

FIRAT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
TÜRKİYE



**DETERMINATION OF SOME BIOCHEMICAL PARAMETERS AND
ELEMENTS IN SUMAC (*RHUS CORIARIA* L.) PLANT SEEDS**

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Doctoral Thesis

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THESIS APPROVAL

This thesis, which was prepared according to the thesis writing rules of the Graduate School of Natural and Applied Sciences, Firat University, was evaluated by the committee members who have signed the following signatures and was unanimously approved after the defense exam made open to the academic audience.

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DECLARATION

I hereby declare that I wrote this Doctoral Thesis titled “Determination of some biochemical parameters and elements in sumac (*Rhus coriaria* L.) plant seeds ” in consistent with the thesis writing guide of the Graduate School of Natural and Applied Sciences, Firat University. I also declare that all information in it is correct, that I acted according to scientific ethics in producing and presenting the findings, cited all the references I used, express all institutions or organizations or persons who supported the thesis financially. I have never used the data and information I provide here in order to get a degree in any way.

02 May 2024

Haval Mohammed ALI



PREFACE

Bismillahi Al-Rahmani Al-Rahim, Praise be to Allah, lord of the worlds, and best peace and best blessings be upon our Prophet Muhammad and his family and his companions.

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ABSTRACT

Determination of some biochemical parameters and elements in sumac (*Rhus coriaria* L.) plant seeds

Haval Mohammed ALI

Doctoral Thesis

FIRAT UNIVERSITY
Graduate School of Natural and Applied Sciences

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In this study, *Rhus coriaria* L. (Sumac) samples collected from different parts of Turkey and Iraq, the first group was freshly ground, the second group was ground and lubricated with sunflower oil in the ratio (90:10), and the third sumac group was only ground. The second and third group samples were analyzed after being stored in the refrigerator at 3-5 degrees Celsius for six months. Elements in sumac samples were determined by ICP-OES, vitamins, β -carotene, lycopene, 4-HNE, glutathione, MDA and amino acids were determined by HPLC, and total phenolics and flavonoids, ABTS, DPPH radical scavenging activity were determined using UV-Vis spectrophotometry. The maximum amounts of Na, K, Mg and P in freshly ground samples are Kadana, Shelladize, Maraş and Derishke regions, respectively. It was determined that the richest regions in terms of trace elements such as Zn, Cu, Fe, Se, Mn, Cr, Mo, Ni and B were Charput, Derishke, Ranya, Charput, Ranya, Derishke, Elazığ, Derishke and Kadana, respectively. The highest amounts of As, Cd, Pb and Hg in sumac samples were determined in the Kadana, Kadana, Trawanish and Charput regions, respectively, and the lowest amounts were determined in the Kadana, Kadana, Trawanish and Charput regions, respectively. The amounts of ascorbic acid, thiamine, riboflavin, nicotine amide, nicotinic acid, pantothenic acid, pyridoxine, folic acid and cyanocobalamin in freshly ground samples were 78.90–36.57, 173.57–61.11, 518.4–182.3, 314.0–105.6, 1292.1–788.7, 779.2–301.7, 385.8–133.4, 826.2–473.1, 192.6–73.9 $\mu\text{g/g dw}$ respectively. The difference between the vitamin amounts in fresh, oiled and unoiled sumac samples from all regions was found to be statistically significant ($p < 0.05$). It was observed that the amounts of vitamins A and E, β -carotene and lycopene in fresh sumac samples varied between 1.12–2.77, 84.40–230.65, 2.48–5.31 and 8.10–26.90 $\mu\text{g/g dw}$, respectively. It was observed that the loss of both water- and fat-soluble vitamins was higher in the group kept without lubrication ($p < 0.05$). The total phenolic and flavonoid substance amounts in fresh samples were found between 27.73–51.75 $\mu\text{gGAE/g dw}$ and 16.16–33.50 $\mu\text{gQE/g dw}$, respectively. IC_{50} and TEAC values in freshly ground sumac samples were found between 14.79–23.80 $\mu\text{g/mL}$ and 359.30–665.62 $\mu\text{mol trolox/g dw}$, respectively. The decreases in the parameters examined in lubricated samples were found to be lower than in the samples kept without lubrication ($p > 0.05$). It was observed that the amounts of GSH, GSSG, MDA and 4-HNE in the samples varied between 1004.12–2550.42, 422.54–1375.38, 13.95–31.30, 7.12–15.40 $\mu\text{g/g dw}$, respectively. It was determined that while the amounts of GSH and GSH/GSSG in the stored sumac samples decreased, the amounts of MDA, GSSG and 4-HNE increased. It was observed that the changes in the examined parameters in fresh, oiled and unoiled sumac samples were statistically significant ($p < 0.05$). Among the amino acids in the sumac samples, it was determined that the Maraş region sumac was the richest in terms of glutamic acid, while the Kadana and

Sheladize regions were the richest in terms of other non-essential amino acids. It was observed that the sumacs of the Shelaza and Maraş regions were the poorest in terms of non-essential amino acids. It has been determined that the sumacs of the Kadana and Sheladize regions are richer in terms of essential amino acids, while the sumacs of the Suleymania and Maraş regions are poorer. It can be said that all of the sumac samples examined were rich in glutamic acid, histidine and alanine and poor in glycine. It was observed that while Kadana sumac was the richest in terms of total essential and non-essential amino acids, Shelaza sumac was the poorest. As a result, it can be said that sumac is a good spice in terms of elements, vitamins, total antioxidant capacity and amino acids.

Keywords: *Rhus coriaria* L, Minerals, Vitamins, Stress biomarkers, Amino acids, ICP-OES, HPLC.



ÖZET

Sumak (*Rhus coriaria* L.) bitkisi tohumlarında bazı biyokimyasal parametrelerin ve elementlerin belirlenmesi

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Bu çalışmada, Türkiye ve Irak'ın farklı yerlerinden toplanan *Rhus coriaria* L. (Sumak) örnekleri birinci grup taze öğütülmüş, ikinci grup öğütülerek (90:10) oranında ayçiçek yağı ile yağlanmış ve üçüncü grup ise öğütülmüştür, ikinci ile üçüncü grup örnekleri altı ay boyunca 3-5 santigrat derecede buzdolabında bekletildikten sonra analizlendi. Sumak örneklerindeki elementler ICP-OES ile, vitaminler, β -karoten, likopen, 4-HNE, glutatyon, MDA ve amino asitler HPLC ile, toplam fenolik ve flavonoidler, ABTS, DPPH radikal temizleme aktivitesi de UV-Gör spektrofotometresi kullanılarak belirlendi. Taze öğütülmüş örneklerdeki maksimum Na, K, Mg ve P miktarları sırasıyla Kadana, Şelladize, Maraş ve Derişke bölgeleridir. Zn, Cu, Fe, Se, Mn, Cr, Mo, Ni ve B gibi eser elementler bakımından en zengin bölgelerin ise sırasıyla Charput, Derishke, Ranya, Charput, Ranya, Derishke, Elazığ, Derishke ve Kadana olduğu belirlendi. Sumak örneklerinde en yüksek As, Cd, Pb ve Hg miktarları sırasıyla Kadana, Kadana, Trawanish ve Charput bölgelerinde, en düşük miktarlar ise sırasıyla Kadana, Kadana, Trawanish ve Charput bölgelerinde belirlendi. Taze öğütülmüş örneklerdeki askorbik asit, tiamin, riboflavin, nikotin amid, nikotinik asit, pantotenik asit, piridoksin, folik asit ve siyanokobalamin miktarları sırasıyla 78.90–36.57, 173.57–61.11, 518.4–182.3, 314.0–105.6, 1292.1–788.7, 779.2–301.7, 385.8–133.4, 826.2–473.1, 192.6–73.9 $\mu\text{g/g dw}$, olarak belirlenmiştir. Bütün bölgelerdeki taze, yağlanmış ve yağlanmamış sumak örneklerindeki vitamin miktarları arasındaki farkın istatistiksel olarak anlamlı ($p<0.05$) olduğu bulunmuştur. Taze sumak örneklerindeki A ve E vitamini, β -karoten ve likopen miktarlarının sırasıyla 1.12–2.77, 84.40 - 230.65, 2.48–5.31 ve 8.10–26.90 $\mu\text{g/g dw}$, arasında değiştiği gözlemlendi. Hem suda hem de yağda çözünen vitamin kaybının yağlanmadan bekletilen grupta fazla olduğu gözlemlenmiştir ($p<0.05$). Taze örneklerdeki toplam fenolik ve flavonoid madde miktarları sırasıyla 27.73-51.75 $\mu\text{gGAE/g dw}$ ve 16.16-33.50 $\mu\text{gQE/g dw}$, arasında bulunmuştur. Taze öğütülmüş sumak örneklerinde IC_{50} ve TEAC değerleri sırasıyla 14.79-23.80 $\mu\text{g/mL}$ ve 359.30-665.62 $\mu\text{mol trolox/g dw}$, arasında bulunmuştur. Yağlanmış örneklerde incelenen parametrelerdeki azalmalar yağlanmadan bekletilen örneklere göre daha düşük bulunmuştur ($p>0.05$). Örneklerdeki GSH, GSSG, MDA ve 4-HNE miktarları sırasıyla 1004.12-2550.42, 422.54-1375.38, 13.95-31.30, 7.12-15.40 $\mu\text{g/g dw}$ arasında değiştiği görülmüştür. Bekletilen sumak örneklerindeki GSH ve GSH/GSSG miktarı azalırken, MDA, GSSG ve 4-HNE miktarlarının arttığı tespit edilmiştir. Taze, yağlanmış ve yağlanmamış sumak örneklerindeki incelenen parametrelerdeki değişimlerin istatistiksel olarak anlamlı ($p<0.05$) olduğu görülmüştür. Sumak örneklerindeki aminoasilerden, glutamik asit bakımından en zengin Maraş bölgesi sumağı iken, non esansiyel diğer amino asitler bakımından ise Kadana ve Sheladize bölgeleri olduğu tespit edilmiştir. Non esansiyel amino asitler açısından en fakir Shelaza ve Maraş bölgesi sumaklarının olduğu gözlemlenmiştir. Esansiyel amino asitler açısından Kadana ve Sheladize bölgesi sumaklarının daha zengin, Süleymaniye ve Maraş bölgesi sumaklarının ise daha fakir olduğu tespit edilmiştir. İncelenen sumak örneklerinin hepsinin, glutamik asit,

histidin ve alanin bakımından zengin ve glisin bakımından fakir oldukları söylenebilir. Toplam esansiyel ve non-esansiyel amino asit bakımından en zengin Kadana sumağı iken, en fakir Shelaza sumağının olduğu görülmüştür. Sonuç olarak, sumağın elementler, vitaminler, toplam antioksidan kapasite ve aminoasitler açısından iyi bir baharat olduğu söylenebilir.

Anahtar Kelimeler: *Rhus coriaria* L, Mineraller, Vitaminler, Stres biyobelirteçleri, Amino asitler, ICP-OES, HPLC.



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SYMBOLS AND ABBREVIATIONS

Abbreviations

A.A.	: Amino acid
GSSG	: Glutathione oxide
4-HNE	: 4-Hydroxynoneal
GSH	: Glutathione reduce
MDA	: Malondialdehyde
HClO ₄	: Perchloric acid
HNO ₃	: Nitric Acid
H ₂ O ₂	: Hydrogen peroxide
TEA	: Triethylamine
ACN	: Acetonitrile
QE	: Quercetin equivalent
GAE	: Gallic acid equivalents
dw	: Dry weight
DPPH	: 2, 2-Diphenyl-1-picrylhydrazyl
ABTS	: 2,2'-Azino-bis-3-ethylbenzothiazoline-6-sulfonic
TEAC	: Trolox Equivalent Antioxidant Capacity
ICP-OES	: Inductively coupled plasma optical emission spectrometry
HPLC	: High Performance Liquid Chromatograph
LOD	: Limit of detection
ROS	: Reactive oxygen species
RNS	: Reactive nitrogen species
EDI	: Estimated daily intake
THQ	: Target hazard coefficient
RfD	: Reference intake dose
TTHQ	: Total target hazard coefficient
IC ₅₀	: Half-maximal inhibitory concentration

QE : Quercetin equivalent

°C : Degree of Celsius

µg : Microgram

Mg : Milligram



1. INTRODUCTION

1.1. Sumac

Sumac, or *Rhus coriaria*, is a flowering shrub in the order Sapindales, which includes some 81 genera and more than 800 types. Plants of *Rhus* may be found all over the globe, particularly in subtropical and temperate climates like Africa, Southeastern Anatolia, the Mediterranean region, and Western Asia. Roughly 250 species belong to this genus [1]. Leaves may be acutely complex, trifoliate, or simple, depending on the species. Each of the tiny, greenish-coloured, milky white or red blooms on the 5- to 30-centimetre-long clusters or spikes has five petals. Sumac bobs are clusters of crimson drupes that develop from the fruit (Figure 1.1) [2]. The drupes are pulverised into a purple spice after drying. Sumac forms enormous colonial clumps via both seed dispersal (through animal faeces) and rhizome-based vegetative growth [3].

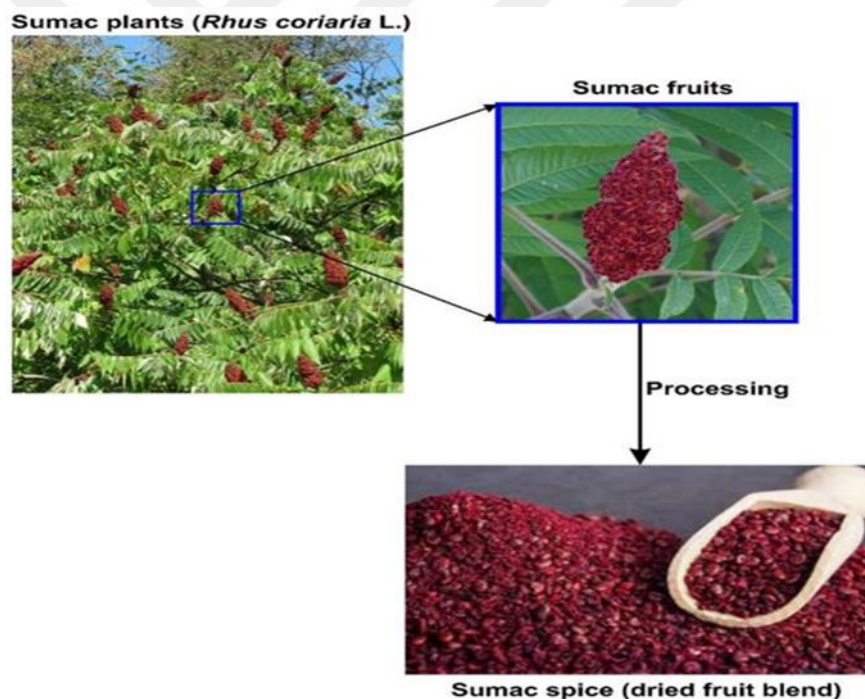


Figure 1.1. Sumac plant and its spice product [2]

In the Middle East, *R. coriaria*'s tangy, delectable fruits are put to use as both a condiment and a sour beverage [4]. Dysentery, diarrhoea, haemorrhoids, and gout are just a few of the many conditions for which this plant has been used for ages in Middle Eastern and Iranian traditional medicine. It is also often used for wound healing and to lower blood sugar, cholesterol, and uric acid levels. Many beneficial biological effects of *R. coriaria* have been shown in previous research. These include antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, hepatoprotective, xanthine oxidase inhibition, hypoglycemia, and cardiovascular protective Activities [5].

Indigestion, anorexia, bleeding, and high blood sugar are just some of the conditions that this folk remedy may help with [6]. Hydrolysable tannins, anthocyanins, organic acids including malic and citric acid, fatty acids, vitamins, flavonoids, and terpenoid derivatives are only some of the physiologically active components found in *R. coriaria*, as documented in previous publications [7,8]. The latter are often subjected to hydro distillation or a suitable mechanical procedure in order to extract the volatile terpenes that make up the essential oils; this yields an oil that is high in monoterpenes and/or sesquiterpenes and is known as "essential oil." [9,10]. Previous phytochemical research on the essential oil content of sumac has identified distinct chemotypes with substantial qualitative and quantitative variance in components [11–13]. Essential oil content has been shown to vary depending on a number of parameters, including location, analytical circumstances, genetics, harvest timing, environmental influences, and so on [9,13]. Proteins, Organic acids, minerals, essential oils, vitamins, and phenolics are only some of the substances found in sumac. In various ways, from combating microbial and fungal infections to delaying oxidative processes, these chemicals are crucial to human health improvement. The search for natural antioxidants in plants for use in human nutrition as an alternative to manufactured chemicals has recently taken centre stage in the food business. *Rhus coriaria* is high in phenolic chemicals, notably gallic acid and its derivatives, which give it a powerful antioxidant effect [14–16]. The worldwide demand for sumac is rising rapidly because of its great economic worth. The fruits and leaves of the sumac tree have many practical applications in the culinary, pharmaceutical, leather, and dye industries [17,18]. Due to the sour taste, it imparts from the organic acids it contains, sumac (*Rhus coriaria*) is widely used in the culinary industry as a spice or sumac sour to enhance the flavour and scent of a wide variety of foods. As a result of its high oleic and linoleic acid content, sumac oil is also a prized commodity in the oil business. The United States and Belgium are only two of the many nations to which Sumac is sold. According to foreign trade data for Turkey between 2009 and 2018, the Turkish Statistical Institute reports that the country exported a total of 15.354.927 kg of sumac, earning the country a total of 34.216.110 dollars. In addition, it has been calculated that the quantity of sumac exported has risen throughout the years without being impacted by the global crisis and that the amount of sumac imported has climbed or decreased, fluctuating in years based on domestic need [19].

1.2. Trace elements

Minerals are essential inorganic nutrients, although only in trace quantities (less than 1.0 to 2500 mg per day). Mineral needs, like those for vitamins and other vital elements, vary across different kinds of animals. Calcium, for instance, is essential for the development and upkeep of bones, as well as the regular functioning of neurons and muscles, in humans and other vertebrates.

Phosphorus is necessary for acid-base equilibrium, bone, and tooth production and is a key component of adenosine triphosphate (ATP) and nucleic acid. The oxygen-carrying pigment haemoglobin in red blood cells cannot do its job without iron. The cytochromes responsible for cellular respiration also include iron. Many metabolic processes can't function without the presence of the essential co-factors magnesium, copper, selenium, zinc, iron, manganese, and molybdenum. Thyroid hormone production in vertebrates requires iodine. The osmotic equilibrium between cells and the interstitial fluid relies on sodium, potassium, and chlorine. The chlorophyll in plants couldn't function without magnesium. There is evidence that what you eat might affect your risk of some illnesses and how your body processes medications. Some minerals, if consumed in large enough quantities, may disrupt homeostasis and lead to harmful consequences. High blood pressure, for instance, has been linked to excessive salt consumption, whereas excessive iron consumption has been linked to liver damage. Furthermore, the delicate balance of physiological activities that support health might be disrupted by acute shortages or self-prescribed minerals. Because chronic disease and some drugs might interfere with the body's ability to utilise certain nutrients, understanding the biochemistry of the mineral elements is also crucial [20]. Previous research found the majority of the minerals in sumac fruit are the electrolytes potassium, calcium, magnesium, and phosphorus. Supplementing your diet with sumac is a great way to get more potassium and calcium [21].

1.3. Vitamins

Vitamins are chemical compounds that are necessary for life but can only be consumed in small doses. Vitamins are classified not by their external appearance but by the biological and chemical roles they play in the body. Vitamins have several roles in biochemical processes. Some, such as vitamin A, regulate cellular development and differentiation, while others, such as vitamin D, regulate mineral metabolism. Some, like vitamins E and C, have antioxidant properties [22].

1.3.1. Water-soluble vitamins (WSVs)

Cofactors or precursors, such as the B-complex vitamins, aid enzymes in their catalytic function throughout metabolism. In this context, vitamins may be thought of as one of the prosthetic groups, with biotin, for instance, being a component of the enzymes responsible for fatty acid formation. They may also be loosely coupled to enzyme catalysts in their roles as coenzymes, which facilitate the transfer of chemical groups or electrons between molecules. For instance, methyl, formyl, and methylene groups are all possible for folic acid to transport in a cell. Perhaps the most well-known function of vitamins is their participation in the substrate reactions of enzymes [23]. Many enzymes need vitamin B1 (thiamine) as a cofactor, including pyruvate dehydrogenase and alpha-ketoglutarate dehydrogenase. both of which function in the tricarboxylic acid cycle of

bacteria [24]. Vitamin B2 (riboflavin) exists in two active forms: flavin adenine dinucleotide and flavin mononucleotide. The TCA cycle and fatty acid oxidation rely on them as cofactors for enzyme processes. These processes are crucial for the production of usable energy [25]. Niacin, or vitamin B3, is a necessary precursor to a coenzyme involved in a crucial cellular redox process. function in aerobic respiration as nicotinamide adenine dinucleotide [26]. Pantothenic acid (Vitamin B5) serves as a precursor to coenzyme A, a necessary cofactor in the TCA cycle for fatty acid oxidation [27]. Pyridoxine, pyridoxal, and pyridoxamine are all different forms of vitamin B6. Both pyridoxal phosphate and pyridoxamine phosphate, which are produced from vitamin B6, play critical roles in a wide range of cellular metabolic activities, including amino acid, lipid, and carbohydrate metabolism [28]. Enzymes that repair carbon dioxide need biotin B7 as a cofactor in carboxylation processes. Carboxylases such as acetyl CoA carboxylase and propionyl CoA carboxylase play crucial roles in fatty acid synthesis and odd-chain fatty acid metabolism, respectively. Carboxylases such as pyruvate carboxylase are necessary for the production of oxaloacetate, a key intermediate in the processes of reverse glycolysis and gluconeogenesis. Folates are a class of heterocyclic molecules having 4-(pteridin-6-ylmethyl) aminobenzoic acid as the active molecule and one or more L-glutamate molecules as the conjugating base. Folic acid participates in processes that produce and use formaldehyde, formimino, and methyl groups. Folic acid must be converted into tetrahydrofolic acid (THFA) for these reactions to take place. The molecular structure of vitamin B12 is similar to that of porphyrin, with tetrapyrrole rings around a central monovalent cobalt metal atom. The transfer of a methyl group from methyl-THFA to homocysteine is catalysed by vitamin B12, resulting in the formation of methionine. The adenosyl derivative of vitamin B12 may also catalyse the transformation of methylmalonyl CoA into succinyl CoA [29]. Ascorbic acid (vitamin C) and dehydroascorbic acid (DHA) are the two L-isomers that make up vitamin C, which is a redox system. Vitamin C is the active, stable form of vitamin C in tissues because of its position as an electron donor, which is essential for the vitamin's biological functions. Vitamin C, when used as a cofactor or antioxidant, is oxidised to the more unstable dehydroascorbic acid, which is readily "recycled" back to vitamin C through various enzyme networks, such as glutathione-dependent systems or reduced nicotinamide adenine dinucleotide phosphate (NADPH)-dependent systems [30]. There has been a dearth of research on the vitamin content of *Rhus coriaria*. Some of the vitamins found in *Rhus coriaria* have been reported in Chinese research comparing Syrian sumac with Chinese sumac. It was reported that the primary vitamins included in sumac were vitamins B1, B2, B6, B12, nicotinamide, biotin, and ascorbic acid. Pyridoxine, ascorbic acid, thiamine, and riboflavin were the most common of these vitamins. The research indicated that the vitamin content of Syrian sumac was much greater than that of Chinese sumac [31].

