydrate accumulation as well as macro and micronutrients. Hussain *et al.* (2018) concluded that soil salinity affects various plant physiological activities through increased oxidative damage, decreased turgor, as well as changes in leaf gas exchange, ultimately leading to reduced plant growth, development, and yield (Hussain *et al.*, 2016 and Roy *et al.*, 2014).

3.3.2. Effect of varietal differences on seed chemical composition of some canola genotypes

Results indicated that four canola genotypes significantly differ in percentages of protein %, N%, P%, K%, Fe ppm, Mn ppm, and Zn ppm as shown in (Table 8). Trapper cultivar gave better values of the oil %, P%, Fe ppm, Mn ppm, and Zn ppm as compared to other cultivars. While Agamax gave the maximum values of the protein % and N%, compared to other cultivars. In this connection, Serw 6 cultivar gave the highest values of K% as compared to other cultivars. In contrast, Serw 4 cultivar produced the lowest values of protein %, N%, P%, and K% when compared with the other cultivars. A similar trend was reported by Bybordi (2010) and El-Habbasha and Mekki (2014).

3.3.3. Effect of proline concentration on seed chemical composition of some canola genotypes

Data in Table (9) showed the effect of increasing proline concentration from 0 to 100 µM on protein content, seed oil content, some macro (Ca, Mg, K, and Na), micro (Fe, Mn, and Zn) nutrients, of some canola varieties (Agamax, Trapper, Serw 4 and Serw 6). Where the results indicated that there was no significant effect of proline concentration on the chemical composition of canola seeds.

3.3.4. Effect of interactions

3.3.4.1. Effect of interaction between salinity levels and proline concentrations on seed chemical composition of some canola genotypes

Table 9. Effect of salinity levels, cultivars, and proline concentration on some chemical characters of canola.

Treatments	Protein %	Oil %	N %	P %	K %	Fe ppm	Mn ppm	Zn ppm
Salinity:	-	-	-	-	-	-	-	-
4500 ppm	22.88	47.78	3.97	0.46	0.90	71.53	13.13	25.17
Tap water	24.89	46.83	4.53	0.52	1.04	81.67	15.00	28.74
F.test	*	*	*	*	*	*	*	*
Cultivars:	-	-	-	-	-	-	-	-
Agamax	25.13	46.42	4.36	0.48	0.95	69.51	13.00	26.35
Serw 4	22.54	47.88	3.91	0.44	0.90	76.25	13.57	25.17
Serw 6	24.33	46.71	4.22	0.47	0.97	63.47	13.51	26.23
Trapper	23.76	47.98	4.12	0.50	0.95	84.89	14.18	27.16
LSD0.05	0.10	0.07	0.03	0.00	0.01	0.93	0.10	0.17
Proline con.	-	-	-	-	-	-	-	-
0	23.92	47.23	4.24	0.49	0.97	76.73	14.04	26.93
50	23.90	47.32	4.24	0.49	0.96	76.12	14.00	26.84
100	23.85	47.36	4.28	0.49	0.98	76.95	14.16	27.09
LSD0.05	NS	NS	NS	NS	NS	NS	NS	NS

In pots irrigated with tape water with proline concentration produced the maximum values of protein %, N%, Fe ppm, Mn ppm, and Zn ppm (Table 10). On the other side, irrigating the plants with salinity at 4500 ppm gave the minimum values of previous characters. These results are in coinciding with those detected by Eyvazlou *et al.* (2019).

3.3.4.2. Effect of interaction between varietal differences and proline concentrations on seed chemical composition of some canola genotypes

Data in (Table 11) showed that there was a significant effect due to the interaction between canola cultivars and proline concentration on protein %, N%, Fe ppm, Mn ppm, and Zn ppm. Cultivation of Serw 6 and application of proline at 100 ppm produced the highest values of protein % and N%. In this connection, Serw 4 gave the maximum values of oil % when addition to proline at the rate of 100 ppm. In this regard, the Trapper cultivar with 100 ppm proline produced the largest values of Fe ppm, Mn ppm, and Zn ppm. While the lowest values of previous characters were recorded with Serw 4 treatment with the addition of 50 or 100 ppm proline concentrations. These results are in accordance with those recorded by El-Habbasha and Mekki (2014).

3.3.4.3. Effect of interaction between salinity levels and varietal differences on seed chemical composition of some canola genotypes

Results presented in (Table 12) illustrated those significant differences in the most of studied characters, except P% and K% as affected by the interaction of salinity levels and varietal differences. Tape water x Agamax was the more efficient interaction for enhancing seeds protein % and N%. While Trapper x tape water gave the maximum seeds of Fe ppm, Mn ppm, and Zn ppm contents (Table 11). Moreover, Serw 4 treatment with salinity produced the largest values of oil %. In contrast, the lowest values of protein %, N%, Fe ppm, Mn ppm, and Zn ppm were recorded with Serw 4 treatment with pots irrigated with saline water at the rate of 4500 ppm. Similar results have been reported by Bybordi (2010) and El-Habbasha and Mekki (2014).

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Table 10. Effect of interaction between salinity levels and spraying by proline concentrations on some chemical characters of canola.

		Protein %	Oil %	N %	P %	K %	Fe ppm	Mn ppm	Zn ppm
4500 Ppm	0	22.89	47.71	3.97	0.46	0.90	71.40	13.13	25.16
	50	22.94	47.92	3.98	0.46	0.90	71.74	13.17	25.23
	100	22.82	47.71	3.96	0.46	0.90	71.44	13.10	25.12
Tap water	0	24.88	46.74	4.50	0.52	1.03	82.07	14.96	28.71
	50	24.85	46.73	4.49	0.52	1.02	80.50	14.82	28.44
	100	24.94	47.01	4.60	0.53	1.05	82.45	15.22	29.07
LSD0.05		0.05	0.03	0.01	NS	NS	0.53	0.04	0.09

Table 11. Effect of interaction between varietal differences and spraying by proline concentrations on some chemical characters of canola.

		Protein %	Oil %	N %	P %	K %	Fe ppm	Mn ppm	Zn ppm
Agamax	0	24.45	47.04	4.24	0.42	0.95	65.95	13.32	27.15
	50	25.92	45.56	4.50	0.50	0.98	75.83	13.46	27.03
	100	25.02	46.65	4.34	0.51	0.91	66.75	12.22	24.87
Serw 4	0	23.53	46.46	4.08	0.41	0.94	83.12	14.17	23.73
	50	22.51	48.57	3.91	0.44	0.92	92.62	14.75	28.98
	100	21.58	48.61	3.74	0.47	0.83	43.00	11.78	22.80
Serw 6	0	22.88	47.80	3.96	0.48	0.98	49.36	13.88	24.82
	50	24.32	46.59	4.22	0.42	0.95	65.61	13.25	27.01
	100	25.78	45.72	4.47	0.50	0.98	75.44	13.39	26.88
Trapper	0	23.95	47.82	4.15	0.50	0.93	82.14	12.59	24.53
	50	22.98	48.60	3.98	0.53	0.94	79.08	14.59	28.33
	100	24.36	47.52	4.23	0.48	0.98	93.44	15.37	28.62
LSD0.05		0.11	0.07	0.02	NS	NS	1.19	0.08	0.20

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Table 12. Effect of interaction between salinity levels and varietal differences on some chemical characters of canola.

		Protein %	Oil %	N %	P %	K %	Fe ppm	Mn ppm	Zn ppm
4500 Ppm	Agamax	24.34	47.16	4.22	0.46	0.92	67.31	12.59	25.52
	Serw 4	21.83	47.91	3.79	0.42	0.87	73.84	13.13	24.38
	Serw 6	24.00	46.79	4.16	0.46	0.96	62.70	13.31	25.88
	Trapper	23.01	48.17	3.99	0.49	0.92	82.21	13.73	26.30
Tap water	Agamax	25.93	45.68	4.50	0.49	0.98	71.71	13.41	27.18
	Serw 4	23.25	47.85	4.04	0.45	0.93	78.65	14.00	25.97
	Serw 6	24.66	46.62	4.28	0.47	0.98	64.24	13.70	26.59
	Trapper	24.52	47.79	4.25	0.52	0.98	87.56	14.63	28.01
LSD0.05		0.27	0.35	0.22	NS	NS	0.72	0.37	0.13

3.3.4.4. Effect of interaction among salinity levels, varietal differences, and proline concentration on seed chemical composition of some canola genotypes

Data presented in (Figs 9, 10, 11, 12, 13, and 14) cleared that the third interaction among salinity levels, varietal differences, and proline concentration on some seed chemical composition of canola genotypes, where these characters significantly affected by the interactions among salinity levels, varietal differences, and proline concentration. The treatment of tap water with the cultivar Agamax and spraying with 50 ppm proline concentration recorded the highest values of protein % (Fig 9). The treatment of tap water in addition to Serw 4 genotype and application of 50 ppm proline recorded the highest values of Fe and Zn (Fig 12 and 14). While, the treatments tap water+ Serw 6 genotype + 100 ppm proline concentration and 4500 ppm + Trapper genotype + 100 ppm concentration recorded the highest value of Mn (Fig 11 and Fig 13).

While the lowest values of the studied characters were recorded by the treatment of 4500 ppm saline water with the cultivar Serw 4 and 100 ppm proline for the characters protein %, N %, Fe, Mn, and Zn (Figs 9, 11, 12, 13 and 14), the same treatment recorded the highest oil % (Fig 10).

4. Conclusions

According to the previous results, it could be concluded that the use of exogenous application of plant growth regulating compounds like proline alleviation the adverse effects of salt stress on canola varieties by improving metabolism and stimulating the growth of plants this tended to significantly increase the most of growth, yield and yield attributes as well as some chemical constituents, proline especially at 100 ppm partially alleviated the harmful effects of salinity stress as well as the chemical composition of seeds of Serw 6 or Trapper cultivar of canola plants and nutritive value of the yielded seeds.

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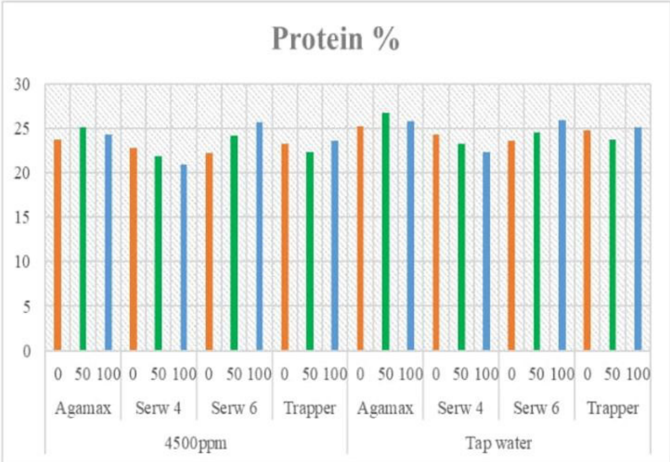

Fig (9): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on protein % of canola seed

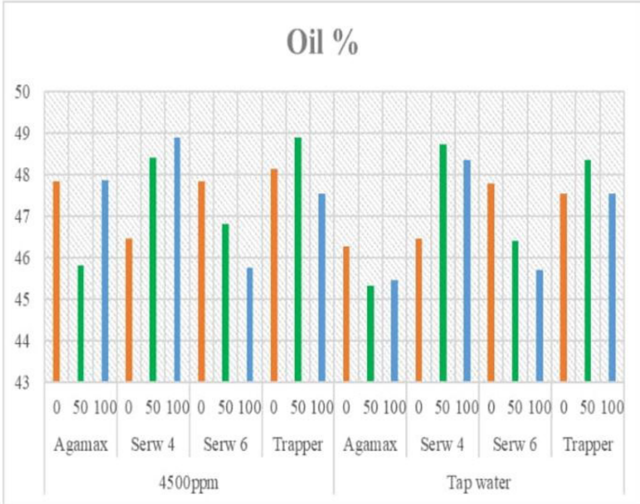

Fig (10): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on oil % of canola seed

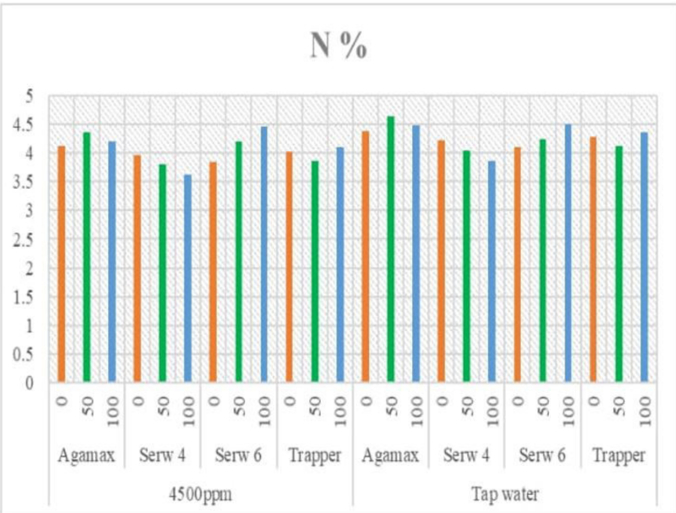

Fig (11): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on N % of canola seed

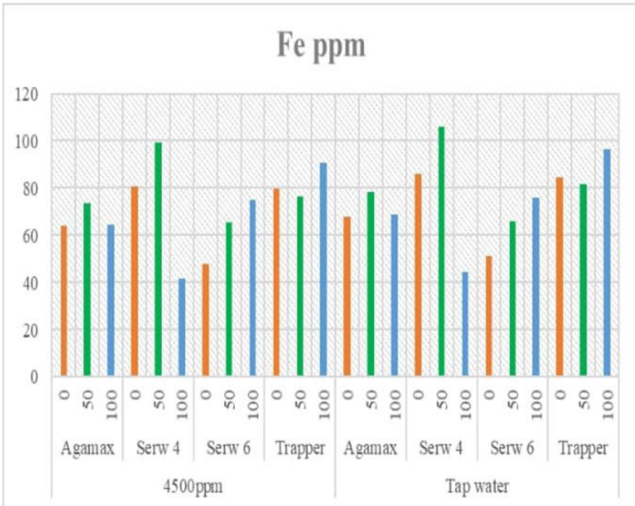

Fig (12): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on Fe content of canola

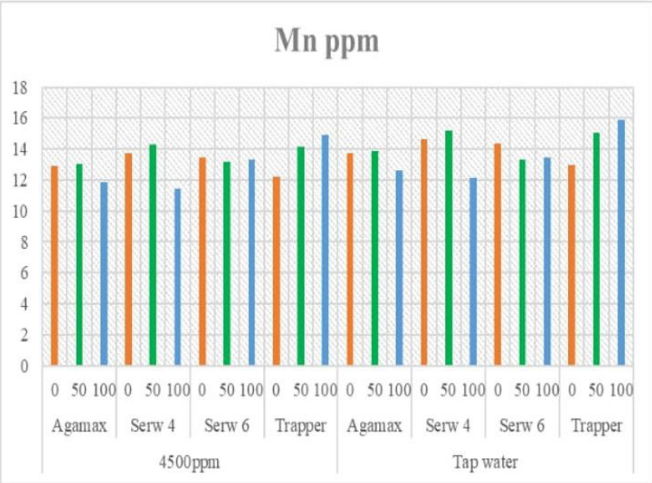

Fig (13): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on Mn content of canola seed

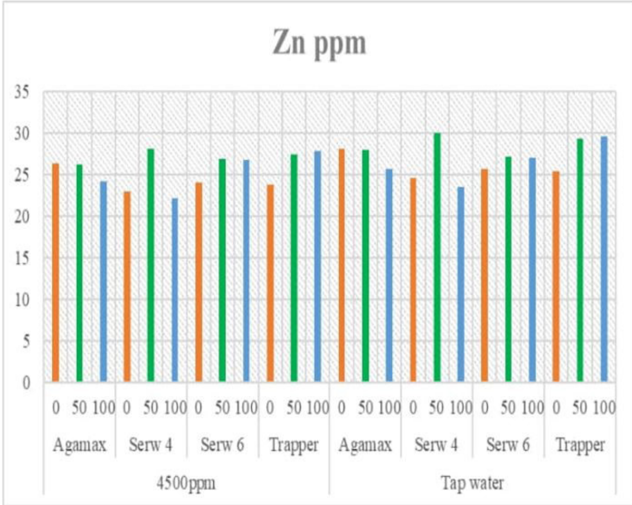

Fig (14): Effect of interaction among salinity levels, varietal differences and spraying by proline concentrations on Zn content of canola seed

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Paper

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Taste masking in vegan food processing with natural substitutes

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Climate change, sustainability issues, and increased risks of a meat diet on both ecology and human health cause changes in the eating habits of individuals. Plant-based foods supply protein sources with health-promoting compounds. The bitterness of plant-based foods is challenging for both food manufacturers and consumers. So far, artificial taste blockers, salt, sugar, and fat have been applied to mask the bitterness of plant-based products. However, people are conscious of "clean labelling" and "natural" food ingredients. Thus, natural taste blockers are the new trend for vegan food manufacturing to mask bitterness. The review focuses on providing information about natural salt, sugar, and fat replacers for foods as taste blockers of bitterness. The study highlights the recent natural taste blockers, application trends, and regulations for food processing.