1.3.2. Fat-soluble vitamins (FSVs) vitamin A, E, β -carotene and lycopene

Vitamin A aids in epithelial cell differentiation and vision, while vitamin D regulates calcium and phosphate levels, vitamin E protects cell membranes from free radical damage, and vitamin K aids in blood clotting. All of these functions rely on fat-soluble vitamins (FSVs). Food or vitamin supplements are the primary ways to get FSV since, with the exception of vitamin D3, the body cannot produce them on its own. The potential for toxicity from excessive ingestion of vitamins A and D makes quality management of commercially accessible vitamin preparations particularly essential, as does the enormous variety of vitamin preparations available [32]. Vitamin A is a vitamin that is fat-soluble and is necessary for healthy development, immunity, and eyesight for optimal health. Research on the function that vitamin A plays in maintaining bone health has been considerable. Two different forms of vitamin A, namely preformed retinol and pro-vitamin A, are available for consumption. The presence of preformed retinol is often discovered in foods that are derived from animals, such as dairy products, liver, and eggs. A variety of provitamin A compounds, including alpha (α)-carotene, beta (β)-carotene, and β -cryptoxanthin, are often discovered in plant-based foods, typically including fruits and vegetables [33]. An important component for human health, vitamin E is one of the four fat-soluble vitamins and has potent antioxidant capabilities. There are eight different forms of this natural compound, and it acts as an antioxidant, protects membrane polyunsaturated fatty acids from oxidation, controls ROS and RNS generation, and modifies signal transmission. Only α -tocopherol, since it is the form that the body preferentially retains after consuming vitamin E, satisfies the body's need for vitamin E [34,35]. β -carotene is a prominent member of the carotenoid family and is a highly pigmented compound that appears as a vibrant red-orange colour. It is found in abundance in plants and fruits. β -carotene is considered the primary carotenoid found in the human diet and is thus the primary source of vitamin A in humans. Epidemiological research as well as studies have demonstrated that antioxidants like vitamin E and carotenoids like β -carotene and lycopene help avoid degenerative illnesses including cardiovascular disease, diabetes, and various malignancies. The phytochemical β -carotene is thought to possess antioxidant and anti-cancer capabilities, leading to its many purported health advantages [36]. The tetraterpene molecule known as lycopene, which is a member of the carotenoids, may be found in abundance in tomato and products that are derived from tomatoes. On a basic level, it is acknowledged as a powerful antioxidant and a carotenoid that does not promote vitamin A production. A number of conditions, including cancer recurrences, diabetes mellitus, cardiac problems, oxidative stress-mediated malfunctions, inflammatory events, bone and skin illnesses, hepatic, neurological, and reproductive abnormalities, have been shown to be effectively treated by lycopene [37]. The deleterious impact of free radicals contributes to the causation and complexities of several illnesses, including diabetes, cancer, cardiovascular ailments, and inflammatory conditions [38]. Neutralising free radical damage may be effectively addressed

by the use of antioxidants. Lycopene is a crucial compound that inhibits the detrimental effects of free radicals. The antioxidant activity of the substance is strengthened by its capacity to capture singlet oxygen and immobilise peroxy radicals [39].

1.4. Deficiency of vitamins

Vitamins are a kind of micronutrient that the body struggles to produce on its own. This is why getting what the body needs from outside sources is crucial for maintaining health. Vitamin deficiency disorders occur when people don't get enough of the vitamins they need. Vitamin deficiencies manifest differently depending on which vitamin is deficient. Deficiencies in vitamins may lead to a variety of illnesses, including Beriberi, Cheilosis, Pellagra, Acne, Pink Eyes, Infant Disorders, Macrocytic Anaemia, Pernicious Anaemia, and Scurvy [40]. Thiamin has a crucial role in facilitating the release of energy from dietary sources, supporting regular appetite regulation, and contributing to the maintenance of optimal functioning of the neurological system. Thiamin deficiency manifests in several symptoms, such as mental disorientation, muscular weakness, wasting, water retention (edema), decreased development, and the pathological condition often referred to as beriberi [41]. The clinical manifestations of riboflavin deficiency include several symptoms such as weariness, impaired development, gastrointestinal disturbances, angular cheilitis, glossitis with a magenta hue, ocular exhaustion, and inflammation and tenderness of the throat [42]. Vitamin B3 and niacin are synonymous, since niacin refers to a collection of chemicals that possess vitamin action. Vitamin B3 consists of nicotinic acid, nicotinamide, and several enzymatic forms. Pellagra is a condition that arises due to a lack of vitamin B3. This vitamin plays a crucial role in human health by facilitating energy synthesis and supporting antioxidative defence mechanisms. Nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP) are two separate variations of vitamin B3 that play a crucial role in the generation of energy from proteins, carbs, and lipids obtained from nutrition. NADP and niacin-containing enzymes serve as antioxidants, neutralising free radicals and safeguarding tissues from oxidative harm. Alcoholism is also linked to a deficit of vitamin B3. Vitamin B3 is linked to several disorders, such as hypercholesterolemia, pellagra, osteoarthritis, Raynaud's syndrome, acne vulgaris, schizophrenia, and type 1 diabetes [43]. The insufficient synthesis of the vitamin pantothenic acid by the gut microbiota may induce intestinal cells to undergo an inflammatory response. This vitamin is crucial for the development of the bacteria *Lactobacillus plantarum*, which, in consequence, plays a vital role in the manufacture of acetylcholine [44,45]. Acetylcholine serves as the primary neurotransmitter of the parasympathetic nervous system. In summary, a lack of vitamin B5 in the body may exacerbate disease and increase sympathetic nervous system activity [46]. Additionally, it was shown to negatively impact the immune system and physical barrier function in fish [47]. Possible disorders associated with a deficit in vitamin B6 include

inflammation, cancer, pneumonia, COVID-19, diabetes, atherosclerosis, and cardiovascular ailments [48]. (Fenech, 2012) reported, the available scientific evidence from both in vitro and in vivo investigations involving human cells consistently demonstrates that a shortage in folate leads to several detrimental effects. These effects include the expression of chromosomal fragile sites, the occurrence of chromosome breaks, an excessive presence of uracil in DNA, the production of micronuclei, DNA hypomethylation, and the occurrence of mitochondrial DNA deletions. The findings from in vivo investigations indicate a substantial association between deficiencies in folate and/or vitamin B12, raised plasma homocysteine levels (a metabolic marker of folate deficiency), and the occurrence of increased micronucleus production and decreased telomere length, respectively [49]. Vitamin A is essential at all stages of the human life process. Alongside its derivatives, it governs a range of activities, including vision, reproduction, embryogenesis, development, cell division and growth, proper metabolism, and immunological function. The capacity of vitamin A to selectively impact and influence many biological processes, with its precise and well-controlled homeostatic regulation [50]. Vitamin E is a kind of antioxidant that is soluble in lipids. It works by interrupting the chain reaction caused by free radicals, which helps to shield cell membranes and lipoproteins from being harmed by oxidative stress. Vitamin E has a role in several physiological processes, including immunological function, inflammation control, gene expression regulation, and cognitive functioning. Vitamin E deficiency is characterised by peripheral neuropathy, ataxia, and anaemia [51]. Vitamin E insufficiency is characterised by a decrease in red cell half-life and altered erythrocyte membrane shape caused by oxidative stress in patients. Cognitive impairments such as ataxia, hyporeflexia, blindness, and dementia may develop from chronic vitamin E insufficiency [52]. Long-term health issues, such as neurological symptoms, osteoporosis, and osteopenia, may be the consequence of subclinical or clinical deficits in fat-soluble vitamins, which may increase morbidity and disease severity [53]. One of the most frequent mild chronic medical diseases in the world is vitamin D insufficiency. In youngsters, this condition is called rickets, and it causes the bones to become flimsy, weak, and brittle [54]. Fat aids in the absorption of vitamins A, D, E, and K, known as fat-soluble vitamins (FSV). Vitamin A deficiency may cause night blindness; vitamin D deficiency can cause osteomalacia; vitamin E deficiency can increase oxidative cell stress; and vitamin K deficiency can cause bleeding [55].

1.5. Phenolic acids

Polyphenols include several compounds such as phenolic acids, coumarins, flavonoids, stilbenes, and lignans (Figure 1.2). Additionally, other polymerized forms, such as tannins and lignins, are included as well. A number of them are accountable for the fragrance, color, antioxidant characteristics of the veggies, fruits, seeds and nuts which we eat. Polyphenols are gaining significance, mostly due to their advantageous impact on health. Undoubtedly, their function as

innate antioxidants is progressively gaining importance in the prevention and management of cancer, inflammatory, cardiovascular, and neurological ailments [56].

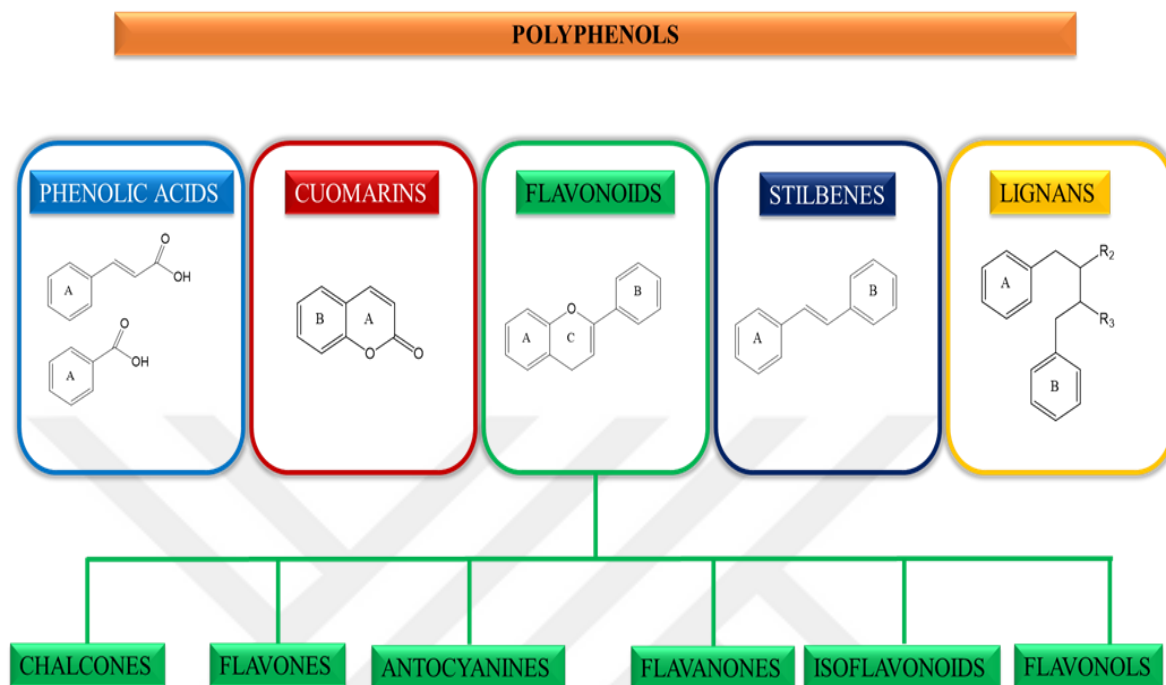


Figure 1.2. Polyphenol classification including phenolic acids, coumarins, flavonoids

The phenolic compounds found in plants are well recognized as an essential part of the human diet due to their high antioxidant activity and other positive health effects. Many illnesses, including cancer, diabetes, and cardiovascular disease, are linked to oxidative stress, but epidemiological research suggests that eating a diet high in antioxidant fruits and vegetables may considerably lower this risk. Variation in antioxidant potential is caused by differences in the amount and location of hydroxyl groups in different phenolic compounds. Polyphenols are easily absorbed in the gut and are the primary source of antioxidants in the diet. The phenol moiety and resonance-stabilised structure of phenolic acids, a subclass of plant phenolics, contribute to their antioxidant function through a radical scavenging mechanism. The antioxidant activity of phenolic acids has been attributed to a number of different mechanisms, including radical quenching through electron donation and singlet oxygen quenching. In addition to their widespread occurrence, phenolic acids have been scientifically shown to provide a variety of health benefits, including antibacterial, anticancer, anti-inflammatory, anti-mutagenic, and so on. Pharmacological applications of phenolic acids are highlighted as a primary focus of this paper [57]. L-phenylalanine and L-tyrosine are the primary precursors for the production of plant phenolics, which include simple phenols, stilbenes, phenolic acids, coumarins, flavonoids, hydrolyzable and condensed

tannins, lignins, and lignans. These phenolic compounds are developed primarily via the shikimate pathway. Phenylalanine and tyrosine are two amino acids that play a significant role in this pathway. This is due to the fact that these amino acids are the essential precursors for the vast majority of the naturally occurring phenolic compounds [58]. The hydroxybenzoic acid and the hydroxycinnamic acid subgroups are the two primary subgroups that are used to classify phenolic acids. In vitro, the antioxidant activity of phenolic acids is much greater than that of the antioxidant vitamins that are well recognised. In foods, hydroxycinnamic acids are often found in the form of simple esters with quinic acid or glucose. These acids are generated from cinnamic acid itself. It is chlorogenic acid, which is a combined form of caffeic and quinic acids, that is the most abundant soluble bound hydroxycinnamic acid that is present. Ferrulic acid, caffeic acid, p-coumaric acid, and sinapic acid are the four types of hydroxycinnamic acids that are most often found. On the other hand, hydroxybenzoic acids are generated from benzoic acid and share a structure that is composed of C6-C1 atoms. The soluble form of these compounds may be discovered conjugated with sugars or organic acids, and they can also be found coupled with cell wall components as lignin. Hydroxybenzoic acids are often found in red fruits, onions, and black radish in very low concentrations. This is in contrast to hydroxycinnamic acids, which are found in concentrated amounts. P-hydroxybenzoic acid, protocatechuic acid, vanillic acid, and syringic acid are the four types of hydroxybenzoic acids that are most often seen [59].

1.6. Flavonoids

Flavonoids, a kind of natural substance with a polyphenolic structure often found in fruits, vegetables, and certain drinks, are crucial to human health. Beneficial biochemical and antioxidant effects are linked to reduced risk of cancer, Alzheimer's disease (AD), atherosclerosis, and other disorders. Flavonoids have been linked to a wide range of health benefits and are used in several nutraceutical, pharmaceutical, medical, and cosmetic products. This is due to their ability to influence important cellular enzyme processes in addition to their antioxidant, anti-inflammatory, anti-mutagenic, and anti-carcinogenic capabilities [60]. Anthocyanins are a kind of flavonoid that is abundantly found in fruits and vegetables. Previous studies have shown that sumac fruits contain high levels of the pigment anthocyanins. The sumac fruit contains the anthocyanins delphinidin-3-glucoside, cyanidin-3-(200 galloyl)galactoside, cyanidin-3-glucoside, 7-methyl-cyanidin-3-(200 galloyl)galactoside, and 7-methyl-cyanidin-3-galactoside in that sequence [61,62]. Based on structural distinctions, this vast family of phenolic plant components may be further classified into flavanols, flavanones, flavonols, isoflavones, flavones, and anthocyanins. Flavonoid analogues and the metal complexes they form are also thought to have favourable health effects. Edible plant portions, such fruits and vegetables, are where these chemicals are most concentrated. The flavonoid system is what gives berries their red and dark blue hues and the citrus fruits their orange

and yellow hues. Their function in the human body is analogous to that of vitamins. Bioflavonoids are a common name for flavonoids that have biological function. They can neutralise lipid, superoxide, and hydroxyl radicals. A number of mechanisms have been proposed to explain the biological effects of dietary flavonoids and their analogues. These include scavenging free radicals, activating survival genes and signalling pathways, chelating transition metal ions, regulating mitochondrial function and bioenergetics, modulating the inflammation response, and even interacting with microbiota. However, flavonoids' effects extend well beyond their health advantages and into many other aspects of plants' ecological relationships, including their roles as signal and defence molecules. The pharmaceutical and nutraceutical industries aren't the only ones that can benefit from them. The structural variety of flavonoid molecules and their derivatives determines their diverse biological functions [63].

1.7. Antioxidants

Antioxidants are chemicals that shield living systems from damage caused by free radical oxidation [64]. Enzymatic and non-enzymatic antioxidants are the two main categories of antioxidants. Nonenzymatic antioxidants include ascorbic acid (Vitamin C), α -tocopherol (Vitamin E), glutathione (GSH), carotenoids, and flavonoids, while enzymatic antioxidants include glutathione peroxidase (GPx), superoxide dismutase (SOD), which protects against low levels of oxidative stress, and catalase (CAT) [65]. When reactive oxygen species (ROS) are not effectively removed from a system, oxidative stress may result. Secondary metabolites, such as phytochemicals and particularly phenolic compounds, are known to have powerful antioxidant effects. Antioxidant-rich plant foods have been linked in recent epidemiological research to a reduced risk of developing many illnesses. Several pathological conditions, including skin injuries, myopathies, overweight, and obesity, may benefit from Sumac's management or therapy due to its powerful antioxidant powers [66].

1.8. Glutathione GSH

Glutathione (GSH), often referred to as γ -L-glutamyl-L-cysteinyl-glycine, is a crucial antioxidant of small molecular weight that is synthesized inside cells. The compound is formed by the consecutive incorporation of cysteine into glutamate, followed by the addition of glycine. The cysteine's sulfhydryl group ($-SH$) plays a crucial role in reduction and conjugation processes, which are often regarded as the primary activities of GSH. These reactions facilitate the elimination of peroxides and several xenobiotic substances. Additionally, GSH has a role in regulating the cell cycle [67]. Glutathione has a crucial role as a constituent of the ascorbate-glutathione cycle, which is responsible for the modulation of hydrogen peroxide (H_2O_2) levels in plants. Excess electrons

generated by the electron transport chains in photosynthesis and respiration may be used for the reduction of oxygen, resulting in the production of superoxide radicals. These radicals are then converted into hydrogen peroxide (H_2O_2) by the action of an enzyme called superoxide dismutase (SOD; EC 1.15.1.1). During the process of eliminating surplus hydrogen peroxide (H_2O_2), the reduced form of glutathione (GSH) undergoes conversion to its oxidized state (GSSG). The restoration of GSH is facilitated by the enzymatic action of NADPH-dependent glutathione reductase (GR; EC 1.6.4.2) (Figure 1.3). Several plant species were shown to have significant levels of GSH content and GR activity at low non-freezing temperatures, suggesting a potential role in enhancing chilling resistance and facilitating cold adaptation. Alterations in the quantity of hydrogen peroxide (H_2O_2) and the ratio of reduced glutathione (GSH) to oxidized glutathione (GSSG) (Table 3.39), have the potential to modify the redox state of cells, hence potentially triggering the activation of certain defence systems via a redox signaling cascade [68].

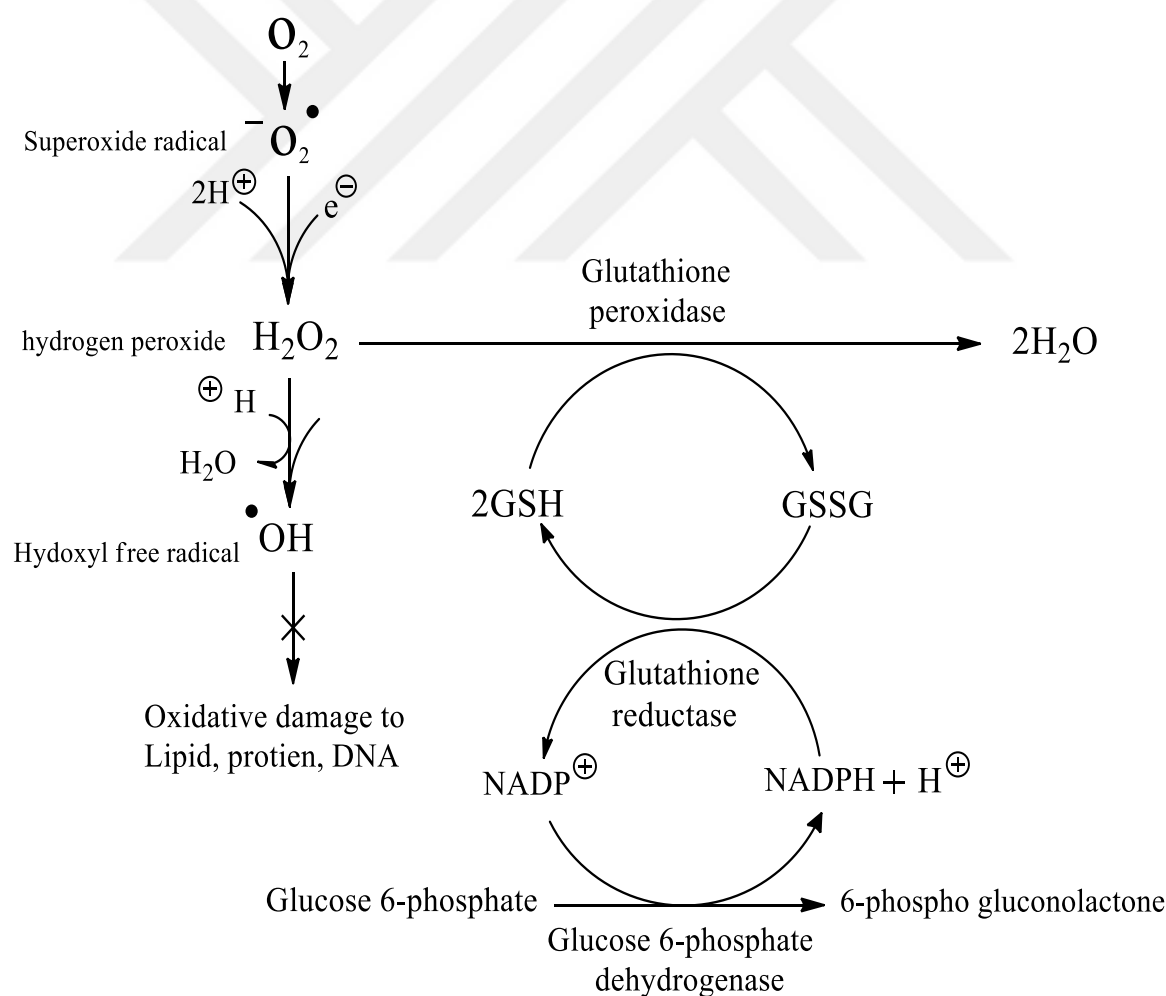


Figure 1.3. Reduced glutathione removing free hydroxyl radical

1.9. Glutathione disulfide GSSG

GSSG, also known as glutathione disulfide, is a disulfide that is produced by combining a pair glutathione molecule equation (1.1) [69]. The reduction of glutathione disulfide into two molecules of glutathione is a process that occurs in live cells. The reducing equivalents for this process come from the coenzyme NADPH. The enzyme known as glutathione reductase is responsible for catalysing this process [70]. For the purpose of reducing peroxides like peroxides made from hydrogen (H_2O_2) and organic hydroperoxides (ROOH), enzymes known as antioxidants such glutathione peroxidases and peroxiredoxins are responsible for the production of glutathione disulfide [71].



Glutaredoxins and similar enzymes produce glutathione disulfide by exchanging thiol-disulfide linkages with protein bonds made of disulfide or other small molecules, such as coenzyme A disulfide or dehydroascorbic acid equation (1.2) [72].



The ratio of reduced glutathione (GSH) to oxidised glutathione (GSSG) is a crucial biomarker for assessing the overall health of cells. A greater GSH:GSSG ratio indicates lower levels of oxidative stress in the body. A decreased ratio may also suggest the presence of neurodegenerative disorders, such as Alzheimer's disease and Parkinson's disease (PD) [73]. The GSSG/GSH redox potential is often used to elucidate redox regulation and other biological phenomena. The significance of the GSSG/GSH redox potential as a driving factor for biological activities is emphasised. It is noted that the concentration ratio of GSSG and GSH mostly represents a stable condition, predominantly influenced by rapid enzymatic processes that involve the utilisation, degradation, or regeneration of GSH. The GSSG/GSH potential might potentially serve as an analytical technique to reveal disruptions in redox metabolism [74].

1.10. Malondialdehyde MDA

Lipid peroxidation leads to the oxidative breakdown of polyunsaturated lipids. The process consists of a series of non-enzymatic autocatalytic processes mediated by free radicals, resulting in significant cellular damage. Components of biological membranes are the most often targeted entities. Lipid peroxidation in biological membranes leads to several issues, such as the formation of cyclic endoperoxides and aldehydes. It is composed of a hazardous substance [75,76]. The lipid radicals that are free ($L^\bullet$) and the peroxide of lipids radicals ($LOO^\bullet$) generated have a significant impact on the permeability of cell membranes, leading to detrimental effects that ultimately lead to

cell death. These reactions exhibit unsaturation. The process starts by extracting hydrogen atoms from the conjugated double bonds of fatty acids and proceeds till the creation of MDA. MDA is a low molecular weight aldehyde with three carbon atoms, which may be generated by many methods [77]. The process by which unsaturated fatty acids are transformed into cyclic endoperoxide and MDA due to peroxidation is shown in (Figure 1.4).

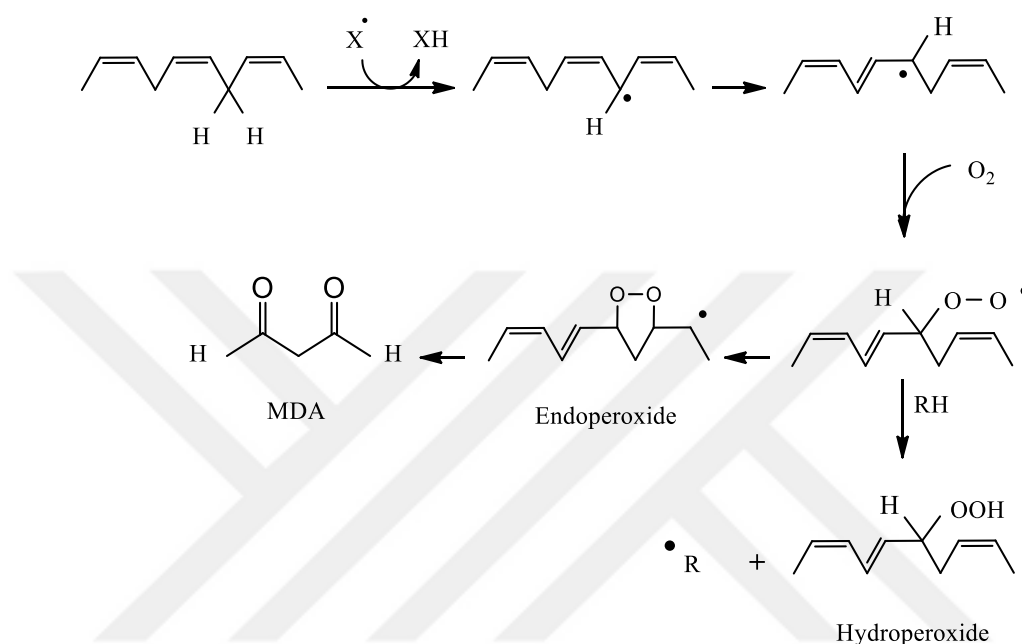


Figure 1.4. Lipid peroxidation process and malondialdehyde formation

The reactive species specifically targets the C-C double bond of unsaturated fatty acids. The presence of this double bond attenuates the strength of the CH bond, rendering the hydrogen susceptible to facile cleavage by a free radical. Subsequently, a free radical may extract a hydrogen atom, resulting in the formation of a peroxy radical. A lipid-free radical is generated, which then undergoes oxidation, resulting in the production of the peroxy radical. The peroxy radical has the ability to engage in a reaction with additional polyunsaturated fatty acids, resulting in the extraction of an electron and the formation of a lipid hydroperoxide as well as another lipid-free radical. This process may persist as a cascading [78–80]. Lipid hydroperoxide is inherently unstable and undergoes breakdown, resulting in the formation of compounds such as malondialdehyde and 4-hydroxy-2-nonenal. MDA generation in this instance is partially attributed to the subsequent oxidation of primary carbonyl [81,82]. This demonstrates that the endoperoxide responsible for the production of prostaglandins is derived from free radical byproducts generated by the iron-dependent oxidative breakdown of amino acids, carbohydrates, and gamma radiation [83]. The use of malondialdehyde (MDA) as a biomarker for the evaluation of oxidative stress in several biological disciplines is extensive. Lipid peroxidation is a sequential process that leads to the generation of diverse bioactive molecules,

ultimately causing harm to cellular structures. The use of biomonitoring for measuring MDA levels has been employed in both in vivo and in vitro investigations as a significant biomarker for a range of disease patterns, including hypertension, diabetes, atherosclerosis, heart failure, and cancer. Elevated levels of MDA have been documented in individuals across different patient cohorts, such as those diagnosed with lung cancer, complicated regional pain syndrome, and glaucoma. The results indicate that the MDA test is a dependable method for assessing oxidative stress in various disease types [84].

1.11. 4-Hydroxynonenal 4-HNE

4-HNE is a highly reactive aldehyde that is produced as a byproduct of lipid peroxidation. The compound known as 4-HNE, sometimes referred to as HNE, has a molecular formula of $C_9H_{16}O_2$. At the beginning of the 1960s, Schauenstein and colleagues were the ones who made the first discovery of the substance that is now known as HNE. They characterised it as a 4-hydroxyalkenal [85,86]. 4-HNE is a type of alpha-beta-unsaturated aldehyde that is produced by the process of lipid peroxidation of omega-6 polyunsaturated fatty acids, including the fatty acids linoleic acid, linolenic acid, and arachidonic acid. The chemical compound known as 4-hydroxynonenal (4-HNE) is shown in (Figure 1.5), illustrating its fundamental molecular arrangement.

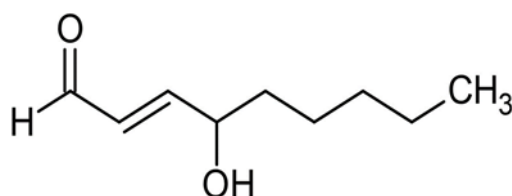


Figure 1.5. 4-Hydroxynonenal (4-HNE)

4-HNE is a highly reactive molecule that has three functional groups, namely a hybrid system comprising a $C = C$ double bond and a $C = O$ carbonyl group, as well as a hydroxyl group ($-OH$). This arrangement results in a partial positive charge being supplied to carbon 3. In several instances, these three functional categories exhibit a propensity for cooperative behaviour, hence elucidating their notable responsiveness [87]. 4-HNE has a broad distribution across several biological systems. Biophospholipid membranes have a high concentration of omega-6 polyunsaturated fatty acids (PUFAs), whereas 4-hydroxynonenal (4-HNE) is a molecule that has both hydrophilic and lipophilic properties. Consequently, 4-HNE is disseminated inside the cells and tissues of many species. Moreover, it should be noted that the processing and storage of food items that include omega-6 polyunsaturated fatty acids (PUFAs) might result in the generation of small quantities of 4-hydroxynonenal (4-HNE) [88]. 4-HNE has the ability to operate as a bioactive molecule in both

physiological and pathological contexts. This is mostly due to its capacity to modulate signalling pathways by creating covalent adducts with the nucleophilic functional groups in proteins, nucleic acids, and membrane lipids. The creation of these adducts, which are mostly irreversible, has the potential to have several detrimental effects, including the suppression of DNA, RNA, and protein synthesis [87]. Besides biochemical adjustments, 4-HNE has the capability to induce physical alterations in proteins and the phospholipid membranes, hence affecting the fluidity of cell membranes [89]. Although most cell types have an active metabolism, the presence of HNE may be identified in many biological tissues using sufficiently accurate techniques, although with varying levels of sensitivity. Significantly elevated levels of 4-hydroxynonenal (HNE) are often seen in many human illness conditions, indicating a potential role of this aldehyde in the development and progression of certain pathological processes. One of the notable pathobiochemical consequences of HNE is its significant induction of fibrogenesis and inflammation. This suggests that the aldehyde may play a role in the development of various chronic diseases, which are known to be driven by inflammatory responses and marked by fibrotic changes. Moreover, it is noteworthy to examine the capacity of HNE to regulate cellular proliferation by disrupting the functions of cyclins, protein kinases, and the apoptotic apparatus [90]. Consequently, 4-HNE functions as a type of biomarker that measures the peroxidation of lipids and oxidative stress. Consequently, the suppression, counteraction, and detoxification of 4-HNE and its adducts have emerged as focal areas in the pursuit of possible treatments for illnesses associated with oxidative stress. Throughout history, plants with medicinal properties have been extensively used for the purpose of preventing and treating a diverse range of ailments over an extended period of time. The extracts and bioactive components possess the capacity to mitigate cellular damage caused by oxidative stress. Certain sources have been proposed as potentially promising agents for mitigating oxidative stress and reducing the toxicity generated by 4-HNE [91].

1.12. Amino acids

Amino acids are chemical molecules containing a side chain (R) and amine ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) functional groups that are structurally distinct from one another. Carbon, hydrogen, oxygen, and nitrogen are the major constituents of amino acids, while additional atoms may be present in the lateral chains of certain amino acids. It is estimated that there are over 300 different amino acids, while the genetic code only contains 20 [92]. In the production of both protein building blocks and intermediates, amino acids play a crucial role. The 20 amino acids contained in proteins indicate a broad range of chemical versatility. The sequence of bases in the gene producing a protein specifies the precise structure of the protein's amino acids and the order in which those amino acids occur in the protein. Amino acids are also crucial because their chemical characteristics dictate the biological activity of a protein. Proteins not only catalyse every reaction

in a live cell but also regulate practically every cellular process. In addition, the amino acid sequences of proteins provide the information required to predict how this protein will fold into a three-dimensional structure and how stable that structure will be. In addition to serving as residues in proteins, amino acids participate in a wide range of functions, such as neurotransmitter transport and biosynthesis. Both protein and non-protein essential amino acids play crucial roles in living organisms. The amino acid L-aspartate is the substrate for the production of proteins, asparagine, arginine, nucleotides, and a number of compounds that have a role in the growth of nervous system tissue and neural transmission. It is of particular significance in the processes of urea synthesis, the purine-nucleotide cycle (PNC), gluconeogenesis, the malate-aspartate shuttle (MAS) and neurotransmission [93]. There is little doubt that asparagine plays a crucial part in the process of nitrogen transportation and storage in plants, which is made possible by the chemical qualities that it has. A variety of tissues are included in this category of accumulation [94]. The de novo production of the purine nucleotide & the pyrimidine nucleotides deoxythymidine monophosphate both get their one-carbon units from serine, which is the major source of these units [95]. About one-third of protein-derived nitrogen is carried in the blood as glutamine. Using oxaloacetate to create aspartate, glutamate and glutamine's amino groups may enter the urea cycle directly. As a nitrogen shuttle, glutamine helps excrete nitrogenous waste and maintain acid-base equilibrium. Glutathione production is regulated by glutamine. The tripeptide glutathione contains glutamate, cysteine, and glycine. Besides providing intracellular glutamate, glutamine may indirectly help to glutathione formation by trading intracellular glutamate. ATP for cellular respiration may be produced via glutamine oxidation [96]. Both aspartate aminotransferase (AST) (EC 2.6.1.1) and alanine aminotransferase (ALT) (EC 2.6.1.2) are enzymes that are mostly located in the liver. However, they are also present in muscle tissue, heart cells, red blood cells, and other organs, such as the pancreas and the kidneys [97]. Along with to functioning as a vital component in the process of protein synthesis, known as non-essential aromatic amino acid L-tyrosine also plays a role as an amino acid precursor to melanin pigment, tyramine/octopamine, catecholamines and thyroid hormones. This occurs via the organification of Iodine that on the tyrosine residue of thyroglobulin, with monoiodo- and diiodotyrosine serving as intermediates [98]. L-Arginine undergoes conversion by arginase into L-ornithine, thus serves as a precursor for the polyamines and urea. This conversion is crucial in the urea cycle. Arginine acts as a building block for creatine, a vital component in the energy metabolism of skeletal muscle, neuron, and testis. Arginine is also involved in the breakdown of arginine itself and the production of agmatine and proteins [99]. Through its function as a substrate for the synthesis of proteins, as well as for the creation of glutathione, hydrogen sulphide (H₂S), and taurine, intracellular L-cysteine plays a significant role in the maintenance of cellular homeostasis [100]. Some of the most important excitatory and inhibitory neurotransmitters in the human brain, respectively, are glutamate (the standard glutamic acid) and gamma-amino-

butyric acid (a non-standard gamma-amino acid) [101]. respectively. Proline, a component of the connective tissue protein collagen, serves as the building block for the synthesis of hydroxyproline. Glycine is involved in the manufacture of porphyrin, which is a component of red blood cells. Lipid transportation employs carnitine. Nine proteinogenic amino acids are deemed "necessary" for humans since they cannot be synthesised by the body from other chemicals. Some people may be absolutely required, depending on age or health status. Some species may have different requirements for essential amino acids. Because of their biological importance, amino acids are widely employed in dietary supplements, agricultural applications, and the food industry. Drug production, biodegradable polymers, and chiral catalysts are only a few of the industrial uses [102].

1.12.1. Essential amino acids

In humans and other vertebrates, there is a class of amino acids called "essential amino acids" that cannot be produced from metabolic intermediates. Since the human body lacks a source of synthesis for these amino acids, they must be supplied exogenously. [103]. In regards to nutrition, amino acids may be broken down into two groups: essential and non-essential. Experiments conducted on early human diets demonstrated that some amino acids are required for development or nitrogen stabilization, despite the abundance of other amino acids. Of the 20 amino acids, nine—phenylalanine, valine, tryptophan, threonine, isoleucine, methionine, histidine, leucine, and lysine—are considered "essential." [104]. The essential amino acids valine, leucine, and isoleucine, together known as branched-chain amino acids (BCAAs), have been extensively researched in many conditions including liver cirrhosis, renal failure, sepsis, trauma, burn damage, and cancer. BCAA supplementation is believed to enhance anabolic pathways, hence reducing cachexia, preventing or treating symptoms of hepatic encephalopathy, reducing tiredness during exercise, promoting wound healing, and stimulating insulin production [105]. Phenylalanine serves as a building block for a wide variety of secondary compounds, including as flavonoids, phenylpropanoids, anthocyanins, and lignin, which is found in the structural component of cell walls [106]. Tryptophan, which is an important amino acid in animals, has a role in a number of key biological processes, particularly the function of neurons, the immune system, and the state of homeostasis of the gut. In human beings, tryptophan is metabolised via the kynurenine and serotonin pathways, which ultimately results in the production of physiologically active chemicals including niacin, serotonin, and melatonin [107]. lysine supplement enhanced the growth ability of the animals, as well as raised the amount of nitrogen that was retained and the amount of protein that was accumulated [108]. Threonine is a crucial component of structural proteins, such as collagen and elastin, which are vital constituents of the skin and connective tissue. Furthermore, it has a role in lipid metabolism and immunological function. Despite its common association with inducing sleepiness, tryptophan serves several purposes. Maintaining proper nitrogen stability is

challenging, as it serves as a precursor to serotonin, a neurotransmitter that governs hunger, sleep, and mood. Methionine has a crucial role in both metabolism and detoxification. It is crucial for tissue growth and the assimilation of zinc and selenium, elements that are vital for your well-being. Leucine Similar to valine, leucine is an essential branched-chain amino acid that plays a crucial role in protein synthesis and muscle recovery. Furthermore, it facilitates the regulation of blood sugar levels, accelerates wound healing, and increases the production of growth hormones. Isoleucine is considered the most superior of the three branched-chain amino acids. Isoleucine plays a crucial role in muscle metabolism and is mostly concentrated in muscle tissue. It is also crucial for immunological function, haemoglobin synthesis, and energy management. Lysine plays a crucial part in protein synthesis, the production of hormones and enzymes, and the absorption of calcium. It is also crucial for energy generation, immunological function, and the synthesis of collagen and elastin. Histidine is used to provide histamine, a neurotransmitter that plays a crucial role in immunological response, digestion, sexual function, and sleep-wake cycles. Preserving the myelin sheath is crucial for maintaining the protective barrier that surrounds your nerve cells. abody, Clinical symptoms might arise from an insufficient supply of vital amino acids, resulting in manifestations such as vomiting and a lack of appetite. The symptoms include despair, anxiety, sleeplessness, lethargy, weakness, and teenage development retardation. The primary cause of these symptoms is mostly attributed to insufficient protein synthesis in the body, resulting from a deficit of crucial (essential) amino acids. The necessary quantity of amino acids is essential for the synthesis of neurotransmitters, hormones, and muscular development [109].

Previous research has shown that sumac has a high concentration of amino acids. Foods containing more than 40.00% total amino acids are considered good protein sources by the FAO and the WHO. Protein-rich animal meals include milk (44.00% total amino acids), fish (40.70%), and eggs (40.20% total amino acids) [110].

It is also possible for sumac to grow in regions that are not ideal for agricultural purposes; this demonstrates the possibility for commercialization of sumac plants without being in competition with other land uses. Sumac, which is a natural source of bioactive compounds, has a large potential with components that may be used in a wide variety of sectors. These components include organic acids, fatty acids, amino acids, vitamins, minerals, anthocyanins, and phenolic acids. As a result of the presence of phenolic chemicals, particularly gallic acid and its derivatives, it also has a powerful antioxidant activity. Sumac, also known as *Rhus coriaria* L., is one of the spices and sumac sour that are used in the culinary sector to provide scent and flavour to a wide variety of foods. In addition, because of the bioactive components that it contains, it is regarded as a desirable raw resource for the food sector. Consumers are becoming more interested in sumac on a daily basis as a result of factors such as the expanding applications of the sumac plant in the food industry and the growing awareness of the plant's positive impact on human health.

Both bioclimate and climate factors have an advantageous impact on plant production via parameters such as the annual ombrothermic index, the thermicity index, precipitation, temperature, and soil water reserve. On the other hand, water shortage and simple continentality index have a negative effect on plant production. On top of that, the growth, development, sustainability, and production of plants are all influenced by a variety of factors. These factors include the bioclimate, climate, varieties, breeding, age, abiotic factors (such as sunlight, air, precipitation, minerals, and soil), diseases, and the periods of dormancy and flowering that the plants go through. The aim of this investigation was to analyze some of the sumac fruit phytochemical compositions such as (minerals, water-soluble vitamins, Vitamin A, E, β -carotene, lycopene, MDA, GSH, GSSG, 4-HNE, total phenolic acid, total flavonoids, antioxidant capacity (TEAC and DPPH) and amino acids of eleven different sumacs from different areas in Iraq and Turkey, collected from different bioclimatic and geographical zones, in order to identify those chemotypes for food, agriculture and industrial uses.

2. MATERIALS AND METHODS

2.1. Sample preparation

Different varieties of mature and dried somac fruits were acquired from the local market during the same harvest season. The samples were collected from two distinct geographical regions, namely Elazig and Marash in Turkey and Trwanish, Shelaza, Shahi, Charput, Sulaymania, Kadana, Derishke, Ranya, and Sheladeze in Iraq. The names assigned to sumac varieties are derived from the villages or cities where they were harvested. Prior to conducting chemical analysis, the raw material was homogenised into a fine powder using a coffee grinder. This fine powder was then divided into three categories. The first category consists of fresh fine powder, which was directly used to determine the bioactive compounds and their antioxidant properties. The second kind underwent preservation by immersion in sunflower oil for a duration of six months at a temperature of 5 degrees Celsius inside a refrigerator, the ratio of sample to sunflower oil is (90:10) (w/w). The third category was stored for six months also at the same temperature in a refrigerator without immersion in cooking oil. The objective of this research division is to investigate the impact of oil on the preservation of food items, specifically focusing on the nutritional content of sumac after a six-month period in comparison to its fresh counterpart.

2.2. Chemicals and equipments

The solid & liquid testing chemicals, including quercetin (dehydrate), potassium persulfate, sodium nitrate, aluminium chloride, gallic acid, butylated hydroxytoluene, flavone, perchloric acid, and all other standard and chemical reagents, were procured from reputable suppliers such as Sigma Aldrich or Merck. The experimental procedure included the use of double-distilled water (dd H₂O) as the solvent. Analytical-grade solvents used for sample preparation were redistilled before use as impurities in the solvent could interfere with the sample peak in the HPLC chromatogram. Solvents for liquid chromatography were of HPLC grade. All solvents used as the mobile phase in HPLC were filtered through a membrane filter system and degassed using an ultrasonic bath. HPLC was performed with the SHIMADZU Prominence-İ LC- 2030C 3D Model and PDA detector. For spectrophotometric readings, a UV-VIS spectrophotometer was used. Trace element detection, Methods of sample digestion (ETHOS EASY, Advanced Microwave Digestion System, and Milestone Connect) are used. Inductively coupled plasma optical emission spectrometry was done with the Thermo Scientific iCAP 7000 Series ICP-OES, CID86: 540*540 pixels. Almost any metal can be measured quickly and accurately with this method. The use of ICP-OES systems has spread rapidly and is now the preferred analytical technique in many fields. This is why many academic institutions favour it.

2.3. Analysis of elements

2.3.1. Microwave digestion

Approximately 0.5 g of material was digested in a microwave digestion machine with 9 mL of HNO₃ and 1 mL of H₂O₂. The mix of ingredients was placed in a microwave bomb vessel. The solutions were then cooled and diluted to 50 mL with distilled water after being subjected to microwave digestion at 210 °C for 45 min at 1800 W.