1. Introduction

We need to eat to survive, but today we also want to feel satisfied with the appearance, aroma, and flavour of the food. Accordingly, society and global trends influence our food preferences; novel foods, and advertisements for new food trends create attractiveness for us (Prescott *et al.*, 2002). However, food trends adhere to varied factors such as global conditions, politics, and ecology (Arenas-Jal *et al.*, 2019). Nowadays, environmental issues are the most important game-changers like climate change and sustainability, creating huge concerns for future food systems. Indeed, the world population is estimated to exist at about 10 billion people by 2050 (UNDESA, 2017). Thus, the significance of the subject increases with the question of how we can feed a huge amount of human mass.

Alternative proteins, such as plant and insect-based proteins, are gaining popularity. However, people are unprepared to consume insects as protein sources because they are afraid to try and have a negative perception of insects (de Koning *et al.*, 2020). Hence, plant sources can be used as an alternative protein. A meat-based diet consumes a lot of water, land, and energy (Sabaté & Soret, 2014). In contrast, a plant-based diet protects people against non-communicable diseases such as cancer, cardiovascular diseases, type 2 diabetes, and obesity (Jakše *et al.*, 2019).

Therefore, the vegan food market is predicted to reach USD 26.1 billion by 2026 (expertmarketresearch.com). The most attractive vegan products are alternative meat, egg alternatives, and dairy substitutes for non-vegan people.

During the coronavirus disease 2019 (COVID-19) pandemic, sustainable and healthy diet preferences have been boosted (Lonnie & Johnstone, 2020). According to case studies, consumption of meat, poultry, and dairy products decreased in China (Jia *et al.*, 2021) and Spain (Rodríguez-Pérez *et al.*, 2020). The main reason is animals carried viruses, and the terminology is "zoonosis" which is thought to possess more functions in the future among different species in nature to cause diseases like COVID-19 (Attwood & Hajat, 2020). Thus, individuals cease consuming meat and animal-based food products to prevent the transmission of infectious pathogens.

In reality, many individuals are unprepared to replace meat with plant derivatives. Some reasons include eating habits and the taste of meat. However, one of the biggest challenges is bitterness and the strong aroma of plant natural products that demonstrate increased bitterness with boosted health functions (Behrens *et al.*, 2018).

Without a doubt, bitterness is unacceptable to consumers, even though the food has elevated health benefits. For instance, glucosinolates from Brassicaceae (Cabbage family) are popular with their specific unpleasant aroma and health advantages (Verkerk *et al.*, 2009). In a study, the undesirable aroma of cabbage compounds has been masked with sucrose, and the final product has proved the palatable cabbage juice (Beck *et al.*, 2014). Thus, sugar is a stunning taste-masking agent for bitterness.

Inasmuch as, sugar, salt, and fat are the most applied taste blockers against bitterness in foods (Goldberg *et al.*, 2017). Even if, the proper amounts of salt, sugar, and fat are crucial for healthy body functions (Downs *et al.*, 2020), consumption rates increase with processed food products. Besides, salt, sugar, and fat cause many health issues such as cardiovascular disorders, obesity, type 2 diabetes, and cancer. Therefore, health authorities recommend reducing or replacing sugar, salt, and fat with natural alternatives (Saraiva *et al.*, 2020).

This review aims to discuss natural and recognized sugar, salt, and fat replacers with health-promoting activities, application benefits, and challenges in vegan food processing. The scope included identifying substitutes of sugar, salt, and fat as natural food ingredients without changing the mouthfeel, texture, and/or flavour characteristics of fat, salt, and sugar in foods. Hence, recommendations are given for vegan processed foods.

2. Literature

2.1 The impact of sugar, salt, and fat in processed foods

In the early 1900s, the food industry discovered sugar, salt and fat can increase the taste of food products (Rao *et al.*, 2018). Indeed, sugar is an essential component for food processing with stability, texture, mouthfeel, flavour, colour, and preservation features (Erickson & Carr, 2020). Furthermore, sugar provides energy to our body as a carbohydrate, however, the origin of the sugar is the main point such as the sugars of fruit and vegetables are natural and rich in fibres (Misra *et al.*, 2016). However, excessive sugar consumption is an important reason for obesity (Stanner & Spiro, 2020). Salt occurs with sodium and chloride, which is an essential compound for body fluid regulation, and transmission of nerve and muscle impulses (Gilbert & Heiser, 2005). Interestingly, excessive and minimal salt consumptions than recommended values cause problems in the body like myocardial infarction (Nikiforov *et al.*, 2021), but low sugar consumption demonstrates no adverse effects on the body.

An adequate amount of fat is essential for health because fats and proteins construct our cell membranes elastic and permeable. Nevertheless, excessive fat consumption creates difficulties in transferring cell waste and obtaining essential nutrients in the cell; a low-fat diet causes constipation, carbohydrate desire, infertility, and insomnia (peaksofhealth.com).

According to the World Health Organization (WHO, 2020a), a healthy diet should include vegetables, fruits, legumes, nuts, whole grains, less than 30% of total energy intake from fats, less than 10% of free sugars, and less than 5 gram of salt for adults. Hence, the recommended amounts of sugar, salt, and fats are essential, however, overconsumption of salt, fat, and sugar causes a weakening of immunity (Moss, 2014). Moreover, relationships between high sugar, salt, and fat consumption and poor diet may create obesity, diabetes, cardiovascular disorders, and cancer (Andarwulan *et al.*, 2021).

Processed foods, which are rich in sugar, salt, and fat, increase dopamine levels in the brain and make people addicted to junk foods (Onaolapo & Onaolapo, 2018). Various food products include hidden salt and sugar as bread and bakery products are the hidden salt sources (Bhat *et al.*, 2020); packaged soups, sauces, salad dressings, canned vegetables, and ready meals are the hidden sources of sugar (Zupanič *et al.*, 2019). Moreover, sugar and salt are excellent preservatives for processed foods because sugar and salt relocate water out of the cell and microorganisms disappear (Barba-Orellana *et al.*, 2020). Thus, to prevent the overconsumption of sugar, salt, and fat in processed foods, Mexico, and Denmark apply over-taxation for junk foods (Blakely *et al.*, 2020).

2.2 Why should sugar, salt, and fat be replaced with natural substitutes?

Sugar is the most utilized taste blocker for the bitterness of plant-based foods. Inasmuch as sugar revokes the first sensory signal to reach the brain. Otherwise, sugar demonstrates bitterness masking function as the consequence of mixture suppression, which combines with bitterness sources and influences the cognitive area of the brain (Keast, 2008). For example, soy protein and pea protein are the most popular plant-based proteins due to their gluten-free and fat-free profiles (Bashi *et al.*, 2019). However, those vegan food components have an unpleasant aroma for consumers. Hence, food manufacturers have utilized sugar to avoid the undesirable flavour of plant-based proteins, and sugar conceals the odour of plant derivatives during food processing (Bangratz & Le Beller, 2020).

Human-kind desires sweet taste as genetically as an evolutionary survival mechanism (Breslin, 2013). Particularly, sweet consumption exhibits psychological necessity, and sweetness is a kind of addiction with numerous adverse effects such as tooth decay, weight gain, obesity, type 2 diabetes mellitus, dyslipidaemia, high blood cholesterol, stroke, depression, and cancer (Pérez *et al.*, 2016; Cediel *et al.*, 2018; Knüppel *et al.*, 2017). Regarding the side effects of sugar consumption, Lustig *et al.* (2012) have suggested removing sugar from the GRAS (Generally Regarded as Safe) list of the FDA (U.S. Food and Drug Administration).

Today, children possess the highest rates of sugar consumption in all age groups (Putnik *et al.*, 2020), and children are potential diabetic individuals of the future. WHO and FDA suggest reducing sugar intake rates to less than 10% per day, due to the connection of sugar with diseases (Johnston *et al.*, 2013). Nevertheless, the sweet desire causes one to search for alternative sources of sugar. For instance, artificial sweeteners had been applied for a while since scientific studies proved synthetic sweeteners generate brain tumours, weight gain, and bladder cancers (Putnik *et al.*, 2020). However, natural and non-nutritive sweeteners might be a solution to the sweet desire of human-being without any caloric content and with a palatable sweetness in an eating plan (Fitch & Keim, 2012).

Salt is the other taste-masking ingredient for processed foods. Keast (2008) has recommended adding salt reduces the bitterness of foods, because salt inhibits the tongue receptors, and decreases the signal transfers to reach through the brain cells. Moreover, psychophysical studies demonstrate salt works as a specific compound in bitterness to supply a favourable taste (Breslin & Beauchamp, 1997). Nevertheless, excessive salt consumption causes kidney damage, neuronal injury, cardiovascular disorders, stomach cancer, and hypertension (Downs *et al.*, 2020; O'Sullivan, 2020; He & MacGregor, 2009).

When we checked salt consumption rates in history, the evolutionary salt intake was 0.25 g per day (Eaton & Konner, 1985), but processed food has increased the rate of salt consumption up to 9-12 g per day with the help of processed meat, bread, and cheese products (Brown *et al.*, 2009). Therefore, salt reduction is fundamental, and recommended salt intake is lower than 5 gr per day, and the WHO aims to decrease salt intake rates by about 30% by 2025 (WHO, 2020b).

Officially recommended salt intake levels create pressure on food manufacturers to produce healthy food products with clean labelling (Erickson & Carr, 2020). The challenge is reducing sodium rates in foods but not accompanied by the salty flavour of foods, so the best solution is to replace salt with natural and healthy alternatives.

Fat is another ingredient of foods, and food manufacturers apply lipids to make the process stable and obtain the right texture (Matheson *et al.*, 2018). Dietary fat increases with passive overconsumption, which is called "high-fat hyperphagia" (Ludwig, 2016), and

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excessive fat consumption causes changes in neurochemical dopamine levels with disorders in mood, weight gain and obesity (Downs *et al*., 2020; Chauhan & Kumar, 2016). Thus far, during food processing varied chemical contents have been utilized to replace fat. However, consumers are aware of artificial chemicals, and the damage of synthetic compounds to the body (Silver & Bassett, 2008). Thus, consumers are looking for natural ingredients in food products (Saraiva *et al*., 2020).

To sum up, vegan food products include high amounts of salt, sugar, and fat to prevent off-flavours of plant derivatives (Tso & Forde, 2021). However, high sugar, fat, and salt consumptions cause side effects on the human body. Therefore, health authorities recommend declining sugar, fat, and salt consumption rates (WHO, 2020b), and with the latest trends, consumers are looking for “clean labels” and natural ingredients in food products without side effects (Erickson & Carr, 2020). The main challenge is salt and sugar is significant parameters for food manufacturing due to the texture, and stability of food products. Thus, suggested natural replacers of sugar, salt and fat can be applied in vegan food products to overcome the faced challenges in vegan food processing.

2.3 Natural replacers of sugar, fat, and salt as taste blockers in vegan food products

2.3.1 Neohesperidin dihydrochalcone (NHDC)

NHDC is a derivative of neohesperidin, which is a flavanone from bitter orange (*Citrus x aurantium* L.), and *Oxytropis myriophylla* (Pall.) DC. NHDC has been identified as a natural plant product, and a non-nutritive sweetener. The sweetness rate is 1800 times more than sucrose (Braune *et al*., 2005). For food processing, through the pasteurization period, NHDC stays stable, and the solubility of NHDC increases in water (Nabors, 2001). Besides, NHDC demonstrates satisfactory results for taste blocking in small amounts with a menthol flavour. Therefore, in some food applications, the menthol flavour might be unacceptable, but innovative vegan food products such as alternative meat from different sources with NHDC may create palatable results for consumers and may increase the popularity of future food applications.

Moreover, NHDC is approved by health authorities as a sweetener and flavour enhancer (Borrego & Montijano, 2001). NHDC obtained GRAS from FDA and European Union has approved NHDC (E-959) as a food additive with suggested consumption rates of 5 mg kg-1 of body weight per day (EFSA, 2011). The other countries which approved the NHDC as a flavour enhancer are Australia, Japan, and New Zealand (ISA, 2015) (Table 1). Thus, approvals from food authorities of the compound are promising to see novel foods in the future.

Thus far, the bitterness-blocking feature of NHDC has been studied for different food and beverages. For instance, caffeine is the most studied compound for bitterness which is a naturally occurring alkaloid in plant-based foods. NHDC increases the hedonic acceptability of caffeine to reduce bitterness (Ly & Drewnowski, 2001). In another literature study, NHDC has been utilized for bitter corn peptides, however, the challenge was the low water-soluble activity of NHDC due to phenolic compounds (Dong *et al*., 2017a). Therefore, some methods have been suggested to increase the water solubility of NHDC, such as graft reaction, inclusion complex, and reverse micelle. In detail, porous structures and small molecules with similar size, polarity, and shape to cavities can create inclusion complexes (Astray *et al*., 2010). On the other hand, grafting is an improvement of the main structure with different molecules for collaboration (Siafaka *et al*., 2016), and finally, reverse micelle is polar and nonpolar phases reverse roles and surfactants are upturned in a micelle (Dong *et al*., 2017a). Thus, different food processing methods may help to increase the possible uses of NHDC as a taste blocker for novel vegan food products.

2.3.2 Neodiosmin

Similar to the NHDC, neodiosmin is a compound of bitter orange. However, neodiosmin is a tasteless and odourless flavonoid (Horowitz & Gentili, 1969), and it may reduce the bitterness of varied compounds (Dong, *et al*., 2017b). For instance, so far, the compound has been used against the bitterness of caffeine, limonin, para-methoxycinnamaldehyde from cinnamon, and quinine (Fletcher *et al*., 2015). Hence, the compound supports many functions for future food applications as a bitterness blocker. However, the health authorities have not approved the neodiosmin for food applications yet, maybe in the forthcoming, it will be possible to see more implementations of the neodiosmin in vegan food products, after the safety approvals.

2.3.3 Thaumatin

Thaumatin is another natural, non-nutritive sugar substitute (Masuda *et al*., 2011). The arils of the African species *Thaumatococcus daniellii* Bennett include the sweet-tasting thaumatin proteins (Mackenzie *et al*., 1985). The sweetness level of thaumatin is 3000 times higher than sucrose without measurable caloric values (Faus & Sisniega, 2003). Besides, the solubility of thaumatin is 80% at pH 6 and 40% at pH 10. Thaumatin is more stable at pH between 2.5 and 5; moreover, thaumatin stays stable above 100 °C (Farag *et al*., 2022). Thus, food applications with thaumatin may present attractive results as a natural ingredient, and thaumatin supplies clean labels for novel food products as well.

So far, thaumatin has been approved as GRAS for flavour enhancement by FDA (FEMA GRAS Number 3732), and European Union (Table 1). Also, thaumatin has been accepted as a sweetener in Australia, Switzerland, and the United Kingdom (Carocho *et al*., 2017). Moreover, thaumatin has been approved as safe in the pregnancy period by the United States Academy of Nutrition and Dietetics (Arévalo *et al*., 2019), and the allowed consumption rate of thaumatin is a maximum of 0.5 mg kg-1 per day (EFSA, 2015). Therefore, the safety characteristics of the compound are an important parameter both for vegan food manufacturers and consumers.

According to the literature studies, the antifungal activity of thaumatin may help to increase shelf-lives of vegan food products as well and the amylase inhibition activity of thaumatin increases its functionality against diabetes (Farag *et al*., 2022). In another literature study, thaumatin has been investigated for the potential changes in blood glucose levels, and weight gain in rats. The study results have been compared with aspartame and sucrose. According to the results, thaumatin has exhibited no changes in the blood glucose levels and weights of the rats. Thus, thaumatin has been suggested as natural sugar replacer (Khayata *et al*., 2016).

Until now, thaumatin has been applied to ice creams, soft drinks, and chewing gums to increase peppermint and spearmint flavours (Lindley, 2012; Joseph *et al*., 2019). However, thaumatin reacts with colourants in beverages and loses the sweetness feature (Miele *et al*., 2017). Thus, thaumatin can be implemented for colourant-free novel vegan food products without any change in the compound features.

2.3.4 Brazzein

Brazzein is the smallest sweet-tasting protein (Hung *et al*., 2019), and is a derivative of *Pentadiplandra brazzeana* Baillon. The sweetness of brazzein is 500 and 2000 times higher than 10% and 5% sucrose solutions respectively (Izawa et. al., 1996). The water solubility of brazzein is 50 mg/mL, the sweetness continues for 4h from 2.5 to 8 pH values (Farag *et al*., 2022), and brazzein is stable during the heating period up to 80 °C (Rajan & Howard, 2018). Moreover, the taste of brazzein is described as similar to sucrose (Guggenbuhl *et al*., 2020).

Without any after-taste or bitterness characteristics of brazzein, the sweet taste starts slower than sucrose and continues. Also, brazzein may apply to prevent tastes of steviol glycosides, NHDC, and/or other natural taste-masking agents (Hellekant & Danilova, 2005).
In the literature, brazzein and a 10% sucrose solution have been tested with mice, and the results of the study show that brazzein does not cause obesity, insulin resistance, or hypertrophy (Kim *et al*., 2020). Moreover, brazzein shows anti-inflammatory, anti-allergic and antioxidant activities (Chung *et al*., 2017). Nevertheless, FDA or EFSA has not approved brazzein yet.

2.3.5 Curculin (Neoculin)

Curculin is extracted from *Molineria latifolia* (Dryand. ex W.T.Aiton) Herb. ex Kurz, which is native to Malaysia (Neiers *et al*., 2016). Local people consume dried fruits of *Molineria* against the bitter taste of black tea and sour foods (Behrens *et al*., 2011). Curculin demonstrates 550 times more sweetness features than sucrose on a weight basis (Yamashita *et al*., 1990), acts as a flavour enhancer, and provides a sweet taste after water and bitter food products. Moreover, water

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solutions of the curculin exhibit a strong sweet taste at low pH (Behrens *et al.*, 2011). Curculin is stable at 50 °C for 1 hour and pH between 3 to 11 with antifungal activities (Farag *et al.*, 2022). However, FDA and EFSA have not approved curculin for food applications yet.

2.3.6 Mabinlin

Mabinlin is another sweet-tasting protein, found in the seeds of *Capparis masaikai* Levl. from Yunnan Chinese region (Neiers *et al.*, 2016). Mabinlin is heat stable and the sweetness maintains following 48 hours of incubation at 80 °C. Moreover, the sweetness of mabinlin is 400 times higher than sucrose on a molar basis (Kant, 2005). However, FDA and EFSA have not approved the compound for food applications yet. Therefore, similar to other taste-masking agents, the natural characteristics and stunning sweetness rates of the material may make it an attractive food ingredient for future vegan foods.

2.3.7 Miraculin

Miraculin, which is found in *Richardella (Synsepalum) dulcifica* (Schumach. & Thonn.) Baehni, demonstrates an unsweet feature. However, miraculin can transform a sour taste into a sweet feeling. The specific features of miraculin provide abilities to apply taste-enhancing of acids (Kurihara & Beidler, 1969). The rhesus monkey, chimpanzees, and individuals have tested the miraculin for taste modification. The activity of miraculin is thought that the molecule binds directly to sweet taste receptors and activation of the receptors occurs with the acidic pH including food intake. Therefore, the sweetness characteristics of miraculin are equal to 0.4 M sucrose after taking 0.1 M of citrate with 1 µM of miraculin, and miraculin 400 000 times sweeter than sucrose (Tafazoli *et al.*, 2019). Indeed, the compound might be an attractive ingredient for alternative meat production from fermented materials to prevent high acids in foods.

The sweetness of miraculin continues for more than 1hour (Misaka, 2013). When miraculin was consumed with lemon and strawberry, the sweet feeling of these fruits increased. Moreover, the savour of miraculin is close to sugar. Miraculin is a protein and is unstable under heating conditions but freeze drying or freezing is suggested to overcome the issue. More interestingly, the miraculin protects its stability for more than 6 months at 4 pH and 5 °C. The sweetness feature of miraculin demonstrates activities for insulin sensitivity and decreasing metallic tastes of foods for patients who take chemotherapy (Demesyeux *et al.*, 2020).

Recently, miraculin has obtained GRAS from FDA (FDA, 2021) (Table 1), and EFSA has approved the dried fruit of *Richardella* as a novel food (Turck *et al.*, 2021). Dried fruit has been suggested as a food supplement for adults except for pregnant and breastfeeding women. However, miraculin has not been approved by EFSA yet.

2.3.8 Monellin

Monellin is a sweet-tasting protein of *Dioscoreophyllum cumminsii* Diels. The sweetness characteristic of monellin is 4000 times higher than sucrose on a weight basis (Xue *et al.*, 2009). Besides, monellin has been applied as a sweetener, and flavour enhancer. The highest activities of monellin can be seen at pH between 2 and 9, however high pH and heating over 70 °C can denature the protein (Kaul *et al.*, 2018).
Monellin possesses a zero glycemic index which can be applied to the diets of diabetic people (Liu *et al.*, 2015). Moreover, any adverse effects of monellin have not been reported for food applications so far (Cai *et al.*, 2016). Nevertheless, except in Japan, EFSA or FDA has not approved monellin for food applications yet (Guggenbuhl *et al.*, 2020) (Table 1).

2.3.9 Steviol glycosides (SGs)

The leaves of the *Stevia rebaudiana* Bertoni are called 'stevia'. (Ramos-Tovar & Muriel, 2019). The sweetness-responsible compounds of stevia are stevioside, rebaudiosides (Reb) A, B, C, D, E, F, and M. Reb A and stevioside are the common compounds of the plant and the sweetness levels are 300 times higher than sucrose. According to sensory evaluation tests of two compounds, flavour of Reb A is close to sugar with fewer astringency characteristics. Lastly, Reb M and Reb D have been explored for their potential sensorial characteristics, and Reb M has exhibited quick sweetness, less off-taste, and less astringency. Nevertheless, Reb D has demonstrated higher sweetness and lower off-taste than Reb A (Mora and Dando, 2021).

Low caloric contents of SGs promote activities against obesity and type 2 diabetes with antifungal, antioxidant, antimicrobial, anti-tumour, anti-inflammatory, anti-hyperglycemic, and diuretic activities (Panagiotou *et al*., 2018; Zou *et al*., 2020; Lemus-Mondaca *et al*., 2012). Moreover, the digestion of SGs occurs poorly in the stomach and upper intestine. Then in the large intestine with the help of intestinal flora, the glycosides are hydrolyzed to aglycone steviol, in the enterohepatic circulation steviol is transformed into the steviol glucuronide and finally, extracted with the urine (Urban *et al*., 2013).

Stevia was approved as GRAS by the FDA, and the European Union accepted SGs as safe, in Argentina, Brazil, Japan, Paraguay, China, India, and South Korea approved SGs as safe as well (Table 1) (Perera & McChesney, 2021). Therefore, the recommended daily intake rate of SGs is the equivalent of 4 mg/kg body weight per day (Commission, 2011).

In the literature, Reb A, D, and M have been used as a sweetener in ice cream production and according to study results, sensorial acceptances of Reb D and M have been higher than Reb A. The characteristics of ice creams prepared with Reb D and M are described as creamy, pleasant, and sweet, but Reb A has been found with a metallic taste. More importantly, the aftertastes of Reb D and M have been described as similar to sucrose (Muenprasitivej *et al*., 2022).

So far, stevia has been applied to food products such as chocolate, chewing gum, beverages, jams, dairy products, pickles, and pastries as food additives (Ameer *et al*., 2017; Shannon *et al*., 2016). However, the aftertaste of stevia is an issue for food manufacturers because consumers are looking for palatable foods. Therefore, different techniques have been applied to eliminate the off-taste of stevia, for example, SGs have been encapsulated by freeze, spray and vacuum drying, and outcomes of the study have demonstrated that drying methods may help to remove the off-taste of stevia (Chranioti *et al*., 2016). Moreover, defined plant-based taste-masking agents in the present study can be applied to suppress the characteristic flavour of stevia for future vegan food products.

2.3.10 Glycyrrhizin

Glycyrrhizin is found in the root of Glycyrrhiza glabra L., with the well-known name licorice (liquorice) (Izawa *et al*., 2010). The sweetness levels of glycyrrhizin are 93-170 times higher than sucrose on a concentration basis (Kim & Kinghorn, 2002). Moreover, the ammonium salt of glycyrrhizic acid and monoammonium glycyrrhizinate is often applied and has been approved as a flavour enhancer by the FDA (Carocho *et al*., 2015) (Table 1). EFSA has also approved glycyrrhizin and the suggested consumption rate is 100 mg per day (Behrens *et al*., 2011). The suggested consumption rates of glycyrrhizin should not be overdosed due to its estrogenic characteristics which may cause side effects in young women, however, can be beneficial to women in the postmenopausal period to improve their bone health (Ishimi *et al*., 2019).

In the literature, glycyrrhizin has been applied to diet-related weight and insulin resistance in rats and according to study results, glycyrrhizin stabilizes the lipid profile (El-Magd *et al*., 2018). Moreover, glycyrrhizin demonstrates activities as an anti-tumour, antiviral and antioxidant agent (Zang *et al*., 2022). In the gastrointestinal tract, glycyrrhizin is converted to glycyrrhetic acid and 18β-glycyrrhetic acid 3-O-monoglucuronide by bacteria and the metabolites of glycyrrhizin are cytotoxic agents of tumour cells (Ruiz-Ojeda *et al*., 2019).

In history, glycyrrhizin was applied to soy sauces, meat products and snacks to mask the saline taste, and glycyrrhizin successfully suppressed the saltiness (Wilson, 2011). So far, glycyrrhizin has been applied to candies to give a specific licorice flavour.

The aftertaste of glycyrrhizin restricts food applications but the compound might be utilized to design innovative vegan foods with a strong taste of licorice, which can be an alternative who is looking for different flavours in vegan foods. In the forthcoming, more spicy and attractive flavours in vegan foods might be applied to be innovative and to design satisfying taste experiences for consumers as well. However, overconsumption of glycyrrhizin may create adverse effects such as pseudoaldosteronism – high blood pressure, and hypokalemia (Sharma *et al*., 2018). Thus, recommended consumption values of glycyrrhizin should be followed to not face the side effects of the compound.

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2.3.11 Mogrosides

Mogrosides are compounds of monk fruit or Luo Han Guo, the Latin name of the plant is *Momordica grosvenorii* Swingle which is native to northern Thailand and southern China. Luo Han Guo demonstrates 200 times more sweetness than sucrose on a weight basis, with metallic aftertaste and long-remaining sweetness (Mora & Dando, 2021). The sweet taste of monk fruit is the result of identified major contents of mogroside V and cucurbitane triterpenoid glycosides with minor contents of isomogroside V, mogroside IV and simamenoside I (Soejarto *et al*., 2019).

In a literature study, mogrosides demonstrate antihyperglycemic effects in rats. Moreover, mogrosides do not change blood glucose, insulin levels, and total energy intake (Mora and Dando, 2021). Besides, mogrosides can be used against diabetes and obesity; as anticancer, and anti-inflammatory agents (Liu *et al*., 2018).

So far, mogroside V has been patented as a bitterness blocker, and the activities of the compound have been tested for grapefruit and coffee, and stunning results have been obtained (Fletcher *et al*., 2015). The Luo Han Guo has been approved by FDA (FDA, 2015) (Table 1), however, is unapproved by European Commission (Wilson, 2011).

2.3.12 *Eriodictyon* derivatives

Eriodictyon californicum (Hook. & Arn.) Torr. is well known as "Yerba Santa" which is native to North America, and has been utilized against headache, asthma, aging, rheumatism, and lung infections (Moerman, 2009). Besides, *Eriodictyon* has demonstrated function in bitterness blocking of quinine (Fletcher *et al*., 2015). Bitterness-blocking compounds of *Eriodictyon* are homoeridictyol, eridioctyol, sterubin, and sodium salt of *E. californicum* (Ley *et al*., 2006; Ley *et al*., 2005). Except for those compounds of *Eriodictyon*, 6-methoxyhesperetin, 4'-isobutyrylhomoeriodictyol, 6-methoxyhomoeriodictyol, 7-methoxylated flavanones, sakuranetin, 6-methoxysakuranetin and jaceosidin are thought to act against bitterness as well (Fletcher *et al*., 2011). Moreover, the flavanones of *Eriodictyon* exhibit health-promoting activities such as eriodictyol demonstrates antioxidant, anti-inflammatory, and antidiabetic activities (Zhang *et al*., 2012). In a literature study, overweight and obese women have been fed with *Eriodictyon* derivatives including capsules for 12 weeks and at the end of the research, the compounds demonstrate reducing features of body weight without any adverse effects (Modinger *et al*., 2021). Thus, similar to other suggested taste-masking agents in the present study, *Eriodictyon* derivatives demonstrate functions not only as taste suppressors but also as health promoters.

2.3.13 Inulin

Inulin occurs inherently in many fruit and vegetables but is yielded commercially from a dahlia, Jerusalem artichoke, and chicory (Flamm *et al*., 2001). Inulin is a part of non-digestible carbohydrates, called fructans, and the structure of inulin consists of β-(2–1)-glycosidic-bond with 2 to 60 fructose molecules and one terminal glucose (Perović *et al*., 2021).

Inulin is used as sugar, fat replacer, and soluble dietary fibre in food products (Barclay *et al*., 2010). The fat substitutive feature of inulin with long-chain fractions makes the material a stunning ingredient for alternative yoghurt, ice cream, and mayonnaise production with rich textural and sensorial aspects (Shoaib *et al*., 2016; Ahmed & Rashid, 2019). In a literature study, inulin has been applied in vegan kefir products, and study results support the benefits of inulin for alternative dairy food production (Alves *et al*., 2021). In another study, sugar-free dark chocolates have been prepared with inulin/polydextrose and stevia/thaumatin mixtures as sugar replacers. The study results have demonstrated similarities with the control group which includes 48% of sugar. However, the health benefits of non-caloric sugar replacers are higher and these natural compounds are supposed to be novel food ingredients for future foods (Aidoo *et al*., 2015).

Moreover, inulin demonstrates anti-cancer and anti-inflammatory activities. Inulin is only digested by gut bacteria and improves healthy microflora which protects from colon cancer. Inulin is non-toxic to the human body and demonstrates activities to increase cardiovascular health with increased calcium and magnesíum intake rates (Barclay *et al*., 2010).

The gelatinization, melting point, and gel integrity characteristics are the most attractive features of inulin for the food industry (Ahmed & Rashid, 2019). Thus, inulin may apply in meat alternatives as a fat replacer with the results of reduced-fat, enhanced texture, and increased mouthfeel features (Shoaib *et al.*, 2016; Devereux *et al.*, 2003). Finally, inulin has been approved by EFSA as a sugar and fat replacer (EFSA, 2007), and by FDA as GRAS (FDA, 2018) (Table 1).

2.3.14 Crude salt replacements as natural flavour enhancers

Salt reduction with substituted natural ingredients is a challenge for the food industry. Due to the features of salt, such as desired texture, long shelf life, flavour, and functionality; however, herbs, spices, and yeast extracts have been applied thus far, as flavour enhancers instead of sodium salt (Ainsworth & Plunkett, 2007; Taladrid *et al.*, 2020). Furthermore, varied plant derivatives are proposed as salt replacers such as garlic, rosemary, oregano, saffron, paprika, chilli, mint, and blended herbs (Taladrid *et al.*, 2020; campdenbri.co.uk). Apart from these, low–sodium-included vegetable juices have been prepared with organic acids (Allison & Fouladkhah, 2018). Also, applications of edible seaweeds are popular in Asian cuisine for salt reduction. Importantly, seaweeds promote high protein, omega-3 fatty acids, carotenoids, polyphenols, minerals, and vitamin contents (Gullón *et al.*, 2021). On the other hand, umami can suppress the bitterness of plant derivatives, and increase the salty taste in foods (Wang *et al.*, 2020). As, taste enhancers activate taste buds in the mouth which are linked to the umami taste receptors (Brandsma, 2006). Therefore, umami taste receptors perceive flavour enhancers as demonstrating high salt content, and the feature deceives the brain signalling. Today, the known umami taste enhancers are glutamate, aspartate, inosinate, guanylate, cytidylate, adenylate, uridylate, and succinate (Wang *et al.*, 2021).

The features of umami help to FDA to approve monosodium glutamate as GRAS (FDA, 2012). Moreover, EFSA accepts glutamates and glutamic acid implementations in foods with the recommended level of a maximum of 10 g/kg of the food product (EFSA, 2017).