2.3.2. Apparatus

Methods of sample digestion (ETHOS EASY, Advanced Microwave Digestion System, and Milestone Connect) are used. Inductively coupled plasma optical emission spectrometry was done with the Thermo Scientific ICAP 7000 Series ICP-OES, CID86: 540*540 pixels. Almost any metal can be measured quickly and accurately with this method. The ICP-OES has a very wide, dynamic, calibration range. For this reason, both wavelength and working ranges were determined for each element. To make the calibration standards, we diluted the 100 mg/L of the stock Multi Element ICP QC Standard sol. in 0.5% (v/v) nitric acid. Boron element was determined on the radial axis, and the other elements were determined on the axial axis. The wavelengths used for the determination of Na, K, Mg, P, Zn, Cu, Fe, Se, Mn, Cr, Mo, Ni, B, As, Cd, Pb, and Hg elements by ICP-OES are 589.592, 766.490, 279.533, 213.618, 206.200, 324.754, 271.441, 196.090, 259.373, 205.560, 202.030, 231.604, 249.773, 189.042, 214.438, 220.353, and 184.950 nm respectively. Limit of detection (LOD) values of Na, K, Mg, P, Zn, Cu, Fe, Se, Mn, Cr, Mo, Ni, B, As, Cd, Pb, and Hg elements by ICP-OES were 8.0, 2.0, 0.8, 100, 0.6716, 3.8606, 5.2631, 12.8696, 0.5124, 0.7184, 2.7717, 4.1727, 0.6677, 12.2302, 0.3318, 12.8395, and 0.7787 ppb respectively. All of the elements' calibration curves ranged between 2.5 and 70 ppb. The argon used in the plasma torch has a purity level more than 99.99%. [111,112] It was observed that the correlation coefficients of the obtained calibration curves were R² ≥ 0.98.

2.4. Health risk assessment

The health risk associated with sumac consumption was estimated based on the estimated daily intake (EDI) equation (2.1). The EDI value was calculated based on the daily consumption of 1.0 g of sumac per 70 kg of body weight.

$$EDI = \frac{MS * C}{BW} \quad (2.1)$$

In the equation, C (mg/kg) is the metal concentration in sumac, MS is the daily amount of sumac consumed by the person (g/day $\times$ person), and BW is the average adult body weight (70 kg). The health risk assessment of metals (non-carcinogenic hazard) in sumac samples was calculated using the equation developed by Dadar et al. [113]. The target hazard coefficient (THQ) value is calculated from the equation below.

$$THQ = \frac{EF * ED * EDI}{RfD * AT} \quad (2.2)$$

EF is the exposure frequency (365 days/year), ED is the exposure duration (70 years), RfD is the reference intake dose of the element (mg/kg/day), and AT is the mean life expectancy (EF $\cdot$ ED) ((365 days/year) 70 year). It has been reported that when THQ is >1 , the possibility of harmful effects of metals increases. The total target hazard coefficient (TTHQ) is the sum of the THQ values of each metal.

2.5. Analysis of water-soluble vitamins

Of 0.5 M HClO₄, 1.0 mL was added to 1.0 g of ground sumac samples and vortexed for 1.0 min. After the total volume was made up to 5.0 mL with distilled water, it was sonicated (Wise Clean, WUC-AO3H, 170 W) for 10 min. Then, it was centrifuged at 4500 rpm for 10 min, and the supernatant was taken into 1.0 mL HPLC vials. SHIMADZU, Prominence-I LC-2030C 3D Model HPLC equipped with PDA detector was used for the determination of water-soluble vitamins using a gradient program on an Inter Sustain AQ-C18 (5 μ m, 150 $\times$ 4.6 mm I.D.) column. By using the prepared stock solutions, the wavelength of maximum absorbance and retention times of each vitamin were determined. It was observed that the retention times were the same as the chromatogram given in the literature [114].

2.6. Determination of vitamins A, E, β -carotene, lycopene and 4-hydroxynonenal

A total of 1.0 grammes of homogenised ground sumac samples were placed into a tube. Subsequently, 5.0 millilitres of ethanol (C₂H₅OH) were added to the tube. The sample was then subjected to sonication for a duration of 10 minutes, followed by vortexing and centrifugation at 7,500 revolutions per minute for 6 minutes. Subsequently, a volume of 1.0 mL of n-hexane was introduced to the sample and agitated using a vortex mixer. This was followed by the extraction of the n-hexane phase, a procedure that was performed twice. The n-hexane phases that were gathered were subjected to vacuum drying. The resulting residue was then dissolved in 1.0 mL of methanol. Analysis of the dissolved residue was conducted using Inertsil ODS-3 column (25.0 cm x 4.6 mm x 5.0 μ m), using a mixture of methanol and water (95:5) as the mobile phase [115].

2.7. Determination of glutathione, glutathione disulfide and malondialdehyde

A mass of 1.0 grammes was measured from each sample of Sumac. Subsequently, a volume of 1.0 millilitres of 0.5 M perchloric acid was introduced into the homogenate of each sample in order to induce protein precipitation. The solution was introduced into a vortex shaker. Each sample was diluted to a volume of 5.0 mL using deionized water and subjected to centrifugation at a speed of 4500 revolutions per minute for a duration of 10 minutes. Subsequently, the supernatant underwent filtration using a Whatman No. 1 filter. A volume of 20 μ L of the supernatant was put straight into the High-Performance Liquid Chromatography (HPLC) system. The amounts of GSH, GSSG and MDA in sumac samples were determined by HPLC on the SGE Walkosil II 5C18 RS (15cm x 4.6 mm x 5 μ m) column, using 50 mM NaClO₄ solution containing 0.1% H₃PO₄ as the mobile phase [115].

2.8. Extraction of ground sumac samples fruit

Samples of sumac were treated with various pre-treatments, followed by homogenization. Subsequently, 15 grammes of the sample were extracted using 250 mL of methanol in a Soxhlet apparatus for a duration of 6 hours. Subsequently, the methanol was eliminated using a rotary evaporator operating at a temperature of 40 °C under decreased pressure. The sample was dehydrated, weighted, and then dissolved in 10 mL of methanol (CH₃OH). The resulting solution was thereafter refrigerated at a temperature of 4 °C until it was ready for analysis [116].

2.9. Determination of total phenolic content

The spectrophotometric determination of total phenolic substances was conducted using the Folin-Ciocalteu technique, as modified by Dewanto et al. (2002). A mixture was prepared by combining 0.50 mL of distilled water, 0.250 mL of either a sample or gallic acid, and 0.125 mL of the Folin-Ciocalteu reagent. The resulting mixture was then subjected to shaking. Following a time interval of 6 minutes, a quantity of 1.250 mL of a sodium carbonate solution with a concentration of 7% was introduced, subsequently augmenting the overall volume to 3.00 mL with the addition of distilled water. The absorption at a wavelength of 760 nm was measured using an ultraviolet-visible spectrophotometer after a duration of 90 minutes. A graph depicting the gallic acid solutions created at various concentrations was constructed Figure A 14. The determination of the total phenolic content of the samples was conducted, and the results were expressed as microgrammes of gallic acid equivalent per gramme of dry weight sample (μ g GAE/g dw) [117].

2.10. Determination of total flavonoids

The quantification of the overall flavonoid content was conducted using spectrophotometric methods, following the procedure outlined by Dewanto et al. (2002). A 0.025 mL sample of quercetin was combined with 1.250 mL of distilled water, 0.075 mL of a 5% sodium nitrite solution, and 0.150 mL of a 10% solution of aluminium chloride in a glass tube. The mixture was left undisturbed for 5 minutes. Subsequently, 0.500 mL of a 1.0 M sodium hydroxide solution was introduced, and the total volume was adjusted to 2.500 mL using distilled water. The resulting solution was then subjected to absorbance measurements at a wavelength of 510 nm. A graph was constructed using quercetin solutions that were created at varying concentrations Figure A 15. The determination of the total flavonoids content of the samples was conducted using the working graph, and the obtained findings were expressed in micrograms of quercetin equivalents per gramme of dry weight [117].

2.11. Antioxidant capacity DPPH method

The measurement of antioxidant capacity was conducted using a technique that relies on the scavenging activities of the stable DPPH free radical. A solution containing 25 µg/mL of DPPH in methyl alcohol was produced, and the absorbance of the DPPH solution was recorded at a wavelength of 510 nm. Subsequently, varying quantities of the sample extracts were introduced into a DPPH solution and allowed to incubate in the absence of light for a duration of 30 minutes, after which the absorbance at a wavelength of 510 nm was measured, the absorptions of measurements applied to equation (2.3). The results were reported in terms of IC₅₀ µg/mL, which represents the concentration of the antioxidant compound required to block 50% of the DPPH radical in the medium Figure A 16. Low IC₅₀ values are indicative of elevated levels of antioxidant activity [118].

$$\% \text{ Inhibition} = \frac{[\text{Abs. control} - \text{Abs. sample}] * 100}{\text{Abs. control}} \quad (2.3)$$

2.12. Antioxidant capacity TEAC method

Using the ABTS (2,2'-Azino-bis-3-ethylbenzothiazoline-6-sulfonic) activity technique, which was established by Re et al. (1999), the antioxidant activities of sumac samples were measured. The ABTS solution was allowed to sit at room temperature in a dark, shady spot for 12–16 hours after preparation. In a 1000 ml volumetric flask, a PBS (Phosphate-buffered saline) solution was made. The pH of the solution was then tested until it reached 7.4. Distilled water was then added to the flask of PBS until it reached 1000 ml. The absorbance of the ABTS solution was

brought up to 0.80 units at 734 nm by diluting it with PBS solution. After adding 2 milliliters of ABTS solution to the 25, 50, 75, and 100 microliters of diluted sample in the reaction mixture, which had been kept in a dark area for 5 minutes, the spectrophotometer reading was taken at 734 nanometers Figure A 16. Every measurement was taken three times. The determination of the antioxidant capacity of the sample was conducted by calculating its Trolox equivalent, expressed in μmol Trolox per gramme of dry weight [119].

$$\% \text{ ABTS} = \frac{[\text{Abs. control} - \text{Abs. sample}] * 100}{\text{Abs. control}} \quad (2.4)$$

2.13. Determination of amino acids

Hydrolysis: A total of 1.0 grams of finely powdered fresh fruit samples were placed in a glass tube. Subsequently, 5.0 mL of 6.0 N hydrochloric acid (HCl) was added, and the mixture was vigorously mixed using a vortex. The samples were then subjected to a temperature of 110 °C for a duration of 24 hours in order to facilitate the cleavage of peptide bonds. Subsequently, the samples were allowed to cool to ambient temperature, followed by filtration. The resulting filtrate was then adjusted to a final volume of 5 mL using distilled water [120].

2.14. Derivatization

A series of standard amino acid solutions were generated by using 0.10 N hydrochloric acid (HCl) at varying concentrations ranging from 1.0 to 5.0 $\mu\text{g/mL}$. Fifty microliters of standard amino acid solutions or hydrolyzed fruit samples were put into glass tubes with a volume of 5.0 millilitres and then subjected to vacuum drying at a temperature of 65 degrees Celsius. Next, a volume of 50 μL of a solution called "reagent 1" was introduced. This solution consisted of a combination of ethanol, water, and triethylamine (TEA) in a ratio of 2:2:1 (v/v). The resulting mixture was then subjected to vortexing and dried under vacuum at a temperature of 65 °C. The dried samples were subjected to vortexing by the addition of 50 μL of a solution referred to as "reagent 2". This solution consisted of a combination of ethanol, water, triethylamine (TEA), and phenyl isothiocyanate in a ratio of 7:1:1:1 (v/v). The vortexed samples were then allowed to incubate at room temperature in the absence of light for a duration of 30 minutes to facilitate the formation of complexes. Following the conclusion of this time frame, the specimens were subjected to a secondary drying process in a vacuum environment at a temperature of 35 °C. Each dried sample was treated with a combination of 1.0 mL of mobile phase A and acetonitrile (in a ratio of 8:2 v/v). The samples were then vortexed and transferred into high-performance liquid chromatography (HPLC) vials for further analysis [121].

2.14.1. Chromatographic procedure for amino acid analysis

The analysis of amino acids was conducted using high-performance liquid chromatography (HPLC), using a modified version. The experimental setup included the use of a Nucleodur 100-5 C18 column with dimensions of 250x4.6 mm and a particle size of 5 µm. The analyses were conducted by implementing the gradient programme at a temperature of 40 °C. The mobile phase is composed of a combination of eluent A and eluent B, with a flow rate of 0.8 mL/min and measured at a wavelength of 254 nm (Table 2.1.). The eluent A used in this experiment is a solution containing 0.07 M of CH₃COONa·3H₂O, with a pH of 6.4 achieved by the addition of CH₃COOH. On the other hand, eluent B is a combination of acetonitrile (ACN) and water in a volumetric ratio of (60:40 v/v) [120,121].

Table 2.1. Gradient program used for the separation of phenylthiocarbamyl-amino acids

Time (minute)	Flow rate (mL/min)	% Eluent A	% Eluent B
0.01	0.8	90	10
12.00	0.8	70	30
16.00	0.8	65	35
16.01	0.8	50	50
25.00	0.8	100	0
30.00	0.8	50	50
30.01	0.8	10	90
35.00	0.8	10	90

Some biochemical parameters in foods change depending on shelf life. Sumac samples are generally sold for consumption in ground form. Therefore, ground and oiled sumac samples were analyzed after being kept for six months to simulate average shelf life of the sumac in the market.

2.15. Trace element analysis

To determine the elements in the sumac samples, a calibration curve was created for the stock Multi Element. This was done by preparing standard solutions with various concentrations and measuring the emission intensity for each element. The calibration curves were then constructed by plotting the emission intensity in counts per second (cps) against the concentration in parts per million (ppb). Finally, the result converted to ppm unit [122,123].

2.16. Water-soluble vitamins and other parameters analysis

The process of calculating for each of the parameters was performed using the operational graph. The data obtained via the HPLC chromatogram were analysed based on the peak area. An equation, such as $y = 141431x + 13951$ (Figure A 10), was used to determine the quantity of vitamin A present in the Sumac sample. The chromatogram of vitamin A was analysed by substituting vitamin A for x in the appropriate equation to compute the retention time peak area in the sample.

The equation utilised the studied chart of amino acids, water soluble vitamins, vitamin A, E, C, β -carotene, lycopene, 4-HNE, MDA, GSH, and GSSG to calculate the quantities of these substances in various Sumac samples. Hence, the equation $y = 141431x + 13951$ represents the relationship between the peak area values in the chromatogram of several compounds (amino acids, water soluble vitamins, vitamin A, E, C, β -carotene, lycopene, 4-HNE, MDA, GSH, and GSSG found in Sumac samples. The levels of amino acids, water-soluble vitamins (including Vitamin A, E, C, β -carotene, lycopene), 4-HNE, MDA, GSH, and GSSG were computed as x for each sample.

The radical scavenging activity of DPPH, ABTS, and the total phenolic + flavonoids content were calculated using the generated graphs obtained from UV-Vis spectroscopy. The calculations for the graphs were performed using each parameter, and the results were obtained using the appropriate equation [124,125].

2.17. Statistical analysis

All analyses were repeated three times and the results are given mean $\pm$ deviation. Findings were subjected to One-Way ANOVA using SPSS 26.0 for MS Windows. Differences between group means were analysed for significance using the Tukey HSD test and statistical significance was expressed as $p < 0.05$. Significant differences in table rows are indicated by different numbers of * while the same numbers of * indicate there is no statistical difference between groups. The same letters in the table column indicate that there is no significant difference ($p > 0.05$) in the regions.

3. RESULT AND DISCUSSION

Table 3.1. Amount of elements in fresh sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw)

	Maraş	Elazığ	Shelaza	Trwanish	Shahi	Charput	Suleymania	Kadana	Derishke	Ranya	Sheladize
Na	846.6±15.5 ^b	661.7±13.2 ^c	486.8±10.1 ^e	634.9±11.5 ^c	423.3±9.5 ^f	541.8±11.0 ^d	634.9±13.5 ^c	931.2±17.0 ^a	656.1±13.5 ^c	211.8±7.8 ^g	656.1±14.1 ^c
K	8549±51 ^e	1033±70 ^{bc}	11042±78 ^a	10351±72 ^{bc}	10508±73 ^b	9617±69 ^d	9439±57 ^d	10152±72 ^c	11042±84 ^a	10330±71 ^{bc}	11220±88 ^a
Mg	1047±25 ^a	932±21 ^{bcd}	864±22 ^{de}	953±25 ^{bc}	781±30 ^{fg}	840±21 ^{ef}	912±23 ^{cd}	992±26 ^{ab}	895±21 ^{cde}	749±21 ^g	986±24 ^{ab}
P	3.26±0.13 ^{de}	2.29±0.10 ^{fg}	1.99±0.05 ^g	3.88±0.20 ^b	3.65±0.18 ^{bc}	3.06±0.11 ^e	2.43±0.08 ^f	3.50±0.12 ^{cd}	4.47±0.14 ^a	2.95±0.09 ^e	2.94±0.11 ^e
Zn	17.7 ±0.62 ^d	22.73±1.63 ^{bc}	10.40±0.56 ^e	16.80±0.85 ^d	24.53±1.82 ^b	29.13±1.90 ^a	16.41±1.04 ^d	25.67±1.93 ^{ab}	24.80±1.87 ^b	20.07±1.59 ^{cd}	16.24±0.91 ^d
Cu	7.13±0.50 ^d	6.70±0.46 ^{de}	3.80±0.20 ^f	6.90±0.50 ^{de}	9.60±0.66 ^{bc}	10.85±0.71 ^{ab}	8.14±0.45 ^{cd}	11.13±0.76 ^{ab}	11.30±0.79 ^a	7.78±0.52 ^d	5.36±0.35 ^{ef}
Fe	203.3±9.0 ^a	199.9±7.9 ^a	147.4±6.5 ^b	112.9±7.1 ^c	77.1±3.7 ^d	117.7±8.9 ^c	106.7±8.1 ^c	107.3±7.7 ^c	200.7±9.5 ^a	222.6±12.5 ^a	99.1±5.7 ^{cd}
Se	1.47±0.12 ^c	1.61±0.13 ^{bc}	1.87±0.11 ^b	1.87±0.11 ^b	0.91±0.08 ^{de}	2.16±0.14 ^a	1.05±0.04 ^{de}	0.85±0.03 ^{ef}	1.89±0.12 ^{ab}	1.14±0.10 ^d	0.58±0.03 ^f
Mn	13.3±0.7 ^{ab}	12.4±0.7 ^{bc}	10.4±0.8 ^{def}	9.0±0.7 ^{ef}	8.5±0.6 ^f	11.6±0.8 ^{bcd}	10.7±0.8 ^{cde}	10.1±0.5 ^{def}	14.5±0.6 ^a	14.7±0.7 ^a	8.7±0.5 ^f
Cr	0.46±0.03 ^d	0.53±0.03 ^{cd}	0.55±0.02 ^c	0.48±0.02 ^{cd}	0.11±0.02 ^g	0.27±0.01 ^f	0.30±0.02 ^{ef}	0.37±0.02 ^c	1.10±0.04 ^a	0.93±0.04 ^b	0.27±0.02 ^f
Mo	0.13±0.01 ^f	4.72±0.23 ^a	0.77±0.03 ^e	2.31±0.14 ^c	2.38±0.19 ^c	0.95±0.07 ^e	0.12±0.01 ^f	2.07±0.14 ^{cd}	4.20±0.18 ^b	4.28±0.19 ^b	1.71±0.13 ^d
Ni	2.88±0.13 ^b	1.94±0.09 ^d	2.02±0.11 ^d	2.26±0.15 ^{cd}	2.64±0.17 ^{bc}	3.73±0.25 ^a	1.96±0.12 ^d	1.83±0.09 ^d	4.06±0.25 ^a	2.18±0.08 ^d	1.82±0.10 ^d
B	0.14±0.01 ^{de}	0.21±0.01 ^{cde}	0.13±0.01 ^{de}	0.24±0.01 ^c	0.22±0.01 ^{cd}	0.13±0.01 ^e	1.38±0.06 ^b	2.11±0.09 ^a	0.19±0.01 ^{cde}	0.19±0.01 ^{cde}	0.18±0.01 ^{cde}
As	0.11±0.0 ^g	1.30±0.05 ^d	0.48±0.02 ^f	0.56±0.03 ^f	1.57±0.06 ^c	1.29±0.04 ^d	3.12±0.09 ^b	5.85±0.15 ^a	1.00±0.05 ^e	0.49±0.03 ^f	0.20±0.01 ^g
Cd	0.05±0.00 ^c	0.03±0.00 ^e	0.03±0.00 ^{ef}	0.05±0.00 ^{cd}	0.04±0.00 ^{de}	0.08±0.01 ^{ab}	0.07±0.00 ^b	0.09±0.01 ^a	0.06±0.00 ^c	0.09±0.01 ^{ab}	0.02±0.00 ^f
Pb	0.40±0.02 ^{cf}	0.030±0.00 ^h	0.42±0.02 ^e	1.17±0.03 ^a	0.49±0.04 ^{cd}	0.53±0.03 ^{bc}	0.35±0.01 ^f	0.46±0.01 ^{de}	0.27±0.01 ^g	0.04±0.00 ^h	0.58±0.02 ^b
Hg	0.22±0.01 ^c	0.25±0.01 ^b	0.18±0.00 ^d	0.05±0.00 ^g	0.14±0.01 ^f	0.27±0.01 ^a	0.16±0.00 ^e	0.17±0.01 ^{de}	0.15±0.00 ^{ef}	0.22±0.01 ^c	0.21±0.00 ^c

Statistical significance level was expressed as $p < 0.05$. Different letters in the lines indicate a statistical difference, while the same letters indicate that there is no statistical different.

Table 3.2. Target Hazard coefficient (THQ) and total target hazard coefficient (TTHQ) for some elements found in sumac samples grown in different regions

Element	Maraş	Elazığ	Shelaza	Trwanish	Shahi	Charput	Suleymania	Kadana	Derishke	Ranya	Sheladize
Zn	0.0008	0.0011	0.0005	0.0008	0.0012	0.0014	0.0008	0.0012	0.0012	0.0010	0.0008
Cu	0.0025	0.0024	0.0014	0.0025	0.0034	0.0039	0.0029	0.0040	0.0040	0.0028	0.0019
Fe	0.0041	0.0041	0.0030	0.0023	0.0016	0.0024	0.0022	0.0022	0.0041	0.0045	0.0020
Se	0.0042	0.0046	0.0053	0.0053	0.0026	0.0062	0.0030	0.0024	0.0054	0.0033	0.0017
Mn	0.0014	0.0013	0.0011	0.0009	0.0009	0.0012	0.0011	0.0010	0.0015	0.0015	0.0009
Cr	0.0022	0.0025	0.0026	0.0023	0.0006	0.0013	0.0014	0.0018	0.0053	0.0044	0.0013
Mo	0.0004	0.0135	0.0022	0.0066	0.0068	0.0027	0.0003	0.0059	0.0120	0.0122	0.0049
Ni	0.0021	0.0014	0.0014	0.0016	0.0019	0.0027	0.0014	0.0013	0.0029	0.0016	0.0013
B	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000
As	0.0052	0.0619	0.0229	0.0267	0.0748	0.0614	0.1486	0.2786	0.0474	0.0233	0.0096
Cd	0.0007	0.0005	0.0004	0.0007	0.0005	0.0012	0.0010	0.0013	0.0008	0.0013	0.0003
Hg	0.0010	0.0012	0.0009	0.0002	0.0006	0.0013	0.0008	0.0008	0.0007	0.0011	0.0010
Pb	0.0016	0.0001	0.0017	0.0048	0.0020	0.0022	0.0014	0.0019	0.0011	0.0002	0.0024
TTHQ	0.0264	0.0945	0.0434	0.0547	0.0968	0.0878	0.1649	0.3024	0.0865	0.0571	0.0280

TTHQ is written in bold to differentiate from the elements

Table 3.3. RfD and RDA values of some elements

Element	RfD (mg/kg.day)	RDA (mg/day)	Vitamins	RDA (mg/day)
Na	–	2300	Ascorbic acid	46.00
K	–	4700	Thiamine	0.90
Mg	–	420	Riboflavin	1.00
P	–	700	Nicotinamide	15.00
Zn	0.0030	11.0000	Pantothenic acid	4.00
Cu	0.0400	0.9000	Pyridoxine	1.40
Fe	0.7000	8.0000	Folic acid	0.50
Se	0.0050	0.0550	Cyanocobalamin	0.20
Mn	0.1400	2.3000	–	–
Cr	0.0030	0.0300	–	–
Mo	0.0050	0.0450	–	–
Ni	0.0200	0.0050	–	–
B	0.2000	0.1500	–	–
As	0.0003	–	–	–
Cd	0.0010	–	–	–
Hg	0.0030	–	–	–
Pb	0.0034	–	–	–

3.1. Minerals

Mineral substances are one of the important food components for the activity of the organism; therefore, foods must contain many elements in order to improve the organism and maintain health. Elements are found in nature in different forms and are necessary for the body to perform different functions, especially trace elements are very important for cell functions at the biological, chemical, and molecular levels. They also act as atomic centers that stabilize the molecular structures of enzymes and proteins [20]. The concentrations of some elements and the calculated THQ and TTHQ values for these elements in sumac samples grown in different regions are given in (Table 3.1 and Table 3.2). Major and trace elements important to living organisms are found in many tissues, including the structure of bones. Trace elements act as cofactors in the structure of many enzymes, and their deficiency has been reported to cause many diseases [126]. Sumac samples are rich in potassium, calcium, magnesium, and phosphorus predominantly, followed by aluminum, iron, sodium, boron, and zinc [21]. In all regions, it has the highest K content and Mg is second, Na content is third, and P content is fourth. While the highest Na, K, Mg, and P were observed in the sumacs of Kadana, Sheladize, Maraş, and Derishke, respectively, the lowest amounts were found in the sumacs of Ranya, Maraş, Ranya, and Shelaza regions (Table 3.1). The amounts of K, Na, Mg, and P in Chinese sumac have been reported to be 5576.0, 183.0,

871, and 1032 mg/kg, respectively [31]. Considering the RDA values of Na, K, Mg, and P in (Table 3.3), it can be said that all sumac samples, except P, are good sources of these elements. There is no statistical difference between the Na concentration of sumacs grown in Elazığ, Trwanish, Suleymania, Derishke, and Sheladize regions ($p>0.05$). Potassium amounts in sumacs of Maraş, Shelaza, Shahi, Charput, and Kadana regions are significantly different ($p<0.05$) (Table 3.1). Some trace elements are responsible for enzymatic reactions, production and use of metabolic energy, and stability of biological molecules [127]. The highest concentrations of Zn, Cu, Fe, and Se were observed in Charput, Derishke, Ranya, and Derishke, while the lowest concentrations were observed in sumac samples grown in Shelaza, Shelaza, Shahi, and Sheladize regions, respectively. In a previous study, it was determined that potassium has the highest concentration of any mineral at 7963 parts per million, followed by calcium at 3661 ppm and phosphorus at 1238 ppm. However, the results showed that the cadmium and selenium levels were very low (0.03 and 0.47 ppm, respectively). The selenium levels of sumac and other medicinal plants were compared. Sumac was found to have the lowest selenium concentration of all the plants tested, while Basil was found to have the most [128]. The amounts of Zn in the sumacs of Maraş, Zhelaza, Shahi, Charput, and Derishke regions are significantly different in group ($p<0.05$). In addition, Maraş, Shelaza, Charput, Sheladize, and Ranya regions were different from each other in terms of Se content ($p<0.05$) (Table 3.1). Colak Esetlili et al. [129] reported that the amounts of Zn, Cu, and Fe in sumac samples were 12.00 ± 0.92 , 4.10 ± 0.29 , and 132 ± 25 mg/kg, respectively. Ozkutlu et al. [128] reported that the selenium content in *Rhus coriaria* L. was 0.011 µg/g dw. Sakhr and Khatib [16] reported that the amount of selenium in the sumac sample was 0.47 µg/g dw. The amount of Se in black *Myrtus communis* L. fruit has been reported to be 0.63 ± 0.01 µg/g dw [130]. When the obtained results in (Table 3.1) and the RDA values in (Table 3.3) are examined, it can be said that sumac is a good source for Zn, Cu, Fe, and Se element if it is consumed daily as a spice in food. When the THQ values of Zn, Cu, Fe, and Se in (Table 3.2) are examined, it can be seen that these elements do not pose a health risk since the values are smaller than 1.0. In the study by Alp et al. [131], the THQ values of Cu, Fe and Zn in *Agaricus campestris* were found to be 0.057, 0.27, and 0.16, respectively. Manganese and chromium amount in sumac samples varied between 8.5–14.7 µg/g dw and 0.11–1.1 µg/g dw, respectively, while the lowest amounts were observed in Shahi region samples. The amount of manganese in Syrian sumac samples was reported to be 10.57 ± 0.39 mg/kg [31]. The amount of chromium in clove and turmeric samples was found to be 411 and 1564 ng/g, respectively [132]. The amount of Mo in the sumac samples varied between 0.120 ± 0.008 and 4.72 ± 0.23 µg/g dw, while the Ni ranged between 1.82 ± 0.10 and 4.06 ± 0.25 µg/g dw. While Cr amounts in Derishke, Ranya, Shelaza, Maraş, Sheladize, and Shahi regions sumacs are significantly different ($p<0.05$), the difference between Elazığ, Shelaza, Suleymania, Kadana, Ranya, and Sheladize regional sumacs is statistically insignificant in terms of Ni element ($p>0.05$) (Table 3.1).

It has been reported that the amount of nickel and molybdenum in cannabis seeds grown in the northwest region of Turkey varies between 0.36-1.66 and 0.25-0.62 $\mu\text{g/kg}$, respectively [133]. Since the THQ values of Mn, Cr, Mo, and Ni are much lower than 1.0, therefore, these elements do not pose a health risk (Table 3.2). Ihugba et al. [134] reported that the THQ values for zinc, copper, and nickel in oyster mushrooms were 0.0033, 0.00875, and 0.000005, respectively. It has been reported that boron is an important in lipid and energy metabolism, immune and endocrine system, and may also be effective in the prevention of osteoporosis, osteoarthritis, and arthritis [135]. The lowest amount of B was found to be 0.127 $\mu\text{g/g dw}$ in sumac sample obtained from Charput region, while the highest amount was found to be as 2.113 $\mu\text{g/g dw}$ in Kadana region. Boron in the sumacs of Kadana, Suleymania, Trwanish, and Charput regions are statistically different ($p<0.05$) (Table 3.1). In a study conducted by Korkmaz et al. [133], it was found that the amount of boron in hempseed samples varied between 11 ± 0.30 and 14 ± 1.73 $\mu\text{g/kg}$. Nielsen and Meacham [136] reported that the tolerable upper limit of boron for adults is 20 mg/day. The amount of boron in all sumac samples is at a level that does not cause toxic effects according to the literature. The THQ values of boron in all sumac samples vary between 0.0000 and 0.0002, and it can be said that it does not pose a health risk (Table 3.2). Arsenic, which is a toxic element, causes an increase in reactive oxygen species (ROS) by inhibiting the reductase enzyme activity, which prevents the formation of ROS in the cell, and also binds to DNA and other cell components, causing damage and the formation of various types of cancer [137]. The amount of As in sumac samples was found to vary between 0.11 and 5.85 $\mu\text{g/g dw}$. Considering the permissible concentration of As in foods 1.0 $\mu\text{g/g}$ [113], it was determined that sumacs grown in Kadana, Suleymania, Shahi, Elazığ, and Charput regions were above this limit value (Table 3.1 and Table 3.2). The As amounts in the sumacs of Kadana, Suleymania, Shahi, Charput, Derişhike, Ranya, and Sheladize regions were significantly different from each other ($p<0.05$). In the study conducted by Kowalska [138], the amount of As in blackcurrant and black pepper grown in Poland was found to be 0.166-0.202 and 0.1-0.863 and 0.053 mg/kg, respectively. High doses of trace elements, which are essential components of biological activities, can lead to many diseases [139]. Since the presence of heavy metals in foods affects the absorption of trace elements, the ratio of heavy metals in foods is important in this respect [140]. Sakhr and Khatib [16] reported that the amount of Cd in sumac is 0.03 $\mu\text{g/g dw}$. The amounts of As, Cd, Hg, and Pb in sumac samples vary between 0.111-5.850, 0.02-0.092, 0.049-0.272, and 0.030-0.577 $\mu\text{g/g dw}$, respectively. The amount of Pb in Trwanish, Sheladize, Shelaza, Ranya, and Suleymania samples was significantly different from each other ($p<0.05$). Kowalska [138] reported that the amount of As, Cd, and Pb in black pepper varied between 0.1-0.863, 0.02-0.08, and 0.01-0.74 mg/kg, respectively. Nkansah and Amoako [141] reported that the amount of Hg in black pepper was 0.002 mg/kg. It was observed that THQ

values for As, Cd, Hg, and Pb in sumac samples vary between 0.0052–0.2786, 0.0003–0.0013, 0.0002–0.0013, and 0.0001–0.0048, respectively (Table 3.2). It can be said that the elements do not pose a health risk for all sumac samples. Kowalska [138] reported that the THQ values of As, Cd, Hg, and Pb in spices were 0.00433, 0.0018, 0.000, and 0.0010, respectively.

3.2. Water-soluble vitamins

Two distinct conservation procedures, namely cooling and the application of edible coating techniques, are often used to preserve seasonal fruits. These methods aim to safeguard the fruits' visual appeal and nutritional content, ensuring their availability for year-round consumer consumption. Nevertheless, these preservation procedures have an impact not only on the visual attributes of fruits but also on their nutritional properties. This research examined eleven distinct varieties of sumac fruits obtained from various regions of Turkey and Iraq. The fruits were subjected to preservation techniques, including refrigeration and the application of an edible coating. The experimental findings are shown in tables [3.4 through 3.84]. Vitamins, which are defined as vitally important micronutrients that cannot be synthesized by mammals, are required for metabolism and must be taken by diet [142].

Table 3.4. Amount of ascorbic acid in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^c 67.20 ± 4.10 *	^{c,d} 43.30 ± 2.20 **	^{b,c} 34.60 ± 2.00 ***
Elazığ	^{a,b} 42.90 ± 4.50 *	^{a,b,c} 37.00 ± 2.00 **	^a 23.40 ± 1.10 ***
Shelaza	^a 36.60 ± 2.00 *	^a 31.00 ± 1.70 **	^a 22.20 ± 1.10 ***
Trwanish	^b 50.60 ± 3.00 *	^{d,e} 45.60 ± 2.10 **	^{c,d} 36.50 ± 1.30 ***
Shahi	^c 66.60 ± 2.20 *	^{f,g} 56.80 ± 2.40 **	^e 45.60 ± 2.20 ***
Charput	^c 64.10 ± 3.30 *	^{e,f} 50.20 ± 2.30 **	^{c,d} 36.00 ± 1.40 ***
Suleymania	^d 78.90 ± 3.20 *	^h 67.10 ± 3.00 **	^e 48.50 ± 1.90 ***
Kadana	^c 68.00 ± 5.10 *	^{f,g} 56.00 ± 2.80 **	^d 39.40 ± 1.40 ***
Derishke	^{a,b} 43.40 ± 2.50 *	^{a,b} 36.20 ± 1.60 **	^b 30.10 ± 1.10 ***
Ranya	^{a,b} 45.30 ± 2.20 *	^{b,c,d} 41.70 ± 2.20 **	^{c,d} 30.00 ± 1.60 ***
Sheladize	^{c,d} 70.30 ± 3.50 *	^{g,h} 61.30 ± 3.00 **	^e 48.80 ± 1.90 ***

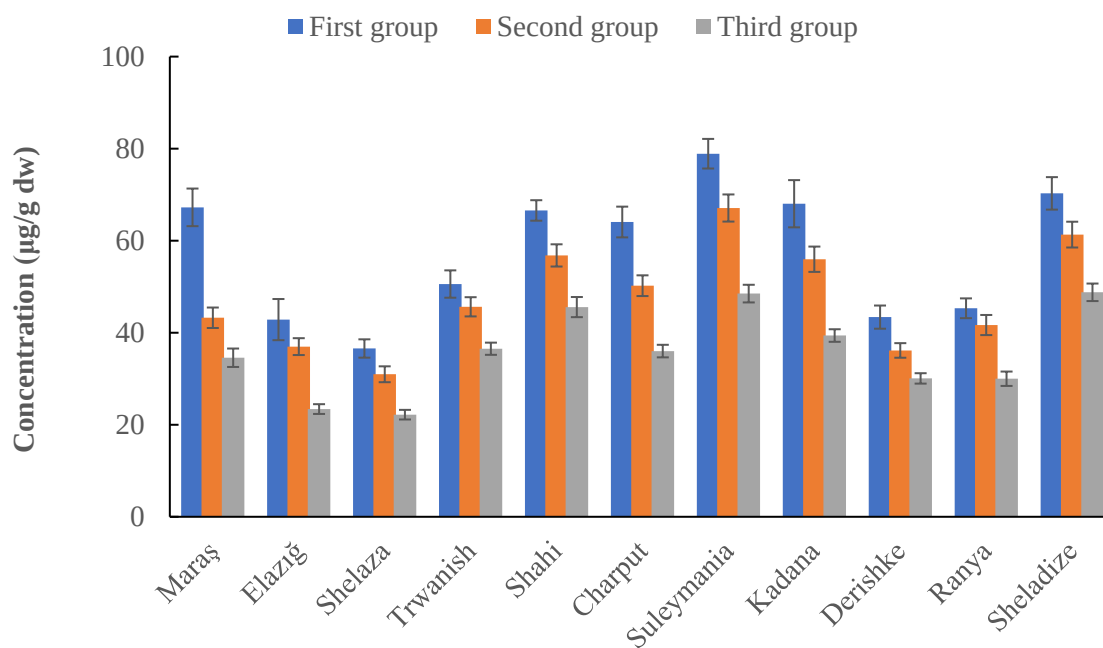


Figure 3.1. Interpretation column chart of vitamin C

Table 3.5. Loss percentage % of vitamin C

Region	Ascorbic acid	
	Second group	Third group
Maraş	35.70	48.60
Elazığ	13.70	45.40
Shelaza	15.20	39.30
Trwanish	9.80	27.80
Shahi	14.70	31.50
Charput	21.60	43.80
Suleymania	15.00	38.50
Kadana	17.70	42.10
Derişke	16.70	30.70
Ranya	8.00	33.80
Sheladize	12.20	30.60

Ascorbic acid concentration in first group sumac samples ranged from 36.57 to 78.90 µg/g dw and the highest in Suleymania sumac sample. It can be said that there is no significant difference between Maraş and Shahi, Charput, Sheladize and Kadana regions, as well as between Trawanish, Derişke, Ranya and Elazığ regions (Table 3.4). on the other hand, concentrations in the second group samples ranged from 30.97 to 67.10 µg/g dw and the highest in Suleymania sumac sample. while the amount Vit. C in the third group samples were ranged between 22.19 µg/g dw recorded for shelaza to 48.78 µg/g dw for sheladeze. it is clear that first group samples have higher vitamin

C concentrations than oil coated samples. The third group have the lowest amount. As seen in the rows of (Table 3.4), the difference between the first, second and third groups is statistically significant ($p < 0.05$).

The loss of vitamin C observed in Maraş second and third groups were 35.7%, 48.6% respectively (Table 3.5). Comparison data between the three groups of vitamin C shown in (Figure 3.1). The breakdown of vitamin C is strongly correlated with the presence of oxygen. Oxygen plays a crucial role in the oxidative breakdown route of vitamin C. The breakdown rate of vitamin C has a direct correlation with the elevated concentration of oxygen throughout the process of food processing. Hence, the use of a vacuum or an inert gas environment proves to be a very advantageous protective atmosphere for mitigating the oxidation of vitamin C [143]. D. Manas (2014), found the amounts of ascorbic acid in mustard, cumin, and clove samples to be 0.08, 0.09, and 0.14 mg/g, respectively [144].

Previous research by Kossah et al. (2009), determined that the quantities of ascorbic acid present in Syrian and Chinese sumac were, respectively, 38.91 ± 0.27 and 13.90 ± 0.20 mg/kg [31].

Table 3.6. Amount of thiamine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^c $105.80 \pm 6.00^*$	^d $91.80 \pm 3.90^{***}$	^e $79.20 \pm 2.90^{**}$
Elazığ	^c $107.40 \pm 5.90^*$	^d $94.00 \pm 3.70^{***}$	^{d,e} $71.90 \pm 2.60^{**}$
Shelaza	^b $87.90 \pm 3.70^*$	^c $75.40 \pm 3.40^{***}$	^d $64.40 \pm 2.40^{**}$
Trwanish	^{a,b} $71.90 \pm 2.50^*$	^{a,b} $60.60 \pm 3.20^{***}$	^{b,c} $48.50 \pm 1.80^{**}$
Shahi	^{a,b} $78.30 \pm 4.50^*$	^{b,c} $66.10 \pm 3.00^{***}$	^c $54.10 \pm 1.90^{**}$
Charput	^a $61.10 \pm 2.50^*$	^a $50.00 \pm 2.50^{***}$	^a $38.90 \pm 1.70^{**}$
Suleymania	^d $135.90 \pm 8.70^*$	^e $115.00 \pm 4.80^{***}$	^f $90.40 \pm 3.40^{**}$
Kadana	^{a,b} $71.30 \pm 5.70^*$	^b $62.80 \pm 3.40^{***}$	^{a,b} $45.40 \pm 2.00^{**}$
Derishke	^{a,b} $75.00 \pm 4.60^*$	^{b,c} $64.60 \pm 3.30^{***}$	^{b,c} $48.20 \pm 2.10^{**}$
Ranya	^d $144.50 \pm 6.80^*$	^f $127.20 \pm 4.80^{***}$	^f $95.70 \pm 3.70^{**}$
Sheladize	^e $173.60 \pm 9.60^*$	^g $150.70 \pm 5.10^{***}$	^g $123.10 \pm 4.10^{**}$

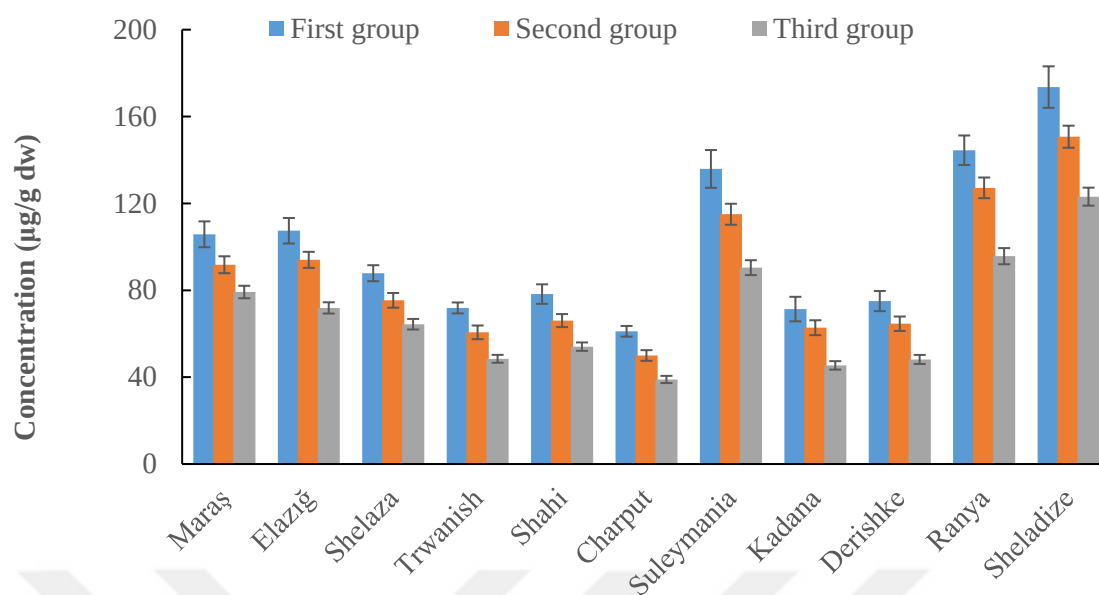


Figure 3.2. Interpretation column chart of vitamin B1

Table 3.7. Loss percentage % of thiamin

Region	Thiamin	
	Second group	Third group
Maraş	13.30	25.10
Elazığ	12.50	33.10
Shelaza	14.20	27.90
Trwanish	15.60	32.60
Shahi	15.60	30.90
Charput	18.20	36.30
Suleymania	15.30	33.50
Kadana	12.00	36.30
Derishke	13.90	35.80
Ranya	12.00	33.80
Sheladize	13.20	29.10

Amount of vitamin B1 in the first group grown in different regions varies in between 61.10 ± 2.50 - 173.60 ± 9.60 µg/g dw. The highest amount of thiamine was obtained in Sheladize and the lowest in Charput sumacs. The vitamin B1 content in the sumac samples from the second and third groups varied between 50.00 ± 2.50 - 150.70 ± 5.10 and 38.90 ± 1.70 - 123.10 ± 4.10 µg/g dw, respectively (Table 3.6). There is no notable disparity in concentrations between the Trwanish area and the Shahi, Kadana, Derishke, and Shelaza regions, as well as between the Maraş and Elazığ regions (Table 3.6). As seen in the rows of (Table 3.6), the difference between the first and third groups is statistically significant ($p < 0.05$), while there is no statical difference between second group and first group as well as between second group and third group ($p > 0.05$). Loss of B1 vitamin

in the second group is less than the third group (Table 3.7). Comparison data between the three groups of vitamin B1 shown in (Figure 3.2). The concentration of vitamin B1 in first and second group samples was found to be higher than that of third group samples. When food is exposed to air, it undergoes oxidation and starts the process of spoilage. The presence of oil retards the oxidation process and acts as a barrier, preventing oxygen and germs from accessing the food [145]. Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 30.65 ± 0.57 and 23.99 ± 0.54 mg/kg of Thiamin, respectively [31].