Table 1. Approvals of natural taste-masking agents by health authorities

Compound	Approval by Health Authorities			
	EFSA	FDA	Other	References
NHDC	✔	✔	✔	EFSA (2011), FDA (2019), ISA (2015)
Thaumatin	✔	✔	✔	EFSA (2016), FDA (2015), Carocho et al. (2017)
Miraculin		✔		FDA (2021)
Monellin			✔	Gugenbühl (2020)
Steviol glycosides	✔	✔	✔	EFSA (2016), FDA (2015), Perera & McChesney (2021)
Glycyrrhizin	✔	✔		Carocho et al. (2015), Behrens et al. (2011)
Mogrosides		✔		FDA (2015)
Inulin	✔	✔		EFSA (2007), FDA (2018)

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2.4 The challenges of natural, non-toxic taste maskers for vegan people and the food manufacturers

Depending to the Grounded-Cognition Theory of Desire (Papies *et al.*, 2020), people employ varied senses at the same time during eating. For instance, imagination or the sound of food stimulates brain cells for appetite. Moreover, the appearance, smell, and texture of the food are the priorities of consumers to purchase a food product. Nevertheless, natural replacers of salt, sugar, and fat may cause some issues with the food texture, because salt, sugar, and fat provide stable texture, enhanced flavour, and anti-microbial activity of food products (Hoppu *et al.*, 2017; Dötsch *et al.*, 2009).

Aftertastes of compounds can seem a challenge for the food industry. The specific flavours of natural taste blockers might be applied in innovative meat and dairy alternatives, and flavours may create interesting outcomes for the final food products.

On the other hand, natural food ingredients influence purchasing activities of consumers (Román *et al.*, 2017). Natural and non-toxic taste blockers function in small amounts without toxicities and with promoting health benefits. Therefore, a small number of natural taste blockers' implementations should have been investigated for food production.

3. Conclusions and future trends

A vegan diet supports healthy body functions and sustainable food systems together. Moreover, during the COVID-19 pandemic, animal-carried viruses created huge concerns (Attwood & Hajat, 2020). Therefore, many people prefer to decrease meat consumption and/or be vegetarian/vegan (Loh *et al.*, 2021).

Natural ingredients in vegan processed food products are more attractive than artificial content. Nevertheless, vegan foods with natural ingredients should exhibit acceptable texture, desirable flavour, and scent, before healthy characteristics. Bitterness and off-tastes of plant-based foods, which are unpalatable for many consumers, are suppressed by sugar, salt, and fat. However, health authorities are looking for strategies to reduce the overconsumption of sugar, salt, and fat in processed foods. Thus, natural taste-masking agents such as glycyrrhizin, miraculin, monellin, inulin, neohesperidin dihydrochalcone, steviol glycosides, and thaumatin can be utilized in small amounts with the approval of health authorities.

However, the food preferences of individuals are shaped by culture and geography (Dao *et al.*, 2021). For instance, Mexican people desire hot-spicy foods, but for many other cultures, traditional Mexican foods are extremely hot and spicy. In other words, hedonic preferences affect the food choices of people (Ludy & Mattes, 2012).

Food transformation of people to novel foods is not easy because of gained food palatabilities which are not only shaped by the appearance, smell, taste, and texture of food products, but also by genetic inheritance, dietary habits, gut microbiota, food affordability and previous experiences with food products are crucial parameters (Mennella *et al.*, 2015; Dao *et al.*, 2021; Chamoun *et al.*, 2018).

Vegan foods are not an issue due to religious beliefs. Veganism is suitable for all religions, but, the main challenge is the neophobia of people or convincing individuals to consume vegan foods because of health and environmental concerns. Thus, to find the best recipes for vegan foods which are going to be prepared with sugar and/or salt substitutes to mask the bitter tastes of plant-based ingredients, extensive sensorial tests are essential to attract many people from varied cultures with different food preferences.

Conflict of interest

The author confirms that this article's content has no conflict of interest.

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Research Paper

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The potential of cabbage waste extract as a bio-stimulant for enhancing growth, biochemical constituents, and oil quality of thyme (*Thymus vulgaris*)

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Thyme herb; total carbohydrates; mineral content; oil composition; correlation

Thyme (*Thymus vulgaris L.*) is an important cultural aromatic plant, whose herb and essential oils (EOs) have been used in many industrial and medicinal applications. Herb and EO yields are often negatively influenced by various factors, so it is important to keep finding new growing procedures that increase the quantitative content of herbs and EOs. Therefore, this paper is focused on the effects of applying cabbage extract (CE) at different concentrations on morphological parameters, mineral contents, total carbohydrates, and the quantitative and qualitative content of EOs in *T. vulgaris* plants. Two trials were conducted during two successive seasons 2017/2018 and 2018/2019 to assess the growth and essential oil response of thyme plants to different concentrations of natural plant extract. Cabbage extract (1, 2, 4, 6, 8 %) was sprayed on thyme plants four times during each season. Besides, spraying cabbage extract had a noticeable positive effect on vegetative growth parameters and the oil percent of thyme plants. All concentrations caused increases in N%, P%, K%, and carbohydrates % and caused variable effects between all oil compositions as compared to control plants. Moreover, foliar spray with 2 and 4% of CE caused an increment in the values of morphological parameters, carbohydrates, minerals, and all oil components as compared with control plants. The major compounds of thyme oil (thymol, p –Cymene, and γ- terpinene) showed the highest percentage in oil of herb harvested at the first and second harvests (H1 and H2) after foliar spray with 2 and 4% CE. In conclusion, the leaves waste of cabbage plants can be used as a bio-stimulant.

1. Introduction

The decrease in natural resources and the environmental disparity induced by current agricultural practices presented a serious challenge to food and nutritional drift sustainability. The overall population has gradually risen (1.13 percent annually) and the food demand has been steady. A significant issue is the adverse effect of ecological threats arising from the non-judicial use of chemical fertilizers and pesticides and from sustainable management of soil fertility (Wezel *et al*., 2014). Unwanted soil biological and chemical changes have not only called into question sustainable food production but have also called for troubling malnutrition. In addition, the changing climate scenario has added enormous unforeseen farming costs. The economic and environmental cost of food rising today is much costlier than in the last decades. Cost-efficient and environmentally sustainable farming practices are necessary in order to combat such situations, and bio-stimulants are a feasible option in this context (Rathore *et al*., 2009; El-Serafy and

El-Sheshtawy 2020). There is a lot of interest in natural products in agriculture (horticulture), which will at the same time boost the yield and biological value of the plants grown without adverse effects on the natural environment. These groundbreaking products are plant-growth bio-stimulants that can be applied effectively to sustainable farming. This behavior leads to the effective use of environmental limited resources (e.g., water) by plants and protects them from harmful agents caused by stressful conditions and pathogens (El-Serafy, 2018; Stamford *et al.*, 2019; Sofy *et al.*, 2020). Bio-stimulants consist of different substances or microorganisms that have been found to boost plant growth and development, improve nutrition uptake, abiotic stress tolerance, and crop quality characteristics (Shubha *et al.*, 2017; Caradonia *et al.*, 2018; Rezaei-Chiyaneh *et al.*, 2019). Plant growth bio-stimulants don't provide plants with sufficient quantities of essential nutrients but boost rooted system uptake and promote plant growth under stress because of increased antioxidant activity (Du Jardin 2015). Several metabolic processes such as photosynthesis, respiration, absorption of ions, and nucleic acid synthesis have been impaired by it. Bio-stimulants improve the availability of food, increase antioxidants, improve the capacity of water retention metabolism, and increase the development of chlorophyll. In addition to several benefits in agricultural practice, the use of bio-stimulants is suggested as a safe method for enhancing food crop nutrition (Latif and Mohamed 2016; Prakash and Verma 2016; Colla *et al.*, 2017; Akladious and Mohamed 2018).

There are different classes of bio-stimulants including seaweed and botanicals extracts, humic and fulvic acids, proteins hydrolysates, other nitrogen compounds, beneficial bacteria, fungal products, chitosan, and other biopolymers, and inorganic compounds (Mohamed and Gomaa 2012; Calvo *et al.*, 2014; Du Jardin 2015). Some research focused on the production of organic stimulants and selected plant biomass from higher plants, which are readily available and recognized for their specific properties, i.e., mugwort (*Artemisia vulgaris L.*), calendula (*Calendula offcinalis*), purple coneflower (*Echinacea purpurea*), chamomile (*Matricaria chamomilla*) and basil (*Ocimum basilicum L.*) (Godlewska *et al.*, 2019). The obtained plant extracts contain plant growth-promoting substances, such as amino acids, vitamins (Paradikovic *et al.*, 2011), nutrients, micro and macro elements, betaines, mannitol (Saa *et al.*, 2015), polyphenols and phytohormones (Ertani *et al.*, 2016). In addition, the extracts from plants promote the absorption and transportation of micro and macro elements of the soil in the plant (Paradikovic *et al.*, 2011).

This study has focused on the production of bio-stimulants from white cabbage (*Brassica oleraceae*) which is one of the most widely grown plants in the world. It belongs to the genus Brassica and the mustard family, Brassicaceae (Cruciferae). Brassicaceae is a monophyletic group of 338 familiar genera and about 3700 species worldwide, except in Antarctica (Al-Shehbaz *et al.*, 2006). White cabbage plays an important role in many countries cultures and traditional cooking and is commonly used in traditional medicine. White cabbage is an important source of phytonutrients in the human diet due to its inexpensive prices and availability in local markets. White cabbage is a cheap, but nutritious food source, which offers nutrients and phytochemicals to promote health. Phytochemicals have been very recent in scientific study, and white cabbage as a major source of glucosinolates, phenolic substances, carotenoids, and vitamins, is well known (Kapusta-Duch *et al.*, 2012; Avato and Argentieri, 2015).

Moreover, white cabbage was used as the raw material for processing bio-extract (the outside cabbage leaves that are peeling off until the cabbage is sold on the market). A source of inorganic nutrients and amino acids was shown to be bio extract from cabbage leaves waste (Grubb and Abel, 2006) and also includes minerals such as phosphorus, potassium, calcium, and iron. Cabbage is one of the most common vegetable plants in the world, besides tomatoes and onions (Nyatuame *et al.*, 2013).

Thyme is one of the most significant species in the family of the Lamiaceae and is used in the food, cosmetic and pharmaceutical industries. The key components of volatile thymus oils are thymol and carvacrol (Nickavar *et al.*, 2005; Trindade *et al.*, 2018). Essential oils play a key role as antiviral, antibacterial, antimycotic, insecticidal, and herbivore defensive in plants in nature (Bakkali *et al.*, 2008). It includes a large range of active phytochemicals (for example, flavonoids, terpenes, polyphenols, and coumarins). It is a supplement for the cancer-prevention agent that is late recommended and has a variety of useful effects such as anti-spasmodic, antioxidants, and anthelmintic (Salehi *et al*., 2018). Also, because of its bactericidal and fungicidal effects, it is important as a crude medicine in the production of plant drugs. The alcoholic extract is antiseptic and expectorant and is an essential component of cough medicines (Nikolić *et al*., 2014). In addition, *T. vulgaris* and thymol are very promising agents to protect agricultural plants and stored products (Matusinsky *et al*., 2015; Park *et al*., 2017).

Little research used the cabbage leaves extract as a bio-stimulant, therefore, the objective of this study was to evaluate the effect of different concentrations of cabbage waste leaves extract on the morphological, biochemical, and oil composition of *T. vulgaris,* and to study the effect of the extract on thyme under harvesting frequency.

2. Materials and Methods

2.1. Cabbage extracts preparation and chemical composition

Fresh leaves of cabbage were cut into small pieces, dried, ground, and extracted. For extraction, ethyl alcohol 80% was added to the powder and shacked on a shaker at room temperature for 48 hrs. Extracts were purified by filtering twice through Whatman filter paper no.1. After purification, the crude ethanolic extracts were concentrated using a rotary evaporator at 45 °C under reduced pressure. Each extract was diluted to the required dose (0, 1, 2, 4, 6, and 8%).

Folin reagent was used to determine the total soluble protein content according to the method of Lowry *et al*., (1951). The phenol-sulphuric acid method was used to determine the total carbohydrates in cabbage extract according to Dubois *et al.* (1956). The absorbance read was at 490 nm using a spectrophotometer. The amounts of total phenols in the plant extract were measured using the folin reagent at 725 nm UV-Vis spectrophotometer according to Dihazi *et al*., (2003) method and the gallic acid curve (99.5 percent) used as a standard. Total nitrogen was determined using a modified Kjeldahl procedure (Bradstreet, 1965). Phosphorus was measured as molybdovanadophosphoric acid and was read at 470 nm on a visible light spectrophotometer (Franson, 1975).

Calcium, magnesium, and potassium were determined by atomic absorption or emission spectrophotometry (Hanlon, 1998). Sulphur was measured using a gravimetric method (Hanlon, 1998). Fe, Zn, Cu, and Mn were determined by atomic absorption spectrophotometer (Marguí *et al*., 2022). The ascorbic acid (vitamin c) concentration of the cabbage extract was analyzed using the method described by Mukherjee and Choudhuri (1983). The tocopherol content was measured at wavelength 520 nm using a 2.2-dipyridyl reagent according to the method of Philip *et al.* (1954). Thiamine, cellulose, and hemicellulose were determined according to Bishop *et al.* (1958) with modification by Dever *et al.* (1968). The amino acid analyser was used to determine amino acid fractions in the leaves of cabbage plants according to El-Gala and Amberger (1988). Essential and non-essential amino acids were injected as standard.

2.2. Experimental layout and design

Seeds of thyme (*T. vulgaris*) were obtained from the Enza Zaden, Assem Doss Co. Egypt. Waste leaves of cabbage were obtained from markets. The seeds were sown in October during the two successive seasons of 2017/2018 and 2018/2019 in the nursery and germinated after about two weeks. In the last week of November, uniform and healthy seedlings of about 10 cm in height were transplanted into 35 cm diameter plastic pots filled with a prepared growing medium composed of sandy loam soil at the Experimental Farm of the Faculty of Agriculture, Cairo University, Egypt. Before sowing, the physical and chemical properties of the soil of the experiment were determined by standard methods according to Jackson (1973). The soil texture during the two growing seasons was consisting of 31.7 and 33.1% sand, 39.6 and 40.2% silt, and 27.3 and 25.1% clay respectively. Chemical analysis of the soil during the two growing seasons showed that pH = 7.5 and 7.3 respectively and available N, P, and K were 45.6 and 47.9, 7.8 and 7.4, and 415 and 434 ppm respectively (Table 1).

The experimental layout for each season was a Randomized complete Blocks Design, with three replications. Thyme plants were sprayed with cabbage extract (1, 2, 3, 6, 9 %) while control plants were sprayed with water by hand sprayer four times along each season starting from six weeks after transplanting and every month thereafter. Thyme plants were harvested twice (first and second harvest at 3 and 6 months after transplantation) manually 10 cm above the soil

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Table 1. Physical and chemical properties of the experimental soil in the two growing seasons.

Soil properties	2017	2018
Coarse sand %	1.4	1.6
Fine sand %	31.7	33.1
Silt %	39.6	40.2
Clay %	27.3	25.1
Soil texture	Clay Loam	Clay Loam
pH	7.5	7.3
Organic matter %	1.93	1.85
Available N ppm	45.6	47.9
Available P ppm	7.8	7.4
Available K ppm	415.0	434.0

ppm: part per million

surface. At harvest, the following parameters were estimated: plant height, fresh and dry weights of the plant (dry weight was carried out by drying at 40°C for 72 hours in an electric oven), essential oil percentage, and composition. Some chemical parameters are measured in the dried leaves as nitrogen, phosphorus, potassium, and carbohydrates. Essential oil yield was also calculated. The extracted essential oil was dehydrated over anhydrous sodium sulphate and stored in a refrigerator until Gas Chromatography Mass Spectrometry (GC/MS) analysis.

2.3. Determination of essential oil content

Volatile oil percentage was determined in dry herbs according to the method described in the Egyptian Pharmacopoeia (1984) using Clevenger's apparatus for the determination of essential oil according to Guenther (1961).

2.4. Determination of carbohydrates

Total carbohydrates in dry herbs of thyme plants were determined based on the method of phenol sulfuric as described by Dubois *et al.* (1956). Pure glucose was used as the standard.