Table 3.8. Amount of riboflavin in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{c,d} $397.30 \pm 11.30^*$	^e $355.60 \pm 11.00^{***}$	^{d,e} $302.20 \pm 9.80^{**}$
Elazığ	^{d,e} $439.20 \pm 20.90^*$	^{e,f} $387.30 \pm 11.60^{***}$	^{e,f} $311.30 \pm 9.90^{**}$
Shelaza	^c $358.50 \pm 13.70^*$	^d $321.40 \pm 10.80^{***}$	^{d,e} $297.80 \pm 9.30^{**}$
Trwanish	^b $270.10 \pm 9.00^*$	^c $243.10 \pm 8.40^{***}$	^b $196.10 \pm 7.40^{**}$
Shahi	^a $182.30 \pm 10.90^*$	^a $157.50 \pm 7.90^{***}$	^a $123.80 \pm 7.30^{**}$
Charput	^b $255.10 \pm 12.10^*$	^b $205.20 \pm 8.40^{***}$	^b $182.70 \pm 8.10^{**}$
Suleymania	^e $449.00 \pm 21.40^*$	^f $407.10 \pm 14.10^{***}$	^f $337.70 \pm 12.00^{**}$
Kadana	^a $199.70 \pm 9.90^*$	^a $168.20 \pm 7.50^{***}$	^a $119.60 \pm 6.10^{**}$
Derishke	^c $362.20 \pm 10.40^*$	^d $319.30 \pm 11.90^{***}$	^c $257.70 \pm 9.50^{**}$
Ranya	^c $359.60 \pm 12.60^*$	^d $308.50 \pm 10.90^{***}$	^{c,d} $281.50 \pm 9.80^{**}$
Sheladize	^f $518.40 \pm 28.60^*$	^g $478.10 \pm 15.90^{***}$	^g $404.70 \pm 14.60^{**}$

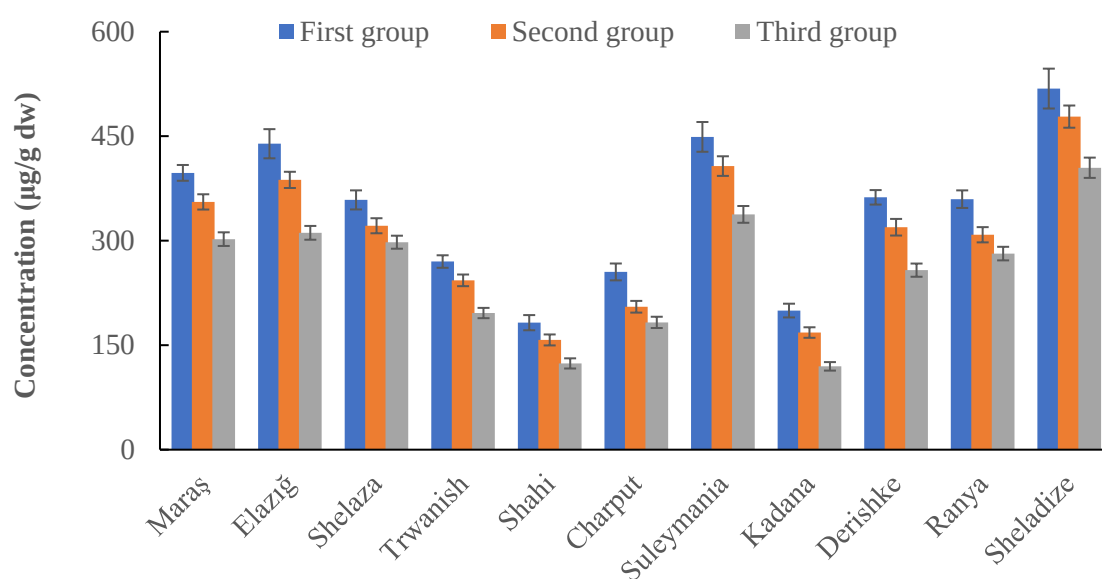


Figure 3.3. Interpretation column chart of vitamin B2

Table 3.9. Loss percentage % of riboflavin

Region	Riboflavin	
	Second group	Third group
Maraş	10.50	23.90
Elazığ	11.80	29.10
Shelaza	10.30	16.90
Trwanish	10.00	27.40
Shahi	13.60	32.10
Charput	19.60	28.40
Suleymania	9.30	24.80
Kadana	15.80	40.10
Derishke	11.80	28.90
Ranya	14.20	21.70
Sheladize	7.80	21.90

The riboflavin (vitamin B2) content in the sumac samples varied between 182.30 ± 10.90 and 518.40 ± 28.60 , 157.50 ± 7.90 and 478.10 ± 15.90 , and 123.80 ± 7.30 and 404.70 ± 14.60 µg/g dw for the first, second, and third groups, respectively (Table 3.8).

The highest amount of riboflavin in first group was observed in Sheladize, and the lowest amount was observed in Shahi region sumac.

Based on the results shown in (Table 3.8), the concentrations of sumac samples in the first group exhibit statistically significant differences ($p < 0.05$) across the locations of Maraş, Elazığ, Trwanish, Shahi, and Sheladize.

According to the data shown in the rows of (Table 3.8), there is a statistically significant difference ($p < 0.05$) between the first and third groups. However, there is no statistically significant difference ($p > 0.05$) between the second group and the first group, as well as between the second group and the third group.

First group exhibited the greatest levels of vitamin B2, while the lowest levels were seen in the third group samples (Table 3.8). It was discovered that the Sheladize sumac area in the second group saw the least amount of vitamin B2 loss, which was 7.80%, while the Kadana region in the third group experienced the most amount of loss, which was 40.10% (Table 3.9). Comparison data between the three groups of vitamin B2 shown in (Figure 3.3).

According to a previous research by Kossah et al. (2009), the riboflavin content of Syrian sumac was determined to be 24.68 ± 0.42 mg/kg, whereas that of Chinese sumac was 24.41 ± 0.33 mg/kg [31].

As per the results of an earlier research by Wahab Gbolahan Ayoade et al. (2023), the amounts of riboflavin (B2) detected in cloves, black pepper, and turmeric were 29.15 ± 0.06 mg/100 g, 28.91 ± 0.03 mg/100 g and 40.36 ± 0.03 , respectively [146].

Table 3.10. Amount of nicotinic acid in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{b,c} 879.60 $\pm$ 32.40 *	^c 778.10 $\pm$ 17.30 **	^d 703.30 $\pm$ 18.80 ***
Elazığ	^d 1005.70 $\pm$ 29.30 *	^e 931.00 $\pm$ 22.00 **	^e 810.80 $\pm$ 19.80 ***
Shelaza	^f 1140.80 $\pm$ 36.70 *	^g 1043.70 $\pm$ 27.80 **	^f 940.20 $\pm$ 20.60 ***
Trwanish	^a 788.70 $\pm$ 15.50 *	^a 612.00 $\pm$ 15.10 **	^a 527.90 $\pm$ 10.90 ***
Shahi	^a 801.70 $\pm$ 15.40 *	^b 710.40 $\pm$ 17.60 **	^b 590.10 $\pm$ 14.50 ***
Charput	^c 913.20 $\pm$ 14.20 *	^{c,d} 816.00 $\pm$ 19.10 **	^c 652.10 $\pm$ 15.90 ***
Suleymania	^{e,f} 1084.00 $\pm$ 24.40 *	^{e,f} 950.50 $\pm$ 21.40 **	^e 854.90 $\pm$ 21.90 ***
Kadana	^{a,b} 834.10 $\pm$ 22.60 *	^b 700.40 $\pm$ 16.50 **	^b 601.30 $\pm$ 12.90 ***
Derishke	^f 1153.60 $\pm$ 21.70 *	^{e,f} 973.60 $\pm$ 21.40 **	^e 815.00 $\pm$ 16.50 ***
Ranya	^{d,e} 1054.40 $\pm$ 26.80 *	^d 862.40 $\pm$ 20.60 **	^d 710.80 $\pm$ 15.40 ***
Sheladize	^g 1292.10 $\pm$ 35.80 *	^{f,g} 1003.10 $\pm$ 21.50 **	^g 993.80 $\pm$ 20.40 ***

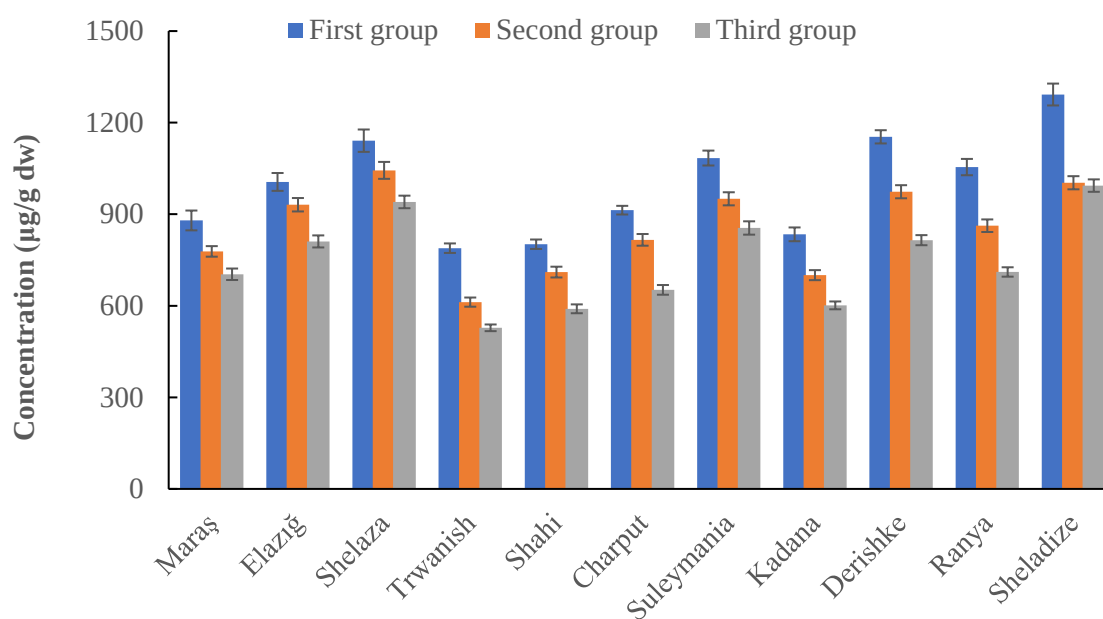


Figure 3.4. Interpretation column chart of nicotinic acid

Table 3.11. Loss percentage % of nicotinic acid

Region	Nicotinic acid	
	Second group	Third group
Maraş	11.50	20.00
Elazığ	7.40	19.40
Shelaza	8.50	17.60
Trwanish	22.40	33.10
Shahi	11.30	26.40
Charput	10.60	28.60
Suleymania	12.30	21.10
Kadana	16.00	27.90
Derishke	15.60	29.40
Ranya	18.20	32.60
Sheladize	22.40	23.10

Table 3.12. Amount of nicotinamide in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^{c,d} 151.80 ± 4.70 *	^c 123.00 ± 6.40 **	^b 98.00 ± 5.30 **
Elazığ	^f 268.60 ± 12.10 *	^e 221.70 ± 9.40 **	^d 195.20 ± 7.80 **
Shelaza	^g 314.00 ± 14.30 *	^f 243.30 ± 10.10 **	^d 203.80 ± 8.50 **
Trwanish	^{c,d} 157.90 ± 10.20 *	^c 119.00 ± 5.20 **	^b 97.70 ± 5.80 **
Shahi	^{a,b,c} 130.90 ± 8.80 *	^{a,b} 98.20 ± 4.80 **	^a 74.40 ± 4.60 **
Charput	^a 105.60 ± 6.90 *	^a 85.00 ± 4.40 **	^a 65.80 ± 4.50 **
Suleymania	^{a,b} 117.70 ± 10.30 *	^{a,b} 92.40 ± 4.60 **	^a 68.50 ± 4.70 **
Kadana	^e 190.80 ± 11.60 *	^d 149.70 ± 7.50 **	^b 114.70 ± 6.10 **
Derishke	^{d,e} 170.60 ± 1.90 *	^d 145.20 ± 7.60 **	^b 108.80 ± 5.70 **
Ranya	^{b,c} 135.70 ± 6.50 *	^{b,c} 105.80 ± 5.40 **	^a 77.80 ± 4.40 **
Sheladize	^f 257.10 ± 11.30 *	^e 211.00 ± 9.50 **	^c 170.20 ± 7.20 **

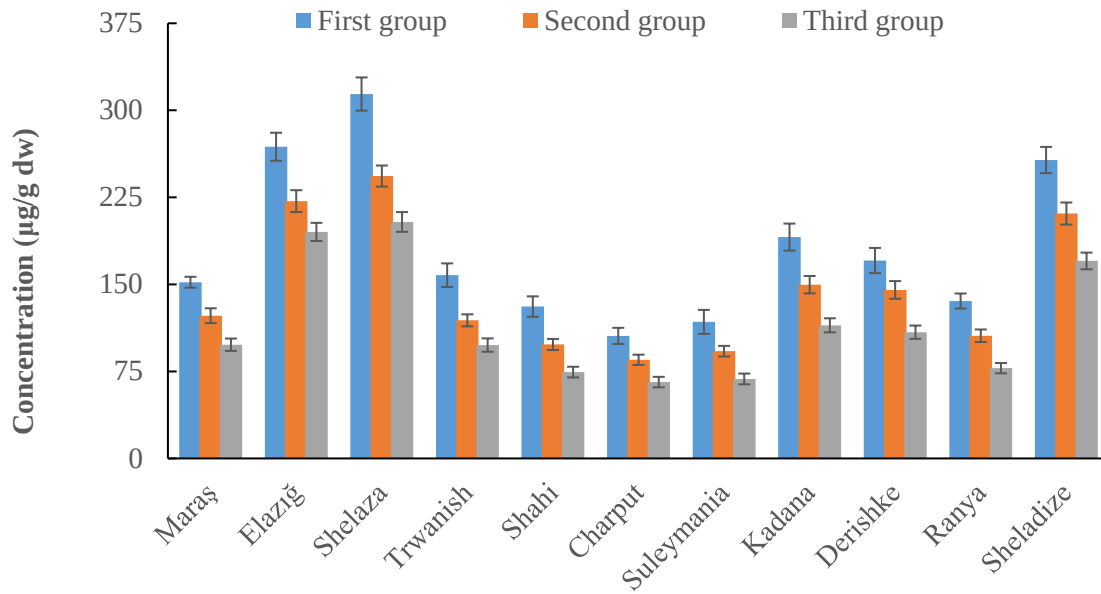


Figure 3.5. Interpretation column chart of nicotinamide

Table 3.13. Loss percentage % of nicotinamide

Region	Nicotinamide	
	Second group	Third group
Maraş	19.00	35.50
Elazığ	17.50	27.30
Shelaza	22.50	35.10
Trwanish	24.60	38.10
Shahi	25.00	43.20
Charput	19.50	37.70
Suleymania	21.50	41.80
Kadana	21.50	39.90
Derishke	14.90	36.20
Ranya	22.00	42.70
Sheladize	17.90	33.80

While the values of nicotine amide and nicotinic acid in the first group samples varied between 105.60 ± 7.00 - 314.00 ± 14.30 and 788.70 ± 15.50 - 1292.10 ± 35.80 respectively, it was determined that they were between $(85.00 \pm 4.40$ - 243.30 ± 10.10 and 612.00 ± 15.10 - $1003.10 \pm 21.50)$ and $(56.20 \pm 3.80$ - 183.80 ± 8.50 and 527.90 ± 10.90 - $993.80 \pm 20.40)$ µg/g dw in the second and third group samples, respectively (Table 3.10 and Table 3.12).

The highest nicotine amide and nicotinic acid levels in First group sumac samples were observed in Shelaza and Sheladize regions, respectively, while the lowest amounts were observed in Charput and Trwanish region sumacs.

It can be said that the amounts of nicotine amide in the first group is significant difference between Maraş, Elazığ, Shelaza, Charput, and Kadana regions ($p < 0.05$) (Table 3.12), as well as between Maraş, Shelaza, Trwanish, Suleymanian and Sheladize regions in the term of nicotinic acid (Table 3.10). The second group sumac samples had the greatest concentrations of nicotine amide and nicotinic acid in the shelaza area, while the Charput and Trwanish regions showed the lowest values, respectively.

As seen in the rows of (Table 3.10) the difference between the first, second and third groups is statistically significant ($p < 0.05$). While As seen in the rows of (Table 3.12), the difference between the first and second groups is statistically significant ($p < 0.05$), while there is no statistical difference between second group and third group ($p > 0.05$).

It was discovered that the Elazığ sumac area in the second group saw the least amount of nicotinic acid loss, which was 7.40%, while the Trwanish region in the third group experienced the most amount of loss, which was 33.10% (Table 3.11).

The least amount of nicotine amide loss was seen in the Derishke sumac area in the second group, at 14.90%, while the largest loss was recorded in the Shahi region in the third group, at 43.20 % (Table 3.13). Comparison data between the three groups of nicotinic acid and nicotinamide shown in (Figure 3.4 and Figure 3.5).

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 17.95 ± 0.28 and 2.39 ± 0.13 mg/kg of nicotinamide, respectively [31].

In their study, Seal and Chaudhuri (2017) provided data on the vitamin B3 content in several plant species, namely *M. indica*, *M. laxiflora*, *S. gilo*, *S. kurzii*, and *V. foetidum*. The reported values for the quantity of vitamin B3 in these species were 4.43 ± 0.03 , 15.04 ± 0.08 , 0.43 ± 0.008 , 0.28 ± 0.008 , and 0.13 ± 0.003 mg/100 gm dry plant material, respectively [147].

Based on a research done by Wahab Gbolahan Ayoade et al. (2023), the amounts of vitamin B3 present in turmeric, black pepper, and cloves were measured to be 19.21 ± 0.04 , 20.93 ± 0.04 , and 23.26 ± 0.03 mg/100g, respectively [146].

Table 3.14. Amount of pantothenic acid in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^d 609.70 $\pm$ 21.80 *	^e 546.30 $\pm$ 16.10 ***	^d 448.40 $\pm$ 12.30 **
Elazığ	^e 779.20 $\pm$ 18.70 *	^f 690.60 $\pm$ 18.60 ***	^f 575.40 $\pm$ 13.70 **
Shelaza	^b 449.30 $\pm$ 24.30 *	^b 393.90 $\pm$ 13.70 ***	^b 302.90 $\pm$ 8.50 **
Trwanish	^e 775.10 $\pm$ 32.40 *	^f 677.60 $\pm$ 16.50 ***	^f 570.00 $\pm$ 13.00 **
Shahi	^a 336.20 $\pm$ 15.30 *	^a 296.00 $\pm$ 8.50 ***	^a 241.70 $\pm$ 7.80 **
Charput	^d 590.50 $\pm$ 29.40 *	^d 493.00 $\pm$ 13.20 ***	^c 404.10 $\pm$ 14.00 **
Suleymania	^{b,c} 512.90 $\pm$ 26.50 *	^c 445.60 $\pm$ 15.00 ***	^c 388.10 $\pm$ 11.90 **
Kadana	^{c,d} 549.70 $\pm$ 27.40 *	^{c,d} 475.70 $\pm$ 16.50 ***	^c 407.90 $\pm$ 12.00 **
Derishke	^a 301.70 $\pm$ 5.20 *	^a 261.50 $\pm$ 6.10 ***	^a 216.70 $\pm$ 7.70 **
Ranya	^e 777.50 $\pm$ 43.00 *	^f 654.60 $\pm$ 17.10 ***	^e 495.40 $\pm$ 11.40 **
Sheladize	^a 356.60 $\pm$ 12.30 *	^a 272.90 $\pm$ 7.90 ***	^a 223.90 $\pm$ 6.90 **

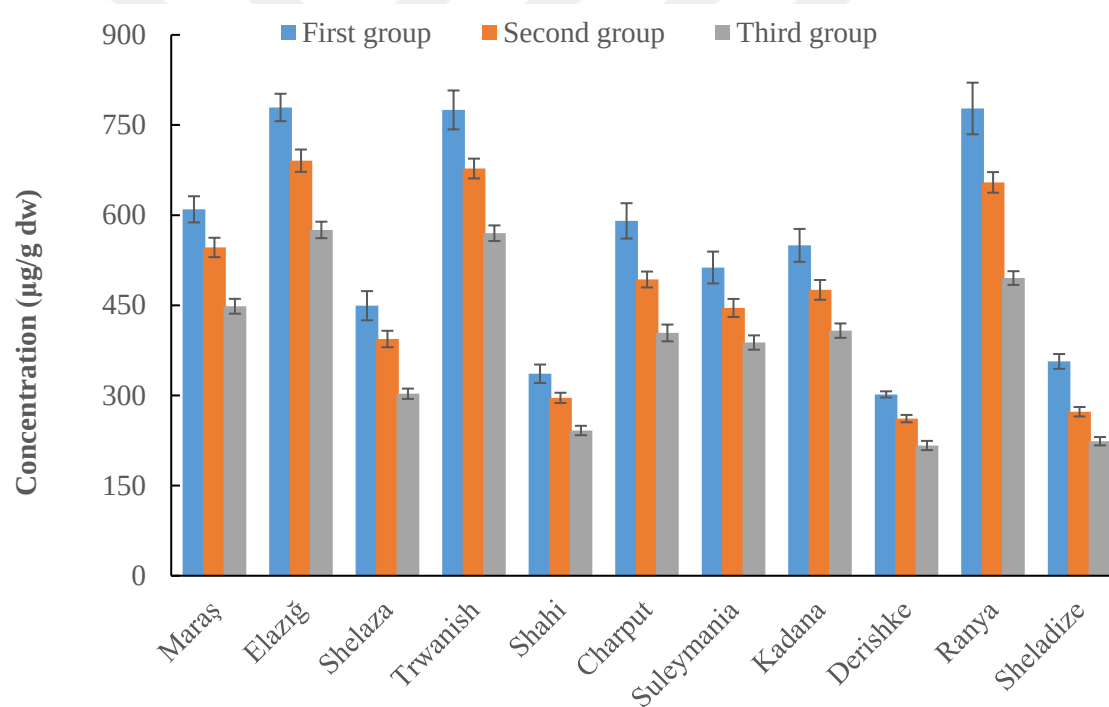


Figure 3.6. Interpretation column chart of pantothenic acid

Table 3.15. Loss percentage % of pantothenic acid

Region	Pantothenic acid	
	Second group	Third group
Maraş	10.40	26.40
Elazığ	5.30	21.10
Shelaza	12.30	32.60
Trwanish	12.60	26.50
Shahi	20.00	28.10
Charput	16.50	31.60
Suleymania	13.10	24.30
Kadana	13.50	25.10
Derishke	13.40	28.10
Ranya	15.80	36.30
Sheladize	23.50	37.20

First-group sumac samples range from 301.70 ± 5.20 to 777.50 ± 43.00 $\mu\text{g/g dw}$ in terms of pantothenic acid content. In the second set of sumac samples, the quantity of pantothenic acid ranges from 261.50 ± 6.10 to 690.60 ± 18.60 $\mu\text{g/g dw}$. The third set of samples had pantothenic acid levels ranging from 216.70 ± 7.70 to 575.40 ± 13.70 $\mu\text{g/g dw}$ (Table 3.14).

It can be said that there is no significant difference between Sheladize, Derishke and Shahiand regions, as well as between Trwanish, Ranya and Elazığ regions in the first group (Table 3.14). There is a statistically significant difference ($p < 0.05$) between the first and third groups, as shown in the rows of (Table 3.14). However, there is no statistical difference ($p > 0.05$) between the second group and either the first or third groups.

After six months of waiting the vitamin loss in second group fruit samples and third group varied from 5.3% to 37.2% (Table 3.15). Comparison data between the three groups of vitamin B5 shown in (Figure 3.6). The degradation level of vitamins is influenced by process circumstances, such as temperature and time [148]. The potential degradation of vitamins during the processing of fruits and vegetables may be influenced by their physical structure, which includes factors such as mechanical damage including bruising, surface abrasions, wrapping, and cutting [143]. In a prior study conducted by Shin and Choung (2023), it was found that the amount of pantothenic acid in red pepper was 0.244 ± 0.006 mg/100g. This indicated that red pepper has a significant amount of Vitamin B5 [149]. The absence of Vitamin B5 in some indigenous green leafy vegetables (GLVs) of Bangladesh and Indian spinach has been reported by Hasan et al. (2013) [150]. In a recent study conducted by Oh and Kim (2019), it was shown that the amount of Pantothenic acid in turmeric (*Curcuma longa* L.) was 1.040 ± 0.028 mg/100g [151]. It is worth mentioning that the exacerbating impact of a lack of pantothenic acid on inflammation is linked to a lack of vitamin D [46].

Table 3.16. Amount of pyridoxine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^f 385.80 $\pm$ 14.20 *	^f 300.00 $\pm$ 10.80 **	^f 244.20 $\pm$ 9.20 **
Elazığ	^{c,d} 183.20 $\pm$ 7.20 *	^c 142.80 $\pm$ 5.30 **	^c 117.90 $\pm$ 5.90 **
Shelaza	^c 168.20 $\pm$ 8.60 *	^{b,c} 123.10 $\pm$ 4.80 **	^b 90.50 $\pm$ 4.70 **
Trwanish	^{b,c} 158.40 $\pm$ 9.00 *	^b 117.40 $\pm$ 4.80 **	^b 89.50 $\pm$ 4.60 **
Shahi	^f 356.00 $\pm$ 11.90 *	^f 285.40 $\pm$ 9.70 **	^f 235.70 $\pm$ 8.00 **
Charput	^a 123.80 $\pm$ 6.50 *	^a 95.70 $\pm$ 4.30 **	^{a,b} 77.70 $\pm$ 4.00 **
Suleymania	^e 242.20 $\pm$ 12.20 *	^e 199.60 $\pm$ 7.90 **	^e 154.80 $\pm$ 5.90 **
Kadana	^{b,c} 157.30 $\pm$ 6.00 *	^b 120.00 $\pm$ 5.50 **	^b 89.70 $\pm$ 4.00 **
Derishke	^{a,b} 133.40 $\pm$ 7.10 *	^a 95.20 $\pm$ 4.30 **	^a 72.20 $\pm$ 3.80 **
Ranya	^e 244.20 $\pm$ 14.00 *	^{d,e} 192.40 $\pm$ 7.80 **	^e 166.10 $\pm$ 5.70 **
Sheladize	^d 208.80 $\pm$ 11.30 *	^d 177.40 $\pm$ 7.40 **	^d 134.80 $\pm$ 4.90 **

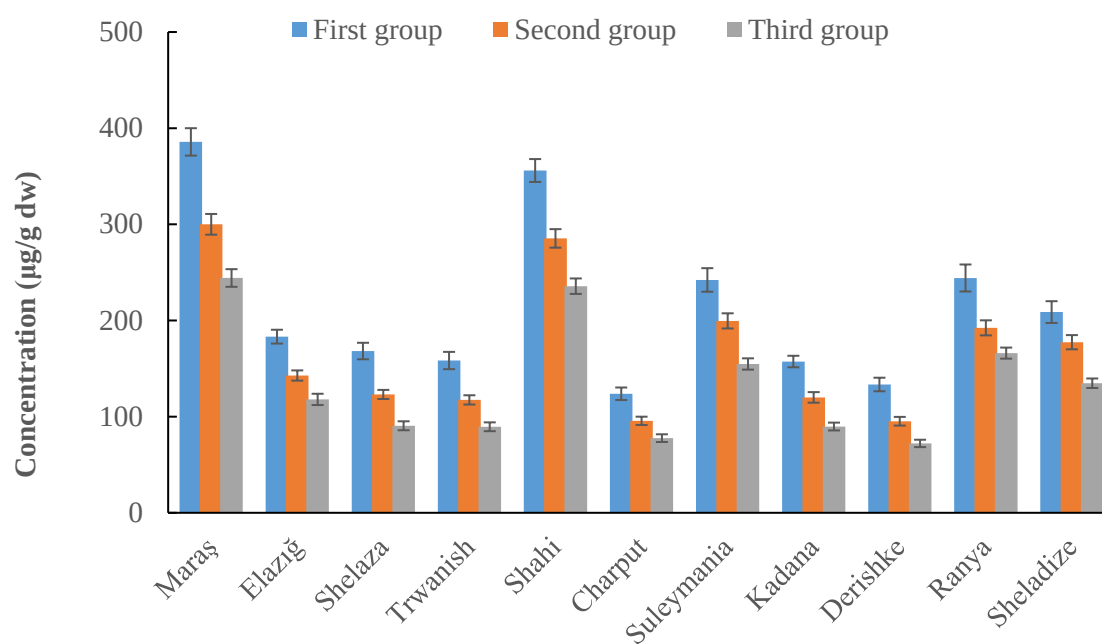


Figure 3.7. Interpretation column chart of pyridoxine

Table 3.17. Loss percentage % of pyridoxine

Region	Pyridoxine	
	Second group	Third group
Maraş	22.20	36.70
Elazığ	22.00	35.60
Shelaza	26.80	46.20
Trwanish	25.90	43.50
Shahi	19.80	33.80
Charput	22.70	37.30
Suleymania	17.60	36.10
Kadana	23.70	43.00
Derishke	28.60	45.00
Ranya	21.20	32.00
Sheladize	15.00	35.40

The pyridoxine levels in the first group of samples range from 123.80 ± 6.50 to 385.80 ± 14.30 $\mu\text{g/g dw}$. The sumac samples in the second group exhibit a range of 95.20 ± 4.30 to 300.00 ± 10.80 $\mu\text{g/g dw}$. The pyridoxine content in the sumac samples from the third group ranges from 72.20 ± 3.80 to 244.20 ± 9.20 $\mu\text{g/g dw}$ (Table 3.16).

It may be claimed that there is substantial difference between Sheladize, Derishke, Ranya and Shahi areas in the first group (Table 3.16). As observed in the rows of (Table 3.16), the difference between the first and second groups is statistically significant ($p < 0.05$), but there is no statistical difference between second group and third group ($p > 0.05$).

It was discovered that the Sheladize sumac area in the second group saw the least amount of vitamin B6 loss, which was 15.00%, while the Shelaza region in the third group experienced the most amount of loss, which was 46.20% (Table 3.17). Comparison data between the three groups of vitamin B6 shown in (Figure 3.7).

In accordance with the findings of a previous research carried out by Kossah et al. (2009), it was discovered that the Syrian and Chinese sumac have a pyridoxine content of 69.83 ± 0.31 mg/kg and 20.28 ± 0.28 mg/kg, respectively [31].

In accordance with the findings of a previous study conducted by Wahab Gbolahan Ayoade et al. (2023), the levels of pyridoxine (B6) found in turmeric, black pepper, and cloves were 22.61 ± 0.02 , 31.81 ± 0.02 and 29.43 ± 0.03 mg/100g, respectively [146].

Table 3.18. Amount of folic acid in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{a,b,c} 535.80 $\pm$ 18.20 *	^{b,c,d} 475.70 $\pm$ 15.90 **	^{a,b} 399.00 $\pm$ 13.10 ***
Elazığ	^{c,d,e} 600.20 $\pm$ 37.30 *	^d 516.80 $\pm$ 17.50 **	^c 468.50 $\pm$ 14.40 ***
Shelaza	^g 826.20 $\pm$ 62.00 *	^f 726.10 $\pm$ 21.50 **	^d 612.80 $\pm$ 19.50 ***
Trwanish	^{b,c,d} 584.20 $\pm$ 33.90 *	^{c,d} 495.50 $\pm$ 16.80 **	^{a,b} 391.50 $\pm$ 13.40 ***
Shahi	^{d,e,f} 663.40 $\pm$ 14.00 *	^e 582.50 $\pm$ 18.10 **	^c 474.00 $\pm$ 15.70 ***
Charput	^f 730.80 $\pm$ 21.30 *	^e 633.40 $\pm$ 20.60 **	^d 570.80 $\pm$ 20.60 ***
Suleymania	^{a,b} 506.60 $\pm$ 15.70 *	^{a,b,c} 449.90 $\pm$ 15.10 **	^{a,b} 366.50 $\pm$ 12.80 ***
Kadana	^{e,f} 689.40 $\pm$ 32.50 *	^e 590.80 $\pm$ 18.70 **	^c 507.70 $\pm$ 17.90 ***
Derishke	^{a,b,c} 516.00 $\pm$ 14.30 *	^{a,b} 443.60 $\pm$ 15.30 **	^{a,b} 386.80 $\pm$ 14.30 ***
Ranya	^{b,c} 563.60 $\pm$ 26.90 *	^{c,d} 499.10 $\pm$ 17.30 **	^b 406.70 $\pm$ 15.50 ***
Sheladize	^a 473.10 $\pm$ 28.60 *	^a 414.30 $\pm$ 15.00 **	^a 359.20 $\pm$ 14.10 ***

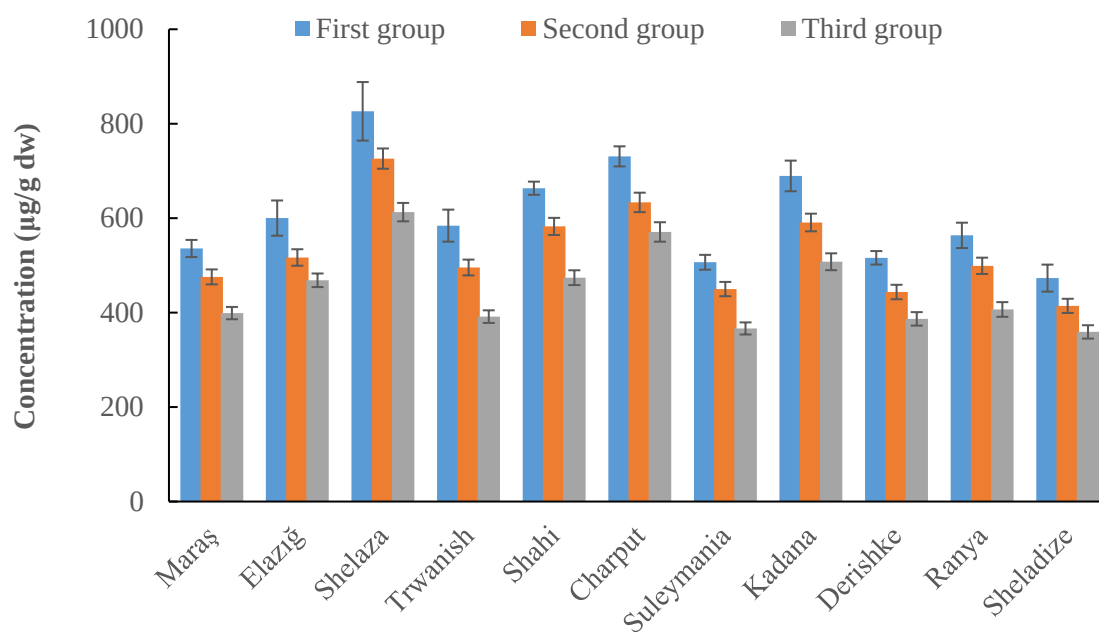


Figure 3.8. Interpretation column chart of folic acid

Table 3.19. Loss percentage % of folic acid

Folic acid		
Region	Second group	Third group
Maraş	11.20	25.50
Elazığ	13.90	21.90
Shelaza	12.10	25.80
Trwanish	15.20	33.00
Shahi	12.20	28.60
Charput	13.30	21.90
Suleymania	11.20	27.70
Kadana	14.30	26.40
Derishke	14.00	25.00
Ranya	11.40	27.80
Sheladize	12.40	24.10

Table 3.20. Amount of cyanocobalamin in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 104.10 ± 8.50 *	^{a,b} 73.60 ± 4.10 **	^{a,b} 50.30 ± 4.00 ***
Elazığ	^{c,d} 155.20 ± 9.10 *	^c 108.40 ± 5.00 **	^c 75.40 ± 4.60 ***
Shelaza	^{d,e} 177.40 ± 10.90 *	^e 134.20 ± 6.00 **	^f 104.00 ± 5.00 ***
Trwanish	^b 105.70 ± 4.40 *	^b 85.60 ± 4.50 **	^b 62.40 ± 4.30 ***
Shahi	^c 147.70 ± 9.10 *	^c 104.00 ± 5.90 **	^{c,d} 75.80 ± 3.80 ***
Charput	^{c,d} 154.10 ± 7.50 *	^c 112.90 ± 6.10 **	^{c,d,e} 83.50 ± 4.20 ***
Suleymania	^{a,b} 94.60 ± 6.40 *	^{a,b} 72.20 ± 4.00 **	^{a,b} 53.60 ± 2.30 ***
Kadana	^{c,d} 164.00 ± 8.90 *	^{d,e} 128.40 ± 5.90 **	^{d,e} 87.80 ± 4.70 ***
Derishke	^{c,d} 159.20 ± 13.30 *	^{c,d} 115.60 ± 5.70 **	^e 90.80 ± 4.70 ***
Ranya	^a 73.90 ± 4.10 *	^a 58.90 ± 3.40 **	^a 43.00 ± 2.20 ***
Sheladize	^e 192.60 ± 9.10 *	^e 133.00 ± 6.30 **	^f 108.80 ± 4.80 ***

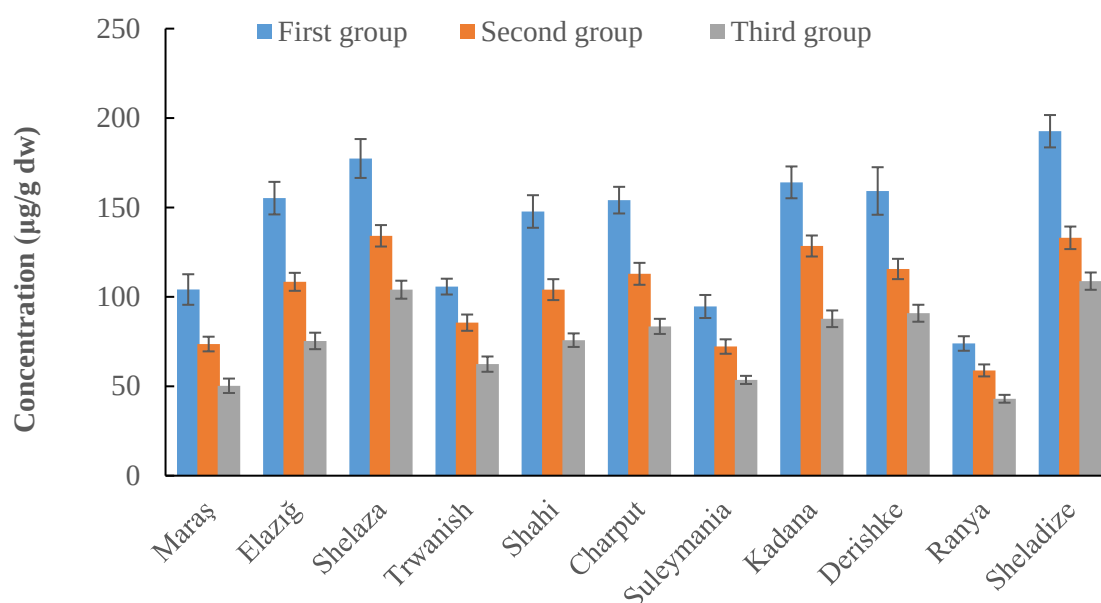


Figure 3.9. interpretation column chart of cyanocobalamin

Table 3.21. Loss percentage % of B12

Region	B12	
	Second group	Third group
Maraş	29.30	51.70
Elazığ	30.10	51.40
Shelaza	24.40	41.40
Trwanish	19.10	41.00
Shahi	29.60	48.70
Charput	26.70	45.80
Suleymania	23.70	43.40
Kadana	21.70	46.50
Derishke	55.40	65.00
Ranya	20.40	41.80
Sheladize	30.90	43.50

In the first group, the folic acid and cyanocobalamin values ranged from 473.10 ± 28.60 to 826.20 ± 62.00 and 73.90 ± 4.10 to 259.20 ± 13.30 µg/g dw, respectively. In the second and third groups, the corresponding values were found to be 414.30 ± 15.00 - 726.10 ± 21.50 and 58.90 ± 3.40 - 134.20 ± 6.00 and 65.80 ± 4.00 - 203.80 ± 8.50 and 43.00 ± 2.20 - 108.80 ± 4.80 µg/g dw, respectively (Table 3.18 and Table 3.20).

The highest concentrations of folic acid and cyanocobalamin in first group sumac samples were observed in Shelaza and Derishke, respectively, while the lowest amounts were observed in Sheladize and Ranya region sumacs.

Table 3.18 shows that there is a substantial variation in the levels of folic acid in the first group between the Maraş, Shelaza, and Charput areas. Similarly, in the term of cyanocobalamin, there is a significant difference between the Maraş, Elazığ, Derishke, Ranya, and Sheladize regions (Table 3.20).

The research results indicated that the first group samples had the highest levels of vitamin B9 and vitamin B12. The concentration of the third group samples was found to be the lowest.

In terms of vitamin B9 and B12, there is a statistically significant difference ($p < 0.05$) between the first, second, and third groups, as shown in the rows of (Table 3.18 and Table 3.20). The third group has a greater loss of vitamin B9 and B12 content compared to the second group (Table 3.19 and Table 3.21).

The impact of fruit preservation techniques on the degradation of vitamin B9 and B12 may be seen via the analysis of (Figure 3.8 and Figure 3.9).

The impact of oxygen on preserved foods and drinks encompasses many outcomes. These include the development of rancidity in unsaturated fats, the promotion of aerobic bacterial and fungal growth leading to the darkening of fresh meat colours, the generation of a stale odour in soft baked items, and the occurrence of phenolic browning in fruits and vegetables. [152].

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 10.08 ± 0.24 and 3.51 ± 0.37 mg/kg of cyanocobalamin (B12), respectively [31].

In accordance with the findings of a previous study conducted by Wahab Gbolahan Ayoade et al. (2023), the levels of Folic acid (B9) found in turmeric, black pepper, and cloves were 16.46 ± 0.03 , 14.22 ± 0.02 and 15.81 ± 0.03 mg/100g, respectively [146].

Based on the results obtained from an earlier investigation carried out by Wahab Gbolahan Ayoade et al. (2023), the concentrations of cobalamine (B12) identified in cloves, black pepper, and turmeric were 14.72 ± 0.02 mg/100g, 15.13 ± 0.03 mg/100g, and 12.84 ± 0.03 mg/100g, respectively [146].

Considering the RDA values, it can be said that all sumac samples are a good source of vitamins, except for ascorbic acid (Table 3.3).

3.3. Vitamin A, E, β -carotene and lycopene

Table 3.22. Amount of vitamin A in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{b,c} 1.90 ± 0.10 *	^{d,e} 1.80 ± 0.10 ***	^{c,d} 1.50 ± 0.10 **
Elazığ	^{b,c} 1.90 ± 0.10 *	^d 1.70 ± 0.10 ***	^c 1.50 ± 0.10 **
Shelaza	^b 1.70 ± 0.10 *	^c 1.50 ± 0.10 ***	^b 1.20 ± 0.10 **
Trwanish	^a 1.30 ± 0.10 *	^{a,b} 1.20 ± 0.10 ***	^a 0.90 ± 0.10 **
Shahi	^{b,c} 1.90 ± 0.10 *	^d 1.70 ± 0.10 ***	^c 1.50 ± 0.10 **
Charput	^d 2.80 ± 0.10 *	^f 2.30 ± 0.10 ***	^f 2.00 ± 0.10 **
Suleymania	^d 2.60 ± 0.10 *	^f 2.20 ± 0.10 ***	^{e,f} 1.90 ± 0.10 **
Kadana	^b 1.70 ± 0.10 *	^c 1.50 ± 0.10 ***	^b 1.20 ± 0.10 **
Derishke	^a 1.10 ± 0.10 *	^a 1.00 ± 0.10 ***	^a 0.90 ± 0.10 **
Ranya	^c 2.20 ± 0.20 *	^e 2.00 ± 0.10 ***	^{d,e} 1.70 ± 0.10 **
Sheladize	^b 1.70 ± 0.10 *	^{b,c} 1.40 ± 0.10 ***	^b 1.20 ± 0.10 **

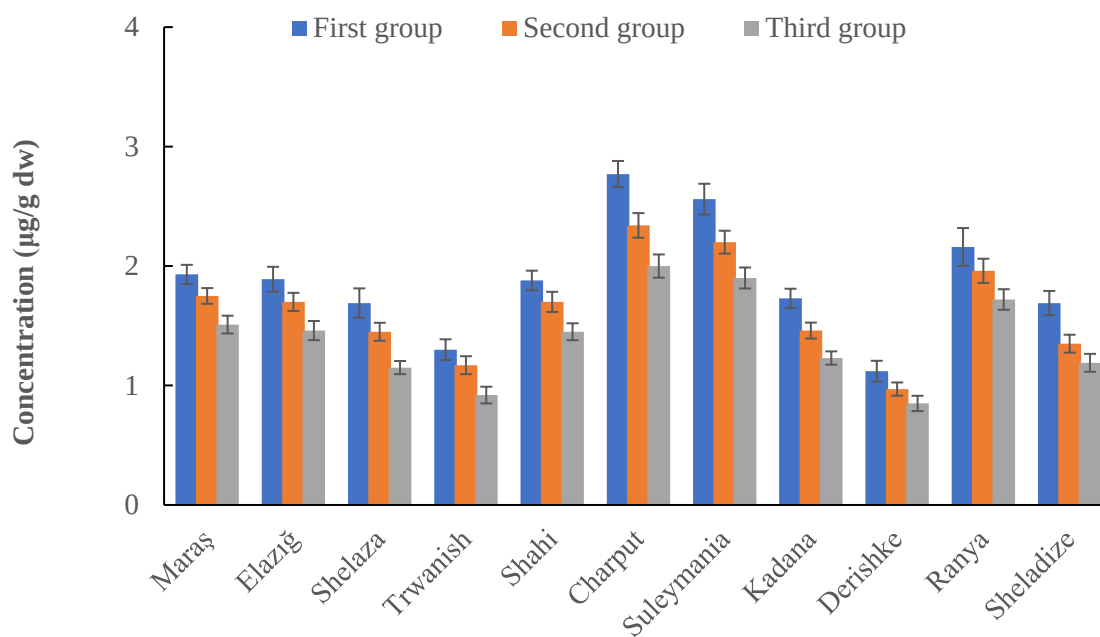


Figure 3.10. Interpretation column chart of vitamin A

Table 3.23. Loss percentage % of vitamin A

Vitamin A		
Region	Second group	Third group
Maraş	9.30	21.70
Elazığ	10.05	22.80
Shelaza	14.20	32.00
Trwanish	10.00	29.20
Shahi	9.60	22.90
Charput	15.50	27.80
Suleymania	14.06	25.80
Kadana	15.60	28.90
Derishke	13.40	24.10
Ranya	9.25	20.40
Sheladize	20.11	29.06

Vitamin A serves several purposes, including the regulation of the visual system, promotion of cellular development and growth, preservation of the integrity of epithelial cells, enhancement of immunological function, and support of reproductive processes [153].

The vitamin A content in the first group, which was cultivated in various areas, ranges from 1.10 ± 0.10 - 2.80 ± 0.10 $\mu\text{g/g dw}$. In contrast, the third set of samples showed a range of 0.90 ± 0.10 - 2.00 ± 0.10 $\mu\text{g/g dw}$ for vitamin A compounds, while the second group showed a range of 1.00 ± 0.10 to 2.30 ± 0.10 $\mu\text{g/g dw}$ (Table 3.22).