2.5. Determination of minerals

For the determination of minerals in dry herb of thyme plants, approximately 1.0 g of the dried leaves were put in a micro-Kjeldahl flask and pure HNO_3 (5 mL) was added. The samples were left to stand overnight at room temperature (25 ± 2°C). Then, the flask contents were heated to 120°C for 3 h in a Kjeldatherm block digestion system. After cooling at room temperature, H_2O_2 (2 mL) was added, and the samples were heated again to 120°C until digestion was completed (approximately 2 h). Finally, colourless solutions were filtered with a Whatman no. 42 filter paper into 100 mL volumetric flasks and diluted (Baker and Smith, 1974). The N concentration was determined using a micro-Kjeldahl apparatus as per Horwitz (1956). The blue colour method was followed to assess the P concentration by reducing molybdenum to molybdophosphoric acid in sulfuric acid to exclude arsenate (Franson, 1975). Standard reagents, such as sulfomolybdic acid (H_2MoO_7S), molybdenum blue, diluted H_2MoO_7S, and 8% (w/v) $NaHSO_3$-H_2SO_4, were used. The K concentration of the herb was assessed using a flame photometer as outlined by Page *et al.* (1982).

2.6. Determination of oil composition using GC-MS analysis

A GC-MS instrument with the following specifications was used for qualitative and quantitative analyses: TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA) coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole

Mass Spectrometer). The GC/MS system was equipped with a TG-WAX MS column (30 m × 0.25 mm i.d., 0.25 µm film thickness.(The carrier gas was helium at a flow rate of 1.0 mL min^{-1} and a split ratio of 1:10 using the following temperature program: 40°C for 1 min; rising at 4.0°C min^{-1} to 160°C and held for 6 min; rising at 6°C min^{-1} to 210°C and held for 1 min. The injector and detector temperatures were held at 210°C. Diluted samples (1:10 hexane, v/v) of 0.2 µL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40–450. Most of the compounds were identified using mass spectra (authentic chemicals, Wiley spectral library collection, and NIST library) and the remained compounds were identified by comparing their mass spectra and relative retention indices of the peaks with those of standard compounds under the same conditions (Vimolmangkang *et al*. 2010).

2.7. Statistical Analysis

In each growing season, normality distributions of data for different traits were checked out by the Shapiro and Wilk technique (Shapiro and Wilk 1965). Data for the studied traits were analysed as a factorial experiment arranged in randomized complete blocks with three replications. A combined analysis of variance was conducted for the two seasons according to Gomez and Gomez (1984). A homogeneity test of error variances was performed by using the Levene test (Levene 1961). Thus, if the hypothesis that the two error variances are homogeneous cannot be rejected, the combined analysis of variance was computed. Tukey's HSD (honestly significant difference) test at the 5% level of significance was used to examine differences among treatment means. The estimates of simple correlation coefficients (r) were calculated between all possible pairs of the studied traits according to the method described by Steel *et al*. (1997) and the statistical significance of correlations was calculated according to Gomez and Gomez (1984).

3. Results

3.1. Chemical composition of cabbage extract

The chemical composition of cabbage leaf extract is shown in Table 2, the cabbage extract is rich in some macro and microelements and vitamins, i.e. thiamine, ascorbic acid, and tocopherols, as well as some osmoprotectants, i.e. amino acids. Also, it contains carbohydrates, protein, fibre, cellulose, and hemicellulose. The extract has high concentrations of zinc, sodium, and manganese (170, 130, and 120 mg $100g^{-1}$DW) respectively, and also high concentrations of potassium, sulphur, phosphorus, calcium, and nitrogen (1.2, 1.1, 0.79, 0.68, and 0.42 g $100g^{-1}$DW) respectively. The extract has high concentrations of vitamin C and vitamin E about 36.6 and 15.0 mg $100g^{-1}$DW respectively. In addition, the extract has high amounts of amino acids such as aspartic acid, glutamic acid, alanine, leucine, proline, threonine, and glycine (70.1, 53.2, 40.2, 39.6, 36.3, 35.2 and 30.1 mg $100g^{-1}$ DW) respectively.

3.2. Effect of cabbage extract on morphological parameters

Foliar application of cabbage leaf extract (CE) had a positive effect on studied vegetative growth parameters of thyme plants compared to control (spraying with water) (Table 3). The results show significant differences among treatments for all studied traits (plant height, plant fresh weight, plant dry weight, and oil percent). Foliar spraying with CE at 4 % concentration gave the highest value of plant height (29.3 cm) and the highest values of plant fresh and dry weights as well as oil percent (25.0, 6.63 g, and 0.15%) respectively. The results in Table 4 showed that the second harvest H2 gives the high pronounced increases in all growth parameters like plant height (29.5 cm), fresh weight (26.1 g), plant dry weight (6.85 g), and oil percent (0.14%). The data also in table 4 showed that the CE at 4% concentration gave the highest values in all growth parameters when the plants were harvested after 6 months of transplantation (H2).

3.3. Effect of cabbage extract on mineral contents and total carbohydrate

Herein, spraying thyme plants with different concentrations of CE (1, 2, 4, 6, and 8%) caused a significant increase in N, P, K, and total carbohydrates as compared to control plants (water spray) (Table 4). The most pronounced increases were recorded in plants sprayed with 2 and 4% of cabbage extract about (3.49 and 3.50%) in N content, (0.48 and 0.48%) in P con-

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Table 2. Chemical analysis of cabbage powder per 100 g dry weight

Component	Concentration	Component	Concentration (mg)
Protein (%)	13.2	Aspartic acid	70.1
Fat (%)	1.6	Threonine	35.2
Carbohydrate	68.7	Serine	25.0
Fiber (%)	5.48	Glutamic acid	53.2
Nitrogen (g)	0.42	Proline	36.3
Phenolic compounds (mg)	90.5	Glycine	30.1
Calcium (g)	0.68	Alanine	40.2
Magnesium (g)	0.11	cysteine	2.27
Phosphorus (g)	0.79	Valine	28.5
Potassium (g)	1.2	Isoleucine	21.0
Copper (mg)	0.4	Leucine	39.6
Iron (mg)	4.5	Tyrosine	22.5
Sulfur (g)	1.1	Phenylalanine	24.1
Sodium (mg)	130	Histidine	10.5
Zn (mg)	170	Lysine	30.2
Manganese (mg)	120	Arginine	22.0
Cellulose (%)	13.7	Tryptophan	4.90
Hemicellulose (%)	11.1		
Vitamin B1 (Thiamine)(mg)	0.124		
Vitamin C (ascorbic acid) (mg)	36.6		
Vitamin E (tocopherols) (mg)	15.0		

tent, (4.10 and 4.18%) in K and (21.2 and 22.3%) in total carbohydrate respectively as compared with control plant. In addition, the plants harvested at the first harvest time after 3 months of transplantation gave the highest value of all the above contents compared with the plants harvested at the second harvest time.

3.4. Effect of cabbage extract on oil composition by GC/MS analysis

The chemical composition of the essential oil of *T. vulgaris* was determined on sample sets from the second (2019) season, thirteen compounds were identified. The identified compounds were grouped into three categories: (i) major compounds (more than 10%), (ii) minor compounds same as (1% and 10%), and (iii) trace compounds (less than 1%) (data are not shown). In addition, thymol (35.9- 56.7%), p -cymene (4.70-18.3%), and γ- terpinene (4.10-17.4%) were the major compounds in *T. vulgaris* (Table 5). The minor compounds were β -myrcene, α -terpinene, cis- sabinene hydrate, linalool, borneol, thymyl methyl ether, carvacrol methyl ether, and caryophellene, and the trace compounds were α-thujene and β-pinene.

Foliar spray with different concentrations of CE showed variable effects between all oil compositions. Foliar spray with 2 and 4% of CE caused an increment in the values of all oil components as compared

Table 3. Effect of foliar spray with cabbage extract on plant height, plant fresh weight, plant dry weight, and oil percent of thyme under different harvesting times

Treatments		Plant H (cm)	FW/P (g)	DW/p (g)	Oil (%)
CE%					
0		19.7±1.5 d	13.7±1.6 d	3.01±0.50 d	0.06±0.010 d
1		24.7±2.2 b	19.2±2.9 bc	4.40±0.82 c	0.09±0.009 c
2		25.9±2.2 b	21.0±3.1 b	5.26±1.05 b	0.12±0.011 b
4		29.3±2.2 a	25.0±3.2 a	6.63±1.23 a	0.15±0.019 a
6		25.2±0.9 b	18.4±2.3 c	4.23±0.68 c	0.13±0.015 b
8		22.5±1.1 c	14.6±1.3 d	3.31±0.38 d	0.08±0.009 c
Harvest:					
H1		19.6±0.5 b	11.2±0.4 b	2.09±0.10 b	0.07±0.004 b
H2		29.5±0.8 a	26.1±1.2 a	6.85±0.43 a	0.14±0.007 a
CE% x Harvest					
0%	H1	15.0±0.7 g	8.6±0.3 i	1.38±0.09 j	0.03±0.005 i
0%	H2	24.4±0.8 de	18.8±0.8 e	4.64±0.21 e	0.10±0.006 d-f
1%	H1	18.1±0.7 f	9.9±0.6 hi	1.74±0.12 i	0.07±0.007 gh
1%	H2	31.4±1.6 b	28.5±1.2 c	7.05±0.32 c	0.12±0.009 d
2%	H1	19.6±0.7 f	10.6±0.6 g-i	1.91±0.13 hi	0.09±0.008 e-g
2%	H2	32.2±1.9 b	31.3±0.7 b	8.61±0.58 b	0.15±0.009 c
4%	H1	22.5±1.2 e	14.7±0.7 f	2.98±0.13 f	0.09±0.009 e-g
4%	H2	36.1±0.6 a	35.2±1.6 a	10.28±1.17 a	0.21±0.009 a
6%	H1	22.9±0.5 e	12.7±0.4 fg	2.42±0.14 g	0.08±0.006 f-h
6%	H2	27.4±1.2 c	24.1±3.2 d	6.05±0.84 d	0.17±0.009 b
8%	H1	19.3±0.7 f	10.7±0.5 gh	2.13±0.14 h	0.06±0.005 h
8%	H2	25.6±1.0 cd	18.5±1.1 e	4.48±0.25 e	0.11±0.006 de

CE = Ethanolic extract of Cabbage leaves (Cabbage Extract).
Values are means ±SD. Different letters next to the mean values in each column indicate significant difference according to Tukey's test

with control plants. The major compounds of thyme oil (thymol, p –cymene, and γ- terpinene %) showed the highest percentages in oil of the herb harvested at the first and second harvests (H1 and H2) after foliar spray with 2 and 4% CE. These compounds represented about 80 % of the oil constituents of thyme. In addition, the highest percentages of the major compounds in *T. vulgaris* oil were recorded in the plants harvested at the second harvest time H2 than the first harvest time H1.

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Table 4. Effect of foliar spray with cabbage extract on mineral contents (N, P, K) and total carbohydrate of thyme under different harvesting time

Treatment	Harvest	N%	P%	K%	TC
CE%					
Control		3.20±0.35 b	0.38±0.02 b	3.14±0.15 b	16.6±0.8 c
1%		3.42±0.29 a	0.46±0.03 ab	3.94±0.13 a	19.4±0.5 b
2%		3.49±0.27 a	0.48±0.04 a	4.10±0.14 a	21.2±0.5 ab
4%		3.50±0.32 a	0.48±0.04 a	4.18±0.12 a	22.3±0.8 a
6%		3.35±0.34 ab	0.50±0.05 a	3.82±0.26 a	19.8±1.0 b
8%		3.32±0.35 ab	0.45±0.05 ab	3.68±0.19 ab	19.4±0.4 b
Harvest					
H1		4.09±0.03 a	0.52±0.02 a	4.10±0.09 a	19.6±0.7 a
H2		2.67±0.04 b	0.39±0.01 b	3.52±0.11 b	20.0±0.4 a
CE% x Harvest					
Control	H1	3.98±0.07 a	0.41±0.03 c	3.38±0.12 b-d	15.1±0.6 e
Control	H2	2.41±0.06 c	0.35±0.04 c	2.90±0.21 d	18.1±0.6 de
1%	H1	4.06±0.07 a	0.51±0.03 b	4.15±0.08 a-c	19.6±0.9 b-d
1%	H2	2.78±0.03 b	0.41±0.03 c	3.72±0.17 a-d	19.1±0.9 b-d
2%	H1	4.09±0.09 a	0.55±0.03 ab	4.34±0.16 a	22.0±0.6 ab
2%	H2	2.89±0.03 b	0.41±0.02 c	3.86±0.13 a-c	20.4±0.3 b-d
4%	H1	4.21±0.05 a	0.54±0.04 ab	4.42±0.09 a	24.0±0.6 a
4%	H2	2.79±0.09 b	0.42±0.06 c	3.94±0.09 a-c	20.58±0.6 b-d
6%	H1	4.11±0.08 a	0.61±0.03 a	4.23±0.15 ab	17.9±0.7 de
6%	H2	2.60±0.06 bc	0.39±0.02 c	3.40±0.37 b-d	21.7±0.9 a-c
8%	H1	4.09±0.06 a	0.52±0.04 b	4.06±0.12 a-c	18.8±0.6 cd
8%	H2	2.56±0.09 bc	0.38±0.03 c	3.30±0.12 cd	20.0±0.6 b-d

CE = Ethanolic extract of Cabbage leaves (Cabbage Extract).
Values are means ±SD. Different letters next to the mean values in each column indicate significant difference according to Tukey's test

Table 5. Effect of foliar spray with cabbage extract on oil composition (%) of thyme under different harvesting times during the second season

Treatment / Component		β -Myrcene	α -Terpinene	ρ -Cymene	γ-terpinene	Cis- sabinene hydrate	Linalool	Borneol	Thymyl methyl ether	Carvacrol methyl ether	Thymol	Caryophellene
CE%												
Control		1.27±0.06 d	1.47±0.03 a	14.5±0.3 ab	9.0±1.4 b	1.57±0.12 a	3.19±0.13 a	4.90±0.39 a	2.21±0.36 b	1.79±0.10 bc	49.7±3.1 a	2.83±0.15 b
1%		1.76±0.04 c	1.49±0.05 a	14.6±1.7 a	10.5±3.1 a	1.53±0.04 ab	2.83±0.10 b	3.65±0.64 bc	2.15±0.27 b	2.02±0.05 a	51.9±6.2 a	3.54±0.42 a
2%		1.97±0.04 bc	1.60±0.09 a	13.4±2.7 b	10.3±2.8 ab	1.44±0.03 b	2.81±0.15 b	4.04±0.25 b	2.48±0.36	1.53±0.09 d	50.1±6.4 a	2.52±0.26 c
4%		2.10±0.03 ab	1.64±0.03 a	10.6±1.7 c	11.2±2.1 a	1.12±0.08 c	2.72±0.09 b	3.34±0.34 c	2.51±0.06 b	1.56±0.05 d	55.3±4.6 a	2.91±0.22 b
6%		1.95±0.04 bc	1.69±0.27 a	9.6±2.2 c	10.2±1.4 ab	1.11±0.04 c	2.69±0.22 b	3.50±0.34 c	3.11±0.46 a	1.84±0.07 b	55.0±0.16 a	3.42±0.16 a
8%		2.27±0.05 a	1.64±0.11 a	9.8±0.2 c	10.1±2.9 ab	1.18±0.19 c	2.14±0.34 c	3.75±0.58 bc	2.21±0.14	1.74±0.09 c	51.6±6.4 a	3.36±0.51 a
Harvest												
H1		1.84±0.08 b	1.42±0.03 b	9.0±0.8 b	5.1±0.4 b	1.40±0.05 a	2.69±0.08 b	4.33±0.15 a	2.67±0.11 a	1.71±0.07 b	65.2±1.5 a	3.46±0.21 a
H2		1.94±0.08 a	1.75±0.08 a	15.1±0.8 a	15.3±0.5 a	1.25±0.09 b	2.77±0.16 a	3.39±0.32 b	2.21±0.23 b	1.79±0.05 a	39.40±1.0 b	2.73±0.13 b
CE% x Harvest												
Control	H1	1.24±0.12 f	1.43±0.02 b	14.6±0.6 b	6.0±0.3 c	1.32±0.06 cd	3.00±0.17 cd	4.03±0.10 cd	3.00±0.02 bc	1.60±0.12 c-e	56.2±2.3 c	2.50±0.06 d
Control	H2	1.30±0.03 f	1.51±0.05 ab	14.4±0.2 b	12.0±0.6 b	1.82±0.06 a	3.37±0.12 a	5.77±0.12 a	1.41±0.06 g	1.98±0.06 ab	43.3±1.2 de	3.15±0.09 c
1%	H1	1.72±0.05 e	1.40±0.03 b	10.8±0.6 c	3.6±0.3 d	1.61±0.03 b	3.03±0.09 b-d	5.04±0.29 ab	2.69±0.12 b-d	1.94±0.06 a-c	65.7±1.7 ab	4.48±0.06 a
1%	H2	1.81±0.06 de	1.58±0.05 ab	18.3±0.6 a	17.4±0.6 a	1.45±0.03 bc	2.63±0.06 e	2.26±0.02 e	1.60±0.23 fg	2.10±0.03 a	38.1±1.2 de	2.60±0.06 d
2%	H1	1.92±0.07 b-e	1.40±0.06 b	7.4±0.2 d	4.1±0.1 d	1.48±0.04 bc	2.48±0.06 e	3.54±0.23 d	3.28±0.10 b	1.32±0.03 e	64.3±1.7 bc	3.09±0.06 c
2%	H2	2.02±0.05 b-e	1.79±0.06 ab	19.4±0.6 a	16.5±0.3 a	1.39±0.03 c	3.14±0.08 bc	4.53±0.06 bc	1.68±0.06 fg	1.74±0.03 bd	35.9±1.7 e	1.95±0.06 e
4%	H1	2.04±0.02 a-d	1.64±0.06 ab	6.8±0.1 d	6.5±0.1 c	1.30±0.01 cd	2.54±0.05 e	4.09±0.06 cd	2.63±0.02 c-e	1.45±0.01 de	65.0±2.9 a-c	2.43±0.06 d
4%	H2	2.15±0.03 a-c	1.65±0.03 ab	14.5±0.3 b	15.9±0.6 a	0.95±0.03 ef	2.89±0.06 d	2.58±0.04 e	2.39±0.04 de	1.67±0.02 b-e	45.7±1.7 d	3.38±0.06 bc
6%	H1	1.90±0.06 c-e	1.27±0.04 b	4.7±0.2 e	7.0±0.1 c	1.08±0.06 e	2.21±0.06 f	4.23±0.12 cd	2.08±0.06 ef	1.99±0.06 ab	74.0±2.3 a	3.76±0.12 b
6%	H2	2.00±0.06 b-e	2.12±0.44 a	14.6±0.2 b	13.3±0.1 b	1.13±0.06 de	3.17±0.10 b	2.77±0.12 e	4.13±0.06 a	1.69±0.03 b-d	36.0±1.2 e	3.07±0.04 c
8%	H1	2.21±0.06 ab	1.40±0.06 b	10.0±0.3 c	3.6±0.1 d	1.61±0.06 b	2.88±0.12 d	5.04±0.12 ab	2.36±0.29 de	1.94±0.03 a-c	65.7±1.9 ab	4.48±0.12 a
8%	H2	2.33±0.06 a	1.87±0.04 ab	9.6±0.3 c	16.6±0.4 a	0.75±0.03 f	1.40±0.06 g	2.45±0.06 e	2.06±0.02 ef	1.54±0.02 de	37.4±0.6 de	2.23±0.06 de
T		**	ns	**	**	**	**	**	**	**	*	**
H		**	**	**	**	**	**	**	**	*	**	**
T x H		ns	*	**	**	**	**	**	**	**	**	**