Regarding the vitamin A molecule, it can be concluded that the Maraş, Elazığ, Shelaza, Shahi, Kadana, and Sheladize areas do not vary significantly in concentrations ($p > 0.05$), and the same holds true for the Trwanish and Derishke regions (Table 3.22). The rows of (Table 3.22) show that there is a statistically significant difference ($p < 0.05$) between the first and third groups, but no statistical difference ($p > 0.05$) between the second and first groups or between the second and third groups.

The sumac samples from the Shelaza region that were belong to the third group showed the biggest decrease in vitamin A concentration, with a value of 32.00%. On the other hand, the sumac samples from the Ranya area that were belong to the second group showed the lowest decrease in vitamin A concentration, with a value of 9.25% (Table 3.23). Comparison data between the three groups of vitamin A shown in (Figure 3.10).

The integrity of fruits and vegetables may impact the breakdown of vitamins during processing since mechanical damage such as bruising, surface abrasions, wrapping, and cuts can occur [143].

The results of the vitamin analysis that was performed on turmeric were presented in a previous research that was carried out by Anyaoku et al. (2023). According to the findings, turmeric

has a significant quantity of vitamin E 15.4 mg/kg. Vitamin A 5.0 mg/kg is one of the several vitamins that may be found in [154].

Cinnamomum Zeylanicum was the subject of a previous investigation that was carried out by Khalisyaseen and Mohammed (2021). The findings indicate that *Cinnamomum Zeylanicum* has a quantity of vitamin E that is 2.622 parts per million. where vitamin A was found to be 27.198 parts per million [155].

An earlier study that Emmanuel-Ikpeme (2014) conducted focused on the long chilli pepper and the small chilli pepper. Both of these peppers were the topic of the inquiry. The results of the study reveal that the amount of vitamin E is 0.41 and 0.35 mg/100g, while the quantity of vitamin A was discovered to be 1.26 and 1.07 µg/100g, respectively, by the researchers [156].

In a study conducted by Ibrahim MS et al. in 2017, it was shown that the vitamin A content in *Crataegus laevigata* specimens was 0.78 ± 0.08 , 0.76 ± 0.08 , and 1.14 ± 0.11 µg/g in the cities of Elazığ, Adiyaman, and Malatya, respectively [157].

Table 3.24. Amount of vitamin E in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^{d,e} 155.50 ± 8.30 *	^{d,e} 139.20 ± 7.00 ***	^{d,e} 118.90 ± 6.80 **
Elazığ	^{a,b} 105.40 ± 6.40 *	^{a,b} 94.20 ± 5.50 ***	^b 85.10 ± 5.30 **
Shelaza	^a 84.40 ± 5.60 *	^a 76.30 ± 5.00 ***	^a 64.10 ± 4.40 **
Trwanish	^{b,c} 120.40 ± 7.30 *	^{b,c} 107.80 ± 6.00 ***	^{b,c} 92.90 ± 5.80 **
Shahi	^f 212.50 ± 10.10 *	^f 197.30 ± 6.40 ***	^g 180.70 ± 6.70 **
Charput	^e 173.40 ± 8.50 *	^e 158.20 ± 6.70 ***	^f 141.40 ± 6.60 **
Suleymania	^{c,d} 137.20 ± 6.90 *	^{c,d} 120.70 ± 5.90 ***	^{c,d} 105.50 ± 5.80 **
Kadana	^f 230.70 ± 11.30 *	^f 207.10 ± 9.10 ***	^g 190.40 ± 8.90 **
Derishke	^e 164.70 ± 8.40 *	^e 145.20 ± 6.80 ***	^{e,f} 127.90 ± 7.20 **
Ranya	^f 217.00 ± 10.90 *	^f 193.10 ± 8.90 ***	^g 175.50 ± 8.60 **
Sheladize	^a 89.30 ± 5.20 *	^a 77.20 ± 4.80 ***	^a 61.90 ± 4.50 **

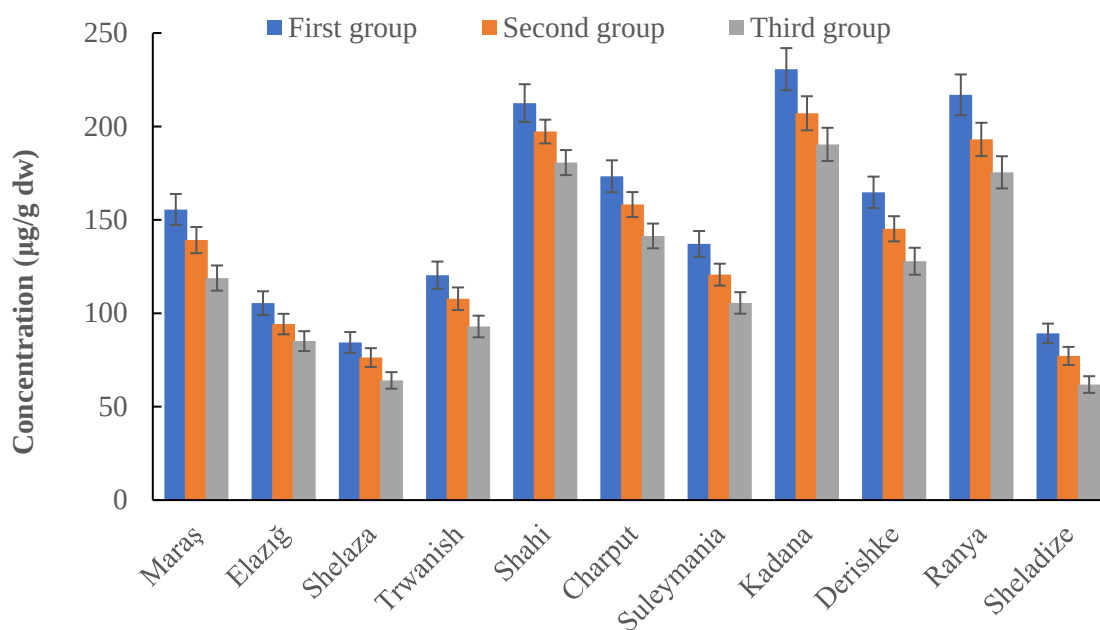


Figure 3.11. Interpretation column chart of vitamin E

Table 3.25. Loss percentage % of vitamin E

Region	Vitamin E	
	Second group	Third group
Maraş	10.50	23.60
Elazığ	10.60	19.30
Shelaza	9.60	24.10
Trwanish	10.50	22.80
Shahi	7.20	15.01
Charput	8.70	18.40
Suleymania	12.02	23.10
Kadana	10.20	17.50
Derishke	11.80	22.40
Ranya	11.00	19.10
Sheladize	13.50	30.70

The amount of vitamin E in the first group was found to vary from 84.40 ± 5.60 to 230.70 ± 11.30 µg/g dry weight. This variation was seen in various areas. In the second group of samples, the quantity of vitamin E compounds fluctuated between 76.30 ± 5.00 to 207.10 ± 9.10 µg/g dw. On the other hand, in the third group of samples, the amount of vitamin E substances varied between 61.90 ± 4.50 to 190.40 ± 8.90 µg/g dw (Table 3.24).

In terms of the vitamin E component, it is possible to assert that there is no statistically significant difference in concentrations between the areas of Elazığ, Shelaza, and Sheladize ($p > 0.05$), as well as between the regions of Shahi, Kadana, and Ranya in the first group (Table 3.24).

After waiting for six months the sumac samples of the third group in the Sheladize region had the greatest concentration loss of vitamin E at 30.70%, while the second group samples in the Shahi area had the lowest concentration loss at 7.20% (Table 3.25). Comparison data between the three groups of vitamin E shown in (Figure 3.11).

Previous research by Irena Perucka and Małgorzata Materska (2007) indicated that different pepper fruit extracts (King Artur, Red Knight, Capel Hot, and Robustini) contained varying amounts of vitamin E, with values of (23.57 ± 0.47 , 13.42 ± 2.34 , 61.23 ± 0.51 , and 56.11 ± 0.0) mg/100g respectively [158].

As to Olatunji and Afolayan report (2018), the amount of vitamin E (alpha-tocopherol) found in capsicum annum is 0.37 milligrammes per one hundred grammes [159].

In accordance with the findings of a previous study conducted by Wahab Gbolahan Ayoade et al. (2023), the levels of α -Tocopherol (E) found in turmeric, black pepper, and cloves were 11.24 ± 0.03 , 15.32 ± 0.04 , and 22.51 ± 0.03 mg/100g, respectively [146].

Table 3.26. Amount of β -carotene in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{e,f} $4.50 \pm 0.20^*$	^d $4.00 \pm 0.20^{**}$	^c $3.70 \pm 0.20^{**}$
Elazığ	^{d,e} $4.20 \pm 0.20^*$	^{c,d} $3.90 \pm 0.20^{**}$	^c $3.50 \pm 0.10^{**}$
Shelaza	^{b,c} $3.60 \pm 0.20^*$	^b $3.10 \pm 0.10^{**}$	^b $2.80 \pm 0.10^{**}$
Trwanish	^{d,e} $4.10 \pm 0.20^*$	^{c,d} $3.90 \pm 0.20^{**}$	^c $3.50 \pm 0.10^{**}$
Shahi	^{c,d,e} $4.10 \pm 0.20^*$	^{c,d} $3.90 \pm 0.20^{**}$	^c $3.50 \pm 0.20^{**}$
Charput	^{b,c,d} $3.90 \pm 0.10^*$	^c $3.50 \pm 0.10^{**}$	^b $3.00 \pm 0.10^{**}$
Suleymania	^f $4.70 \pm 0.20^*$	^d $4.10 \pm 0.20^{**}$	^c $3.70 \pm 0.10^{**}$
Kadana	^g $5.30 \pm 0.20^*$	^e $4.90 \pm 0.20^{**}$	^d $4.30 \pm 0.20^{**}$
Derishke	^b $3.50 \pm 0.20^*$	^b $3.10 \pm 0.10^{**}$	^b $2.70 \pm 0.10^{**}$
Ranya	^{f,g} $4.90 \pm 0.20^*$	^d $4.20 \pm 0.20^{**}$	^c $3.80 \pm 0.20^{**}$
Sheladize	^a $2.50 \pm 0.10^*$	^a $2.20 \pm 0.10^{**}$	^a $1.90 \pm 0.10^{**}$

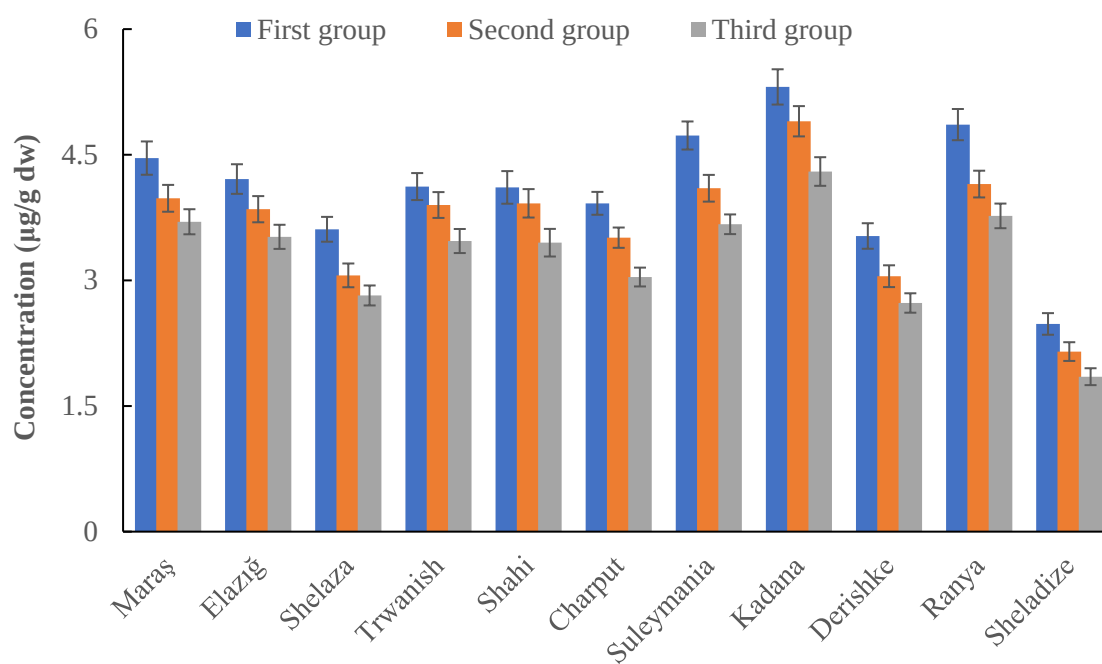


Figure 3.12. Interpretation column chart of β -carotene

Table 3.27. Loss percentage % of β -carotene

Region	β -carotene	
	Second group	Third group
Maraş	10.80	17.04
Elazığ	8.60	16.40
Shelaza	15.20	21.90
Trwanish	5.30	15.80
Shahi	4.60	16.10
Charput	10.50	22.40
Suleymania	13.30	22.40
Kadana	7.70	19.00
Derishke	13.60	22.70
Ranya	14.60	22.40
Sheladize	13.30	25.40

β -carotene, a provitamin A compound, is present in plants, fruits, and vegetables. Chlorophyll is a red-orange pigment that gives plants and vegetables their colour [160].

β -carotene is a powerful antioxidant that is recognised for its ability to provide protection against the harmful effects of light and to inhibit the growth of cancer cells [161].

In the first group, the levels of β -carotene varied between 2.50 ± 0.10 and 5.30 ± 0.20 $\mu\text{g/g}$ dry weight. Different regions displayed this variance. The amount of β -carotene compounds varied between 2.20 ± 0.10 and 4.90 ± 0.20 $\mu\text{g/g dw}$ in the second set of samples. Conversely, the

concentration of β -carotene compounds ranged from 1.90 ± 0.10 to 4.30 ± 0.20 $\mu\text{g/g dw}$ in the third set of samples (Table 3.26).

When it comes to the β -carotene component, we can say that the concentrations differ significantly between Elazığ, Shelaza, Suleymania, Kadana, and Sheladize ($p < 0.05$). Similarly, in the first group, we can see that there is a difference between Charput, Sheladize, and Ranya (Table 3.26). No statistical difference exists between the second and third groups ($p > 0.05$), but there is a significant difference between the first and second groups ($p < 0.05$) and between the first and third groups ($p < 0.05$), as can be shown in the rows of (Table 3.26).

When the loss of β -carotene was measured in various regions, it was discovered that the second group had a loss amounting to between 4.60 and 15.20%, while the third group saw a loss ranging from 15.80 to 25.40%. (Table 3.27). Comparison data between the three groups of β -carotene shown in (Figure 3.12).

There is a possibility that deteriorative enzyme activity and oxidation processes are responsible for the loss of bioactive substances. The fact that the exclusion of oxygen, which serves as a facilitator of degradative processes of the lipid substrate, was not possible lends credence to the premise that this is the case [162].

An analysis conducted by Schweiggert et al. 2007, revealed that the quantity of β -carotene found in Chilli pods and Paprika pods was 0.25 mg/g and 0.22 mg/g, respectively. Same study reported that before mincing, a heat treatment was performed to the material. A loss of 25–34% of the original carotenoid concentrations was seen in chilli, whereas a loss of 20–53% was observed in paprika as a consequence of processing [163].

Osuna-Garcia and Wall (1998) reported, when it comes to paprika, high levels of moisture (10–18%) slowed down the process of colour loss, whereas low moisture levels (<8%) sped up the degradation of pigment. Nevertheless, the presence of high moisture concentrations enhanced the likelihood of microbial growth, browning that was not caused by enzymes. [164].

According to the findings of earlier investigations, these losses that occur during mincing and lyophilization are consistent [165].

In a recent study conducted by Çakmak et al. (2021), the β -carotene concentration in fresh, frozen, sun-dried, and microwave-dried in wild white *Myrtus communis* L. fruit was found to be 5.89 ± 0.35 , 5.5 ± 0.25 , 3.10 ± 0.18 , and 3.46 ± 0.15 $\mu\text{g/g dw}$, respectively. The content of β -carotene in fresh, frozen, sun-dried, and microwave-dried in cultivated white *Myrtus communis* L. fruit was measured to be 5.17 ± 0.35 , 4.96 ± 0.25 , 3.14 ± 0.16 , and 3.54 ± 0.10 $\mu\text{g/g dw}$, respectively [166].

Table 3.28. Amount of lycopene in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{b,c} $11.10 \pm 0.60^*$	^{c,d} $9.80 \pm 0.40^{**}$	^{b,c} $8.40 \pm 0.50^{***}$
Elazığ	^a $8.10 \pm 0.50^*$	^{a,b} $7.00 \pm 0.40^{**}$	^a $5.40 \pm 0.40^{***}$
Shelaza	^{a,b} $10.40 \pm 0.60^*$	^{b,c} $8.80 \pm 0.50^{**}$	^b $7.60 \pm 0.40^{***}$
Trwanish	^f $22.20 \pm 1.30^*$	^f $18.30 \pm 0.80^{**}$	^d $16.20 \pm 0.90^{***}$
Shahi	^d $14.80 \pm 1.10^*$	^{a,b} $7.10 \pm 0.40^{**}$	^a $5.60 \pm 0.30^{***}$
Charput	^e $18.90 \pm 0.90^*$	^e $15.20 \pm 0.80^{**}$	^{b,c} $8.90 \pm 0.60^{***}$
Suleymania	^g $26.90 \pm 1.40^*$	^d $10.70 \pm 0.60^{**}$	^{b,c} $8.40 \pm 0.50^{***}$
Kadana	^{b,c,d} $12.60 \pm 0.70^*$	^a $9.40 \pm 0.60^{**}$	^c $6.00 \pm 0.30^{***}$
Derishke	^g $25.60 \pm 1.30^*$	^g $21.90 \pm 1.20^{**}$	^a $4.30 \pm 0.20^{***}$
Ranya	^{c,d} $13.30 \pm 0.80^*$	^d $11.30 \pm 0.70^{**}$	^c $9.70 \pm 0.60^{***}$
Sheladize	^{b,c} $11.60 \pm 0.60^*$	^{c,d} $9.80 \pm 0.50^{**}$	^{b,c} $8.60 \pm 0.50^{***}$

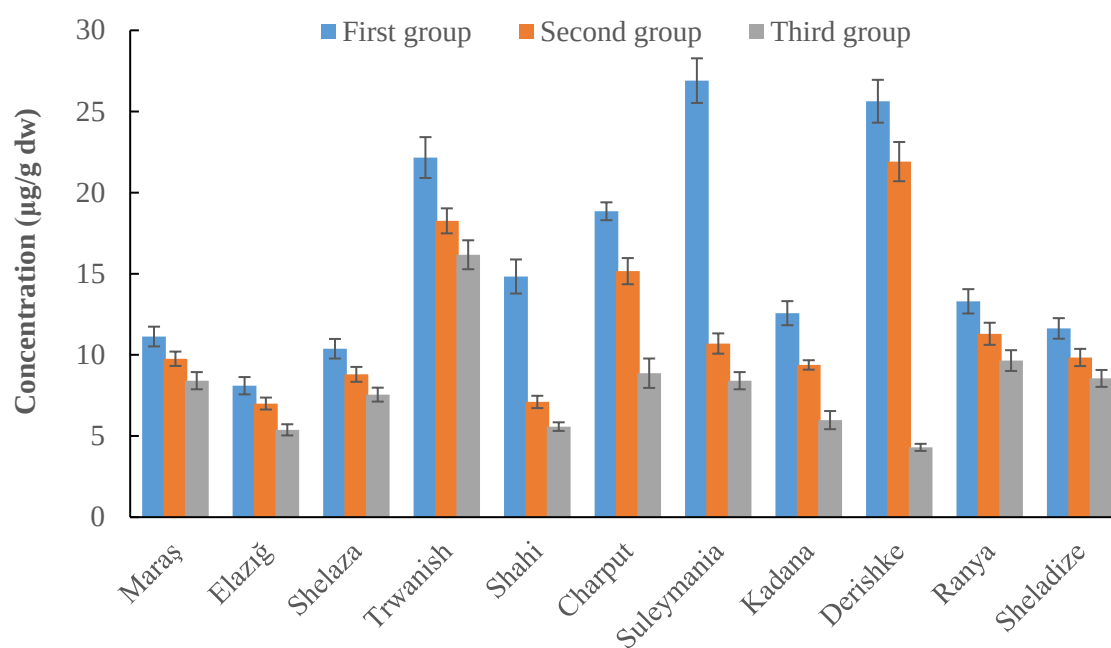


Figure 3.13. Interpretation column chart of lycopene

Table 3.29. Loss percentage % of lycopene

Region	Lycopene	
	Second group	Third group
Maraş	12.30	24.40
Elazığ	13.60	33.60
Shelaza	15.20	27.30
Trwanish	17.60	27.03
Shahi	52.10	62.40
Charput	19.60	52.91
Suleymania	60.20	68.70
Kadana	25.40	52.40
Derishke	14.50	83.20
Ranya	15.03	27.40
Sheladize	15.40	26.50

The values of lycopene in the first group ranged from 8.10 ± 0.50 to 26.90 ± 1.40 $\mu\text{g/g dw}$. There was variation in this among areas. In the second group of samples, the amounts of lycopene compounds ranged from 6.00 ± 0.30 to 21.90 ± 1.20 $\mu\text{g/g dw}$. In contrast, the third group of samples included lycopene compounds with concentrations ranging from 4.30 ± 0.20 to 18.90 ± 0.90 $\mu\text{g/g dw}$ (Table 3.28). The sumac fruit exhibited a concentration loss ranging from 83.2% to 12.3%. The largest loss of 83.2% was seen in the third group Derishke area, while the lowest loss of 12.3% was recorded in the Maraş area second group sample (Table 3.29). Comparison data between the three groups of lycopene shown in (Figure 3.13).

The lycopene component allows us to conclude that the areas of Elazığ, Trwanish, Suleymania, Shahi, and Suleymania have significantly different concentrations ($p < 0.05$), and that the first group also shows a difference between Elazığ and Sheladize (Table 3.28).

According to Ozgur et al. (2011) findings, the quantity of lycopene found in fresh green pepper samples was 6.71 mg/kg dw, whereas the fresh red pepper samples had 13.45 mg/kg dw. On the other hand, the dried samples of green pepper and red pepper had respective values of 171.55 and 123.89 mg/kg dw [167].

Aminu Yakubu et al. (2018), reported that high temperatures have an effect on the percentage of lycopene that is produced during the preservation process. According to the findings of the study, even a little rise in temperature may lower the percentage of lycopene that is produced. As a result, high temperatures will result in a decrease in the amount of lycopene that is produced. Consequently, in order to minimise the amount of lycopene that is lost during the processing of lycopene, it is necessary to keep the temperature between 0.0 and 50.0 degrees Celsius. This is because the pharmaceuticals sector and the food processing industry have a high need for lycopene [168].

3.4. Total phenolic acid, total flavonoids and antioxidant capacities (DPPH and ABTS)

Table 3.30. Total phenolic substance in sumac samples ($\mu\text{g GAE/g dw}$)

Region	First group	Second group	Third group
Maraş	^b $38.80 \pm 1.10^*$	^b $30.70 \pm 1.10^{**}$	^{d,e} $27.60 \pm 1.00^{***}$
Elazığ	^c $44.90 \pm 1.50^*$	^c $41.70 \pm