CE = Ethanolic extract of Cabbage leaves (Cabbage Extract).

Values are means ±SD. Different letters next to the mean values in each column indicate significant difference according to Tukey's test

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3.5. Response curve of dry weight and oil% to different levels of cabbage extract (CE %)

Linear and quadratic regression models were used to examine the response of dry weight (g $plant^{-1}$) and oil% for thyme plants to different levels of cabbage extract (Figure 1). For dry weight (Figure 1 a), the results of regressing coefficient indicated that cabbage extract (CE %) at 1.0 % decreased the dry weight by 0.014. The R^2 was higher for quadratic response (83.0%) than linear (0.1%). These results indicated that 83.0% of the variation in dry weight could be explained by the quadratic regression model following the equation: $y = 3.14 + 1.42x - 0.18x^2$ (i.e. the quadratic model was a more important and better fit than the linear model). Also Figure 1 (a), for the quadratic curve, dry weight = 6.63 g $plant^{-1}$ was the maximum when CE % (x) = 4%. For oil% (Figure 1 (b) results of regressing coefficient indicated that an increase of 1.0 % CE, caused an increase of 0.003 %. Also, Figure 1 (b) showed that R2 was increased from 7.7% (linear) to 99.2% (quadratic). These results exhibited that 99.2 % of the variation in oil % could be explained by the quadratic regression model following the equation: $y = 0.057 + 0.042x - 0.005x^2$. Meanwhile, oil% scored the maximum value (0.15%) at 4% CE.

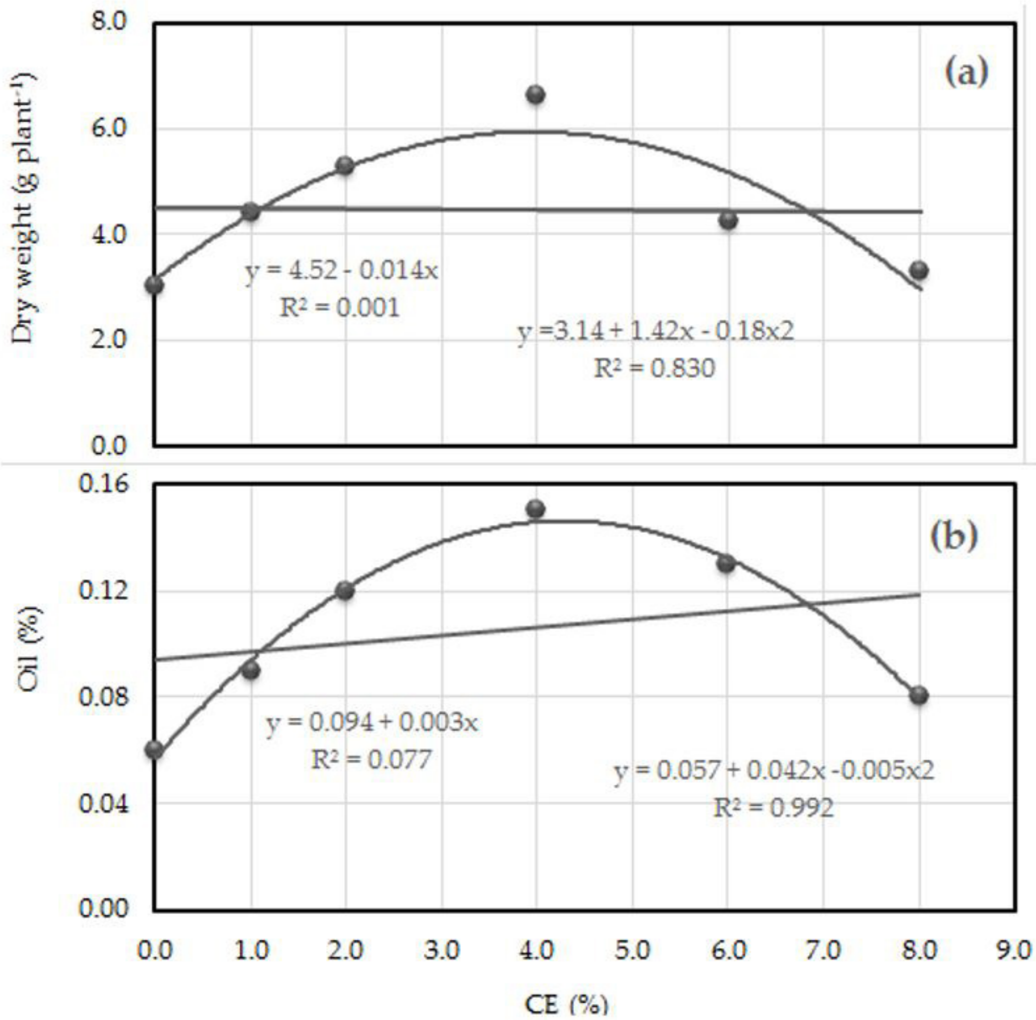

Figure 1. Linear and quadratic response of dry weight (a) and oil (b) to the level of cabbage extract

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Table 6. Pearson correlation coefficient of evaluated traits of thyme

	N	P	K	TC	Oil	PH	FW
N	1						
P	0.856**	1					
K	0.744**	0.887**	1				
TC	-0.012ns	0.227ns	0.464 ns	1			
Oil	-0.676**	-0.392ns	-0.109 ns	0.471ns	1		
PH	-0.724**	-0.413ns	-0.132 ns	0.309 ns	0.900**	1	
FW	-0.754**	-0.524ns	-0.214 ns	0.249 ns	0.897**	0.981**	1
DW	-0.751**	-0.535ns	-0.222 ns	0.231 ns	0.905**	0.973**	0.996**

ns: non-significant. ** Significant at $p < 0.001$.
PH; plant height, FW, fresh weight, DW; dry weight, TC; total carbohydrate

3.6. Correlation matrix

The matrix in Table (6) shows the simple correlation between each pair of variables. These correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables. Dry and fresh weight (g plant^{-1}) was positively and significantly correlated with oil% (r = 0.905** and r = 0.897**, respectively), plant height (r = 0.973** and r = 0.897**, respectively). However, the correlation coefficients between dry and fresh weight with N% content were significant and negative (-0.751** and -0.754**, respectively). Plant height (cm) was positively and significantly correlated with oil% (r = 0.900**). However, plant height and oil% showed negatively and significantly correlated with N% content (-0.724** and -0.676**, respectively). N, P, and K % contents were positively and significantly correlated with each other (Table 6). These results indicated that plant height and fresh and dry weights contribute to increasing in oil %. These relationships need to be considered by the thyme breeder when searching for superior genotypes that have desirable traits. However, the matrix of correlation showed positive and highly significant approximately full correlation coefficients (≈ 1.00) for many relations in Table 6, indicating that these traits are identical and we can use any one of them to identify the other.

4. Discussion

The cabbage extract is rich in macro and microelements, carbohydrates, protein, fiber, phenolic compounds, cellulose, hemicellulose, and vitamins, i.e. thiamine, ascorbic acid, and tocopherols, as well as some amino acids (Table 2). In the human diet, white cabbage is commonly used. It is mainly common because of the growth in local farmers' practices, customer preferences, affordable prices, and local availability. Moreover, this plant is most famous because of the abundance of antioxidants and anti-cancer agents such as polyphenolic contents, glucosinolates, carotenoids, and vitamin C (Park *et al.*, 2014a, b) and potential anti-obesity properties (Williams *et al.*, 2013). White cabbage is an essential source of dietary fiber, phytochemicals, and vitamins. Up to 40% of the white cabbage leaves, commonly used as fertilizer or animal feed, have been reported to be lost after processing (Nilnakara *et al.*, 2009).
An idea was therefore suggested of using outside cab-

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bage leaves which are normally discarded for the production of added-value items. Of particular concern are many products that contain the most abundant food fibre powder and phytochemical substances, including glucosinolates (Tanongkankit *et al*., 2012). In addition, white cabbage has been also reported as a good source of phenolic compounds (Park *et al*., 2014a). Also, tocopherols (vitamin E analogues) together with vitamin C are compounds with proven antioxidant activity and contribute to white cabbage health benefits (Podsedek, 2007).

Spraying CE extract at 2 and 4 % concentrations significantly increased plant height, plant fresh and dry weights, and oil % compared to the control. Maximum plant height, plant fresh and dry weight, and oil % were obtained in thyme herbs foliar sprayed with CE at 4% (Table 4). The positive effects of CE on the growth of thyme plants might result from the presence of an appropriate mix of inorganic nutrients and organic nutrients, such as amino acids in cabbage extract. Using the cabbage bio-extract resulted in high levels of leaf biomass and volatile oil with the highest content of carvone and menthol which was noted also in *Mentha spicata* and *Mentha arvensis* (Sitthithaworn *et al*. 2011). Cabbage is a sulfur-rich plant since the glucosinolate accumulating in the cabbage can be broken up to generate primary sulphur. For the synthesis of monoterpenoid compounds in volatile oil, sulfur is a donor of the methyl group and a source of methylene groups (Avato and Argentieri 2015). The increment in fresh and dry weights of thyme herb may be due to the effect of cabbage extract which enhanced the growth of the herb resulting from cell division and elongation in the meristematic zones and due to the rich of cabbage extract in macro and micronutrients and amino acids (Park *et al*., 2014a). In addition, cabbage extract contains minerals that produced increases in plant growth and oil content. NP treatments produced the highest growth and essential oil of garden thyme (*Thymus vulgaris L.*) compared with the control treatment (Sharafzadeh, 2011).

Maximum plant height, plant fresh and dry weights, and oil % were obtained in plants harvested at the second harvest time H2 (Table 3). These findings were in line with Said-Al Ahl *et al*. (2018), who found that at the second (April) crop and afterward the third (August), the fourth (October), the first (February), and finally the sixth (December) harvests, the highest essential oil yield of thyme was obtained.

This may be due to that the second and the third harvests happened at more suitable growth stages for herbage and oil production. Also, Zhekova *et al*. (2011) also reported an increase from 0.3% to 0.41% in the essential oil content of fresh thyme when the blossoming stage changed from the beginning of blossom to full blossom. In addition, Khazaie *et al*. (2008) reported an increasing trend in the essential oil content of *T. vulgaris* as the irrigation interval increases and the harvest time increases. Significant differences in herb fresh weight and essential oil content, when harvested on different dates, were also reported previously by Ezz (2009) and Hegazy *et al*. (2016). Plant growth and yield are affected by the surrounding environment including temperature, humidity, and light intensity, which influence the various physiological parameters and the photosynthesis process (Zhou *et al*. 2022).

The most pronounced increases in mineral contents and total carbohydrate % were recorded in plants sprayed with 2 and 4% of cabbage extract as compared with control plants and plants harvested at the first harvest time after 3 months of transplantation (Table 4). The cabbage extract contains elements (N, P, and K) that caused an increase in the mineral and carbohydrates in thyme herbs. N plays an important role in the synthesis of plant constituents through the action of different enzyme activity and protein synthesis (Jones *et al*., 1991) reflected in the increase in growth parameters. The presence of N in cabbage extract increased the vegetative growth, essential oil, fixed oil, total carbohydrates, soluble sugars, and NPK content of *Nigella sativa L.* plants (Khalid, 2001). Also, the high concentrations of P in cabbage extract had a stimulating effect on the growth parameters, total carbohydrates, soluble sugars, mineral contents, and the percentage of essential oil production from chamomile flowers compared with the control (Nassar *et al*., 2004).

The major compounds of thyme oil (thymol, p –cymene, and γ- terpinene %) showed the highest percentage in oil harvested from herbs at the first and second harvests (H1 and H2) after foliar spray with 2 and 4% (Table 5). Variation in the composition of essential oils is influenced by different plant parts and their different stages of development and modifications due to the environment (Pirbalouti *et al*., 2013). These factors influence the plant's biosynthetic pathways and, consequently, the relative proportion of the main constituents. Harvesting time and environmental conditions are very important to obtain higher and better-quality essential oil content (Pirbalouti *et al*., 2013). Optimizing the harvesting time is vital for maximizing the quality of essential oil. Several studies have demonstrated that essential oil accumulation and its composition were affected by water stress and harvest dates (Said-Al Ahl and Omer, 2016). Essential oils (EOs) are synthesized through secondary metabolic pathways of plants as communication and defense molecules. In addition to their important roles in direct and indirect plant defenses against herbivores and pathogens, reproduction (through the attraction of pollinators and seed disseminators), and plant thermotolerance, EOs are responsible for the specific taste and aroma of plants. These characteristics, together with their diverse biological activities, have made them highly attractive for industrial purposes, food processing, perfumery, and medicine, including the development of plant protection products (Pavela and Benelli, 2016).

5. Conclusion

The present study indicated that different concentrations of cabbage waste leaf extract affected plant growth, oil percentage, nutrient uptake, and total carbohydrate in *T. vulgaris*. Thus, the utilization of cabbage waste leaves extract could be pondered as a strong biotechnological approach for plant growth development in sustainable agriculture systems. In addition, cabbage extract is constructed to positively change biological activities, essential oil content, and its major constituents in *T. vulgaris*. It concluded that the foliar spray with 2 and 4% cabbage extract gave the highest values of oil components under the two harvest times, so that, the cabbage extract can be used as a bio-stimulant.

Conflict of Interest

The authors declare no conflict of interest. Besides, the funders had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Sustainable Eating Futures: A Case Study in Saudi Arabia

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Food systems are central to human societies. Developing sustainable, nutritious, and healthy food systems will be crucial to accomplishing sustainable development goals. The multifarious politics underlying food production, distributions as well as consumption are often ignored. The present paper analyses different factors affecting food consumption in the local population of Saudi Arabia and relates them to the supply chain. Different futuristic scenarios are discussed to develop sustainable food consumption practices in Saudi Arabia. This paper also addresses opportunities at the intersection of food and smart technologies. Moreover, the scenarios discuss the roles played by society and technological advancements in food conservation and consumption in Saudi society.

1. Introduction

Food is an integral part of all human life and the sustainability of the planet. It is vital to several social, political, cultural, and economic practices throughout history. Food security determines foods that are sufficient, nutritious, and safe to meet the needs of all people at all times. The concept covers availability, accessibility, and adequacy of food (Tyczewska, A., et al., 2018). Sustainable food has a lot of definitions and it has two main resources. Sustainable food can be roughly defined as "the system that works to provide food for all people and to secure food for the next generation" (Hamilton, H. et al., 2020). This sustainable system should also be economically profitable, socially beneficial, and have a positive impact on the environment (Belasco, W., 2012; Hurley, K., 2008).

World Economic Forum (WEF) 2010, proposed its new vision for agriculture and the production of food. The roadmap produced by this conference eventually concludes by outlining the necessity to 'produce more with less, thus suggesting an ecologically modern clarification of sustainability through its idea of a technologically driven agri-business future (Davies, A. R., 2014; Hirsh, 2010; Borch. K., 2007). The United Nations describes a sustainable food system that, "delivers food and nutrition security for all in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised" (United Nations, 2018).

The Kingdom of Saudi Arabia covers an area of 2,149,690 square kilometers and is home to 35,993,994 people (Fiaz, S., et al., 2018; Worldometers, 2022). It is expected that the volume of food consumption in the Kingdom of Saudi Arabia will reach about 221 billion riyals ($ 59 billion), with expectations that the volume of these investments will grow by 6% annually, according to the Saudi General Investment Authority

(SAGIA, 2021). There are some basic food items that are found in every household such as rice, flour, sugar, meat, tea, and coffee. The annual per capita food consumption figures in Saudi Arabia are shown in Figure 1. Wheat is an important component of the Saudi diet and is used in bread making, forms 64% of the country's total available cereals and its per capita consumption is around 298 g day−1(Ahmed, H. F., & Mousa. H, 2016). The quantities are so high that it may lead to a shortage of food in the coming years (World Bank, 2020).

There are many behaviours that make Saudis waste a lot of food (Saudi Gazatte, 2018). Firstly, they are known to buy more food than they really need. The excess food expires over time and gets wasted. Secondly, some Saudi people do not follow the appropriate food preservation practices which cause the food to rot and consequently get wasted. Thirdly, there are many people who normally fill their dishes and they do not consume all the food. This is a common practice at restaurants and even at home. Fourth, another common wrong behaviour is to preparing large quantities of food with large dishes for visitors during weddings or family gatherings as a sign of respect and generosity. Lastly, one of the fundamental reasons that make people waste a lot of food in Saudi Arabia is that people do not take their excess food from restaurants and consequently restaurants throw away any excess food. In addition, the relatively low living expenses in Saudi Arabia compared to other countries also negatively impact food consumption and waste. Therefore, with such behaviours, achieving sustainable food supplies in Saudi Arabia is a challenging task (Abdullah, N., et al., 2022).

Food security in Saudi Arabia is very critical considering that it is a large country with a very young population (Faridi M. R., & Sulphey M. M., 2019). The research shows that the government of Saudi Arabia evaluates food consumption to be about 70 billion dollars annually (UNFO, 2011). Rice is one of the most popular food sources in Saudi Arabia. People use it to make the famous dishes of Kabsa and Mandi. and it is estimated that Saudi people consume 1 million tons of rice every year. Also Saudi Arabia is ranked as the sixth consumer of rice in the world. Saudi Arabia's consumption of flour is also massive and it is estimated to be more than 3.7 million tons per year. Moreover, Saudi Arabia consumes 8 billion cups of tea and coffee every year. This escalates the use of sugar which is used for these beverages and sweets to 1.3 million tons annually. Meat is also consumed massively in Saudi Arabia since it provides the main source of protein. These massive consumption numbers put a lot of challenges on the food chains and consumption in Saudi Arabia (Tugendhat, E. 2019).

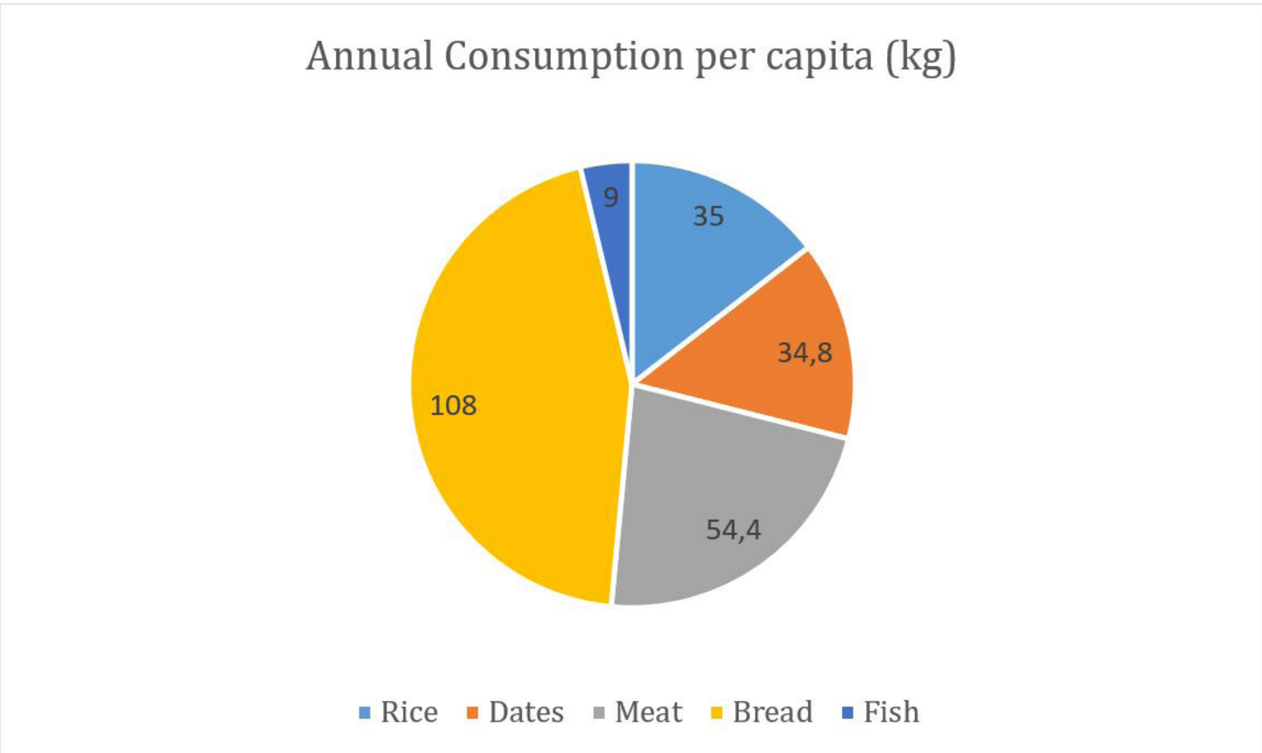

Figure 1. Annual consumption of various foods per capita in KSA

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To meet these challenging food chains, Saudi Arabia spends more than 35 billion dollars to import a lot of food like meat, rice, tea, and flour. Saudi Arabia imports around 1.4 million tons of rice. Furthermore, 60% of this importation comes from India, 15% from America, 12% from Pakistan, 5% from Australia, and 3% from Thailand. Moreover, Saudi Arabia imports 3.8 million tons of flour from India, America, and France (Baig et al, 2022; Best Food Importers, 2020). These numbers are massive and put a lot of burden on the government budget and as such, it is critical that food is consumed and preserved through sustainable practices.

2. Methodology

The focal question in the current research was to explore the scenarios that will be able to feed the population of KSA in 2050. The focal question of a scenario analysis encompasses the central query to be explored through the scenarios. The methodology includes the identification of potential uncertainties and the development of scenarios.

2.1 Potential Uncertainties

The critical uncertainties in a scenario analysis are the most important yet unpredictable driving forces that will have a significant impact on the central question. Through surveys, interviews, and meetings with food systems experts from business, academia, and relevant organizations, an initial list of critical uncertainties was compiled.

i. Monetary Swings: Will the country pursue cooperative trade through open markets, or will it pursue more isolationist policies? How will commodity market confidence evolve? Will markets be more stable or volatile? Will food prices accurately and consistently reflect the externalities of health care costs and environmental impact? What effect will trade policies have on global and local markets?

ii. Technology Developments: What will be the rate of wide-scale adoption and availability of new food-related technology? Will technological advancements be primarily targeted at wealthy or impoverished population segments? How will technological advances' benefits and risks be distributed?

iii. Social Change: Will people choose to consume healthier, more balanced diets or diets high in animal-based protein and sugar, salt, and fat? Will consumers demand food that is produced in an environmentally sustainable way?

iv. Environmental Tendencies: How will policy and business decisions affect climate mitigation and adaptation in food systems? How will climate change and other threats affect ecological systems' long-term productive capacity, including soil health? How will increased water scarcity affect food production? What will be the rate of energy consumption, and where will it come from?

3. Results & Discussion

Combining the above uncertainties reveals three scenarios for the future of food systems in KSA. These scenarios with implications are discussed below.

3.1 Unrestricted Consumption

Food production and distribution have become more efficient as a result of technological advancements, with yield improvement being the top priority. Obesity and healthcare costs are skyrocketing as billions of people switch to a high-volume, high-calorie, low-nutrient-density diet. As natural resources – including water, biodiversity, and land – are depleted, components of key ecosystems such as fisheries and dry lands begin to collapse, raising the cost of water purification and exacerbating impacts in various provinces as consumers seek alternative food sources. Growing food demand is driving climate change well beyond 2°C of global warming. This future scenario has several short-term beneficiaries. Many international food producers and retailers benefit from increased sales as a result of increased food demand, particularly multinational corporations. A conviction that society can grow now and fix environmental issues contributed to this scenario.

3.1.1 Implications of Unchecked Consumption

In this scenario, the proportion of the population that is overweight or obese has surpassed the 2050 target of one-third of the global population. The majority of the country's population now has increased access to large quantities of mostly unhealthy foods. Confusion is created by conflicting evidence on social me-

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dia about healthy diets and the spread of labels, which spreads unhealthy choices and increased calorie consumption. Natural resource depletion has accelerated in this scenario to make room for new agricultural production, and the effects of intensifying climate change are more acutely felt in the marketplace. Long and complex supply chains have unclear transparencies. Consumers are not interested in knowing where their food comes from and what its ingredients are.

3.2 Local Is the New Foreign

In this scenario, resource-efficient consumption and market connectivity have resulted in fragmented food systems in which the nation relies heavily on self-sufficiency. Local food movements are on the rise as consumers place a greater emphasis on sustainable local products. Consumers rediscover and value local diets, developing a new respect for food and taking additional steps to reduce food waste. Progressive policies by the government have successfully lowered the cost of healthier diets in comparison to unhealthy diets. These factors, when combined, allow for a shift toward more balanced diets and a reduction in obesity and related diseases.

This scenario brings about a change in Community Eating Culture (CEC) with high levels of lifestyle change. Figure 2 shows the details that how eating practices are performed by modifying the lifestyles and social norms of the people. Production of meat in the laboratory will be common with the advancement of stem cell technology. It is reported that lab-cultured meat would consume around 45% less energy, 90% less CO2 production, and 99% less land than what is used today. The cost of protein ingredients (e.g., fish and soybean-meal) is exacerbated by their competitive use in the Kingdom; therefore, alternative sources of food and protein are required. Among the alternatives, Locusts are sought-after insects for their medicinal properties and edibility. Agricultural regions in many parts of the Kingdom are in the grip of locust invasions. The skies are seen swathed in a moving carpet of these insects. Although eating these insects as such is not recommended due to the usage of pesticides and other chemicals. However, with a certain procedure, these creatures can become a rich source of vitamins, minerals, and micronutrients in future scenarios. Genetic modification of food is expected to increase manifold by 2050. By using the gene-editing tool CRISPR/Cas-9, food technologists will be able to create perfect food (Guraua, 2016). Non-browning apples, virus-resistant goats/camels, and the non-bruising potato will be available in this scenario. Local growth of vegetables will be supported by municipalities under "grow-it-yourself" and "community space" initiatives. Fast food will become less popular as against "slow food" events and sources in edible parks.

Figure 2. Public eating scenario 2050

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In a world of fragmented local markets with resource-efficient consumption, resource-rich countries focus on local foods, whereas import dependent regions become hunger hotspots. Therefore, for KSA the best futuristic scenario is "Local Is the New Foreign". Public eating scenarios include "slow food" events in edible parks developed in metropolitan areas. Grow-it-yourself campaign whereby grow groups share land and experience with each other. Similarly, "Farmers Market" whereby farmers sell their products directly to consumers. Composting of waste food and provision of community spaces for growing, cooking, and eating together are other possibilities. Similarly, Figure 3 shows scenarios using advanced technology contributing towards self-sufficiency. The idea of a living wall where vegetables and herbs can be germinated and grown using fertilizer from a food waste processor and filtered water from washings etc. Smart refrigerator can give information about leftovers, menu suggestions, and food safety information. Green fast food can be easily available in canteens, and small shops and to order online. Smartphones can be used as scanners in green supermarkets, as well as to provide information on the social, environmental, and health aspects of food products. Moreover, the use of Artificial Intelligence (AI) technologies in Saudi Arabia will also increase productivity and achieve food security, because artificial intelligence can ease many things such as planting seeds and harvesting fruits (Choi, J. H.-J. 2014). Furthermore, the Global Positioning System (GPS) will be used to alert fishermen on the best places for fishing and also to avoid storms. GPS systems and drone technology will also be used to seed plantations and implement sanctuaries to protect animals from overhunting.

Another important aspect of the future of food consumption in Saudi society is 3D-printed food. By using 3D printing technology, suitable ingredients can be mixed and then processed into the most intricate shapes and structures that are impossible to be made or are uneconomical to produce under the traditional manufacturing process. These kinds of food can have entirely novel textures and flavours that are unimaginable to be produced through traditional cooking processes. Thus, in this scenario, 3D printing technology will take food preparation into the digital age. A wide variety of ingredients can be automatically mixed during printing on the basis of certain selected recipes and be made in the absence of an operator (cook) by introducing advanced settings. As Saudi society is going to be more and more health conscious, 3D printing of food will provide a calculated intake of proteins, carbohydrates, and fats (Zhang et al., 2021).

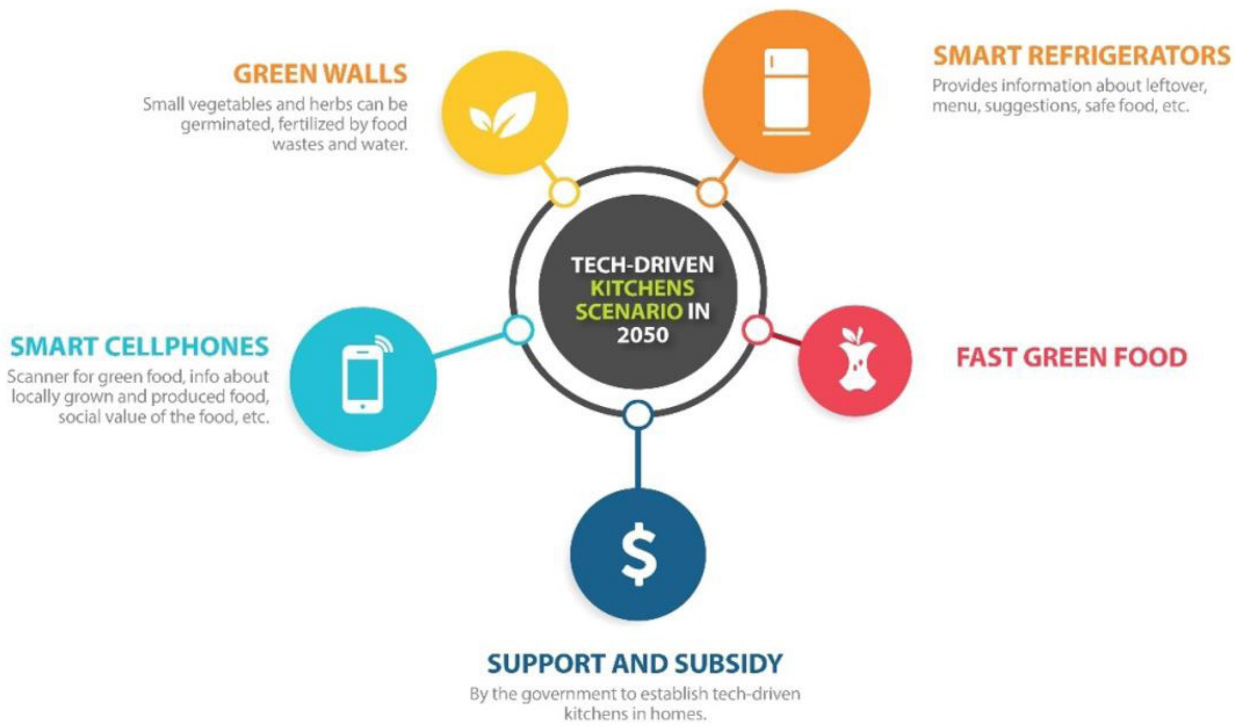

Figure 3. Technology-Driven Scenario 2050

3.2.1 Implications

In this scenario, the environmental impact of food production is reduced. Smaller food chains and more resource-efficient consumption reduce the agri-food sector's environmental impact. Digital transformation will play a pivotal role in the food consumption culture of the people. However, in the long run, a lack of access to foreign markets may result in unsustainable pressures on local land and ecosystems in certain regions of the Kingdom.

3.3 Survival of the Richest

In this scenario, only a few isolated, wealthy population segments can produce and innovate to meet their needs; isolated, poor, or import-dependent markets are experiencing increased hunger and poverty (Sundbo, 2016). Population growth, rising inequality, and rising food prices have increased resource needs. This has prompted a new wave of foreign investments in land and water resources. Climate change is accelerating. In this scenario, the majority of people are worse off than others. The upper classes are relatively better off than those in poorer contexts because they can still afford high food prices and comfortable lifestyles for the time being. In this scenario, there are many losers. For example, life has become risky and more uncertain for smallholder farmers than ever before: desperate economic conditions, limited access to natural resources (particularly water), and more adverse weather conditions have forced many to seek alternative sources of income to feed themselves and their families.

3.3.1 Implications

In this scenario, the majority of the people consume unhealthy diets, while a wealthy minority consumes nutritious foods and animal-based protein. In contrast, the vast majority of consumers are either eating high-calorie, low-nutrient diets, becoming increasingly overweight or obese, or are unable to access enough food, becoming increasingly undernourished.

4. Conclusions

Among the scenarios discussed, the "Local is the new Foreign" seems to be a more desirable future. In this regards many important steps can be taken in the kingdom of Saudi Arabia to secure food for the future. These steps can range from penalties for those who do not contribute positively to incentives for those who enhance the future of food sustainability in Saudi Arabia.

• The government to establish a policy to mandate regulations to protect against food wastage. This should be followed by establishing violations for those who break the food security policy. For example, if a person does not complete his dish, he must pay for the amount of the remaining food.

• The government should create authorities to facilitate and encourage local food production, global supply chains, and building relations with other countries to enhance the economic importation of food.

• Enhanced use of social media and advertisements can also play a major role to enhance socialites' compliance with food preservation and sustainability. This should include conducting competitions for young men and women to make the best documentary film about food security and its importance for Saudi Arabia.

• One of the most important steps that must be taken by Saudi Arabia is to encourage the private sector to establish companies specialized in more active roles in food security. An example of these efforts is the focus of Saudi Aramco on helping farmers in the Jazan area to increase their coffee, mango, and honey production.

• The government can focuses on increasing the agricultural lands in the Kingdom, and availing these to the farmer at reasonable rents will help to encourage farmers to start their businesses, increase crop production and achieving food security.

• The authorities should focuses on establishing investment funds to encourage local businesses to implement their strategies that support food sustainability within the kingdom.

• The government also focus on linking health illnesses with overeating practices which will help in reducing food consumption and achieve better sustainabil-

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ity.

• The government of Saudi Arabia focus on building healthy diplomatic relationships with various food-producing countries. This will help in the event of wars or diplomatic conflict to eliminate any disturbance to the food chains and production.

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Can a simple cup of Coffee with milk have an anti-inflammatory effect?

Inflammation is an immune system reaction that happens when bacteria, viruses and other foreign substances enter the body. Thus, our immune systems react by deploying white blood cells and chemical substances to protect us. Inflammation also occurs whenever we overload tendons and muscles and is characteristic of diseases like rheumatoid arthritis.

Polyphenols are antioxidants that are found in humans, plants, fruits and vegetables. The food industry also uses this group of antioxidants to slow the oxidation and deterioration of food quality and thereby avoid off flavors and rancidity. Polyphenols are also known to be healthy for humans, as they help reduce oxidative stress in the body, giving rise to inflammation. However, few studies have investigated polyphenols and what happens when polyphenols react with other molecules, such as proteins, mixed into foods that we then consume.

A new study conducted at the Department of Food Science, in collaboration with researchers from the Department of Veterinary and Animal Sciences at the University of Copenhagen, investigated how polyphenols behave when combined with amino acids, the building blocks of proteins. The results have been promising.

"In the study, we show that as a polyphenol reacts with an amino acid, its inhibitory effect on inflammation in immune cells is enhanced. As such, it is clearly imaginable that this cocktail could also have a beneficial effect on human inflammation. We will now investigate further, initially in animals. After that, we hope to receive research funding which will allow us to study the effect in humans," says Professor Marianne Nissen Lund from the Department of Food Science, who headed the study.

The researchers investigated the anti-inflammatory effect of combining polyphenols with proteins by applying artificial inflammation to immune cells. Some of the cells received various doses of polyphenols that had reacted with an amino acid, while others only received polyphenols in the same doses. A control group received nothing. Observations showed that immune cells treated with the combination of polyphenols and amino acids were twice as effective at fighting inflammation as the cells to which only polyphenols were added.

Moreover, previous studies by researchers demonstrated that polyphenols bind to proteins in meat products, milk and beer. In another new study, they tested whether the molecules also bind to each other in a coffee drink with milk. Indeed, coffee beans are filled with polyphenols, while milk is rich in proteins.
"Our result demonstrates that the reaction between polyphenols and proteins also happens in some of the coffee drinks with milk that we studied. In fact, the reaction happens so quickly that it has been difficult to avoid in any of the foods that we've studied so far," says Marianne Nissen Lund.
Now, the researchers are working on how to add the right quantities of polyphenols in foods to achieve the best quality. The new research results are promising in this context as well.

1. Jingyuan Liu, Mahesha M. Poojary, Ling Zhu, Andrew R. Williams, Marianne N. Lund. Phenolic Acid–Amino Acid Adducts Exert Distinct Immunomodulatory Effects in Macrophages Compared to Parent Phenolic Acids. Journal of Agricultural and Food Chemistry, 2023; DOI: 10.1021/acs.jafc.2c06658

2. Mahesha M. Poojary, Michael Hellwig, Thomas Henle, Marianne N. Lund. Covalent bonding between polyphenols and proteins: Synthesis of caffeic acid-cysteine and chlorogenic acid-cysteine adducts and their quantification in dairy beverages. Food Chemistry, 2023; 403: 134406 DOI: 10.1016/j.foodchem.2022.134406

Reducing pesticide pollution and the intensity of harvesting can increase crop yield and contribute to climate change mitigation

Researchers have found that carbon sequestration, plant resilience, and forage pasture yield can be increased through key adjustments in agricultural management. The results provide a roadmap for reducing pesticide loads in soils and the first steps towards increasing climate change mitigation while improving crop yield in grasslands.

Food demand has been increasing significantly through the years, resulting in agricultural intensification to maximize crop production.

Agriculture management has a great impact on yield. In two new study were conducted at the University of Turku in Finland, it was found that carbon sequestration, plant resilience, and forage pasture yield can be increased through key adjustments in agricultural management.

Soil properties significantly influence plant quality, including resilience against climatic extremes and resistance against insect pests and pathogens. **Intensive harvesting and pesticide residues in soil limit root growth.**

The results are highly important in reducing pesticide loads in soils and are the first steps towards increasing climate change mitigation while improving crop yield in grasslands.

"However, in recent decades, we have observed both a reduction in plant resilience and crop yields and the degradation of soil quality. This has resulted in an exponential need for chemical fertilizers and pesticides," says Docent **Benjamin Fuchs** from the Biodiversity Unit of the University of Turku, Finland.
One key challenge in the research was to find practical and sustainable ways to improve plant resilience and elevate crop yield while mitigating the carbon (CO2) emissions caused by human activity by enhancing carbon sequestration in the soil.

The researchers conducted two independent experiments. One is in a greenhouse, and another one is in a common garden. The observations showed that the intensity of mowing has a great impact on pastures. Reducing the intensity of the mowing and cutting the plant higher will increase the overall yield of the pasture and helps the plants develop bigger roots. This indicates higher atmospheric carbon sequestration into belowground storage. Moreover, researchers found a detrimental effect of herbicide residues in soil on root growth regardless of the intensity of the yield harvest.

"This demonstrates a tremendous limitation to the potential carbon binding and storage belowground when pesticides pollute soils. Considering the vast amount of pesticides applied to agricultural fields yearly, we can conclude that the impact on soil quality is a major driver of limited root growth, carbon sequestration, and consequently plant resilience and productivity," Dr Fuchs says.

The authors propose additional field studies to extrapolate their findings onto a field scale. Both studies conclude that climate change mitigation via optimizing carbon sequestration and storage in the soil can be achieved by reducing pesticides, which will facilitate root growth and improve plant resilience.

1. Sanna Keronen, Marjo Helander, Kari Saikkonen, Benjamin Fuchs. **Management practice and soil properties affect plant productivity and root biomass in endophyte-symbiotic and endophyte-free meadow fescue grasses.** Journal of Sustainable Agriculture and Environment, 2022; DOI: 10.1002/sae2.12035

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Mites, extreme weather and pesticides could be linked to the honey bee colony loss in the U.S.

About one-third of the food eaten by Americans comes from crops pollinated by honey bees. However, bee colonies are disappearing at alarming rates. Between April 2019 and April 2020, a study reported a 43% colony loss in honey bees across the United States.

A new study led by Penn State researchers is studying several variables exploring their potential effects on honey bees, including some linked to climate change. The research study the honey bee colony loss across the United States over the last five years. Results show that honey bee colony loss in the U.S. over the last five years is primarily related to the presence of parasitic mites, extreme weather events, nearby pesticides, as well as challenges with overwintering. The study is the first to consider a variety of potential honey bee stressors at a national scale. Besides, it took advantage of novel statistical methods. The study, published online in the journal Scientific Reports, suggests several areas of concern to prioritize in beekeeping practices.

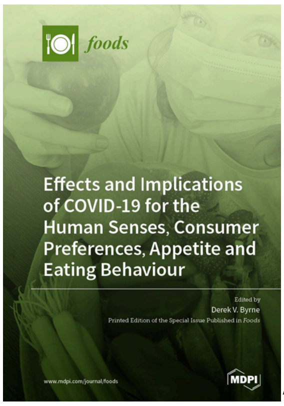
"Honey bees are vital pollinators for more than 100 species of crops in the United States, and the widespread loss of honey bee colonies is increasingly concerning," said Luca Insolia, first author of the study, a visiting graduate student in the Department of Statistics at Penn State at the time of the research, and currently a postdoctoral researcher at the University of Geneva in Switzerland. "Some previous studies have explored several potential stressors related to colony loss in a detailed way but are limited to narrow regional areas. The one study we know of at the national level in the United States explored only a single potential stressor. For this study, we integrated many large datasets at different spatial and temporal resolutions. We used new, sophisticated statistical methods to assess several potential stressors associated with colony collapse across the U.S."

The research team was various, composed of statisticians, geographers, and entomologists. Data were gathered from a publicly available resource about honey bee colonies, land use, weather, and other potential stressors from 2015 to 2021.

The research team found that several variables impacted honey bee colony loss at the national level, including the presence of nearby pesticides, frequent extreme weather events, and weather instability. The parasitic mite, Varroa destructor, was one of the main stressors related to colony loss. It reproduces in honey bee colonies, weakens the bees, and potentially exposes them to viruses. The researchers also found that losses typically occurred between January and March, likely related to overwintering challenges, but some states do not follow this pattern.

"A changing climate and high-profile extreme weather events like Hurricane Ian -- which threatened about 15% of the nation's bees that were in its path as well as their food sources -- are important reminders that we urgently need to better understand the stressors that are driving honey bee colony collapse and to develop strategies to mitigate them," said Francesca Chiaromonte, professor of statistics and the holder of the Lloyd and Dorothy Foehr Huck Chair in Statistics for the Life Sciences at Penn State and a senior member of the research team. "Our results highlight the role of parasitic mites, pesticide exposure, extreme weather events, and overwintering in bee colony collapse. We hope that they will help inform improved beekeeping practices and direct future data collection efforts that allow us to understand the problem at finer and finer resolutions."

1. Luca Insolia, Roberto Molinari, Stephanie R. Rogers, Geoffrey R. Williams, Francesca Chiaromonte, Martina Calovi. Author Correction: Honey bee colony loss linked to parasites, pesticides and extreme weather across the United States. Scientific Reports, 2023; 13 (1) DOI: 10.1038/s41598-023-28374-w



Effects and Implications of COVID-19 for the Human Senses, Consumer Preferences, Appetite and Eating Behaviour

A review by Diana Ismael

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Food is a basic need of significant value for various reasons. Aside from the primary need for basic survival, it is also significant for the health and nourishment of individuals, growth of economies through the food supply chain, peace and success of a nation and existing cultures and traditions. However, food systems describe every process involved with food, from production to consumption. The functionality of these food systems depends on government and policies, relationships between countries, and global trends. This thrilling book discusses various topics such as food systems, nutrition, healthy diets and their contribution to human health, food policy and governance, the effect of food policy on diets and nutrition and finally, challenges to achieving healthy diets for nutrition. It also poses question such as who influence food policy and governance and who influences food systems.

This book is introduced by showing the importance of the food system, depicting how every individual engages daily with the food system through making choices that influence them in various ways. However, a constantly growing human population, the environmental degradation, the changes in diets, and climate change threaten food security due to the pressures placed on the food systems. Therefore, creating, investing, and implementing effective policies are crucial to strengthening sustainable food systems for advanced nutrition and diets with these restrictions and challenges.

Chapter one of this book highlights food and its significant role in society. Food as a necessity limits people to various dietary choices. These dietary choices describe an individual's identity, aspirations and habits. However, food choices are guided by beliefs, values, desires, preferences and the relationships people have with the food origin. Food has many societal roles, such as nourishing and growing the economy, tradition representation, and cultural preservation through eating practices and gastronomic knowledge.

Chapter two explains the concept of food policy and governance. It emphasises the effect of food policies on food system operations and the decision-making process by manufacturers, customers and other investors. Food policies are strategies that influence organisations, establishments, governmental and private institutions, and stakeholders working in food systems. These policies act as a guide for decision-making processes to ensure accountability. On the other hand, food governance encompasses establishing and implementing food policies by actors such as NGOs, producers, governments, consumers and business institutions. In recent times, food policies have changed to mirror evolving global trends. Because of this, activists such as civil society groups and consumers vouch for an all-inclusive food policy incorporating policies from different sectors and areas essential for the food system.

Chapter three of this book focuses on diet concepts and the impact of diet on human health. Various factors affect the diets of individuals. For instance, individuals who consume healthy diets meet their nutritional needs and are overall healthy. Diets comprise nutritious or less nutritious foods that make humans healthy or unhealthy when consumed. Nutritious foods include fruits and vegetables, nuts and seeds, whole grains, fish and seafood, dairy and dairy products, and legumes and beans.

On the other hand, less nutritious foods include junk foods and highly processed and packaged foods such as sausages, hot dogs, bacon, ham, chips, crackers, breakfast cereals, instant noodles and pastries. In conclusion, less nutritious and unhealthy diets are the leading causes of cardiovascular diseases and deaths.

The concluding chapter describes the influence of policies on diet, nutrition, and the overall flood supply chain. Food policies outline the kind of foods to be produced and the movement along the supply chain at local, regional, and global levels. The supply chain encompasses all processes and activities involved in food movement from farm to fork. Various players and actors are responsible for creating, implementing, and executing these policies. An efficient and operative food supply chain supplies adequate nutritious and safe food for people locally, regionally, and all over the world.

Overall, this book was informative and educative as it discusses and enlightens readers on the global food system, diets and nutrition. In addition, it discusses the concept of food policy and governance, various diet concepts and the impact on human health and, finally, how food policies affect nutrition and health.

About the author:

Diana Ismael is a sensory specialist with a PhD in Food and Sensory Science/Consumer Behavior from Kassel University, Germany. Her research focuses on understanding the intention-behaviour gap in organic food consumption. Currently, she works as the Managing Editor at the Future of Food Journal: Journal on Food, Agriculture & Society.

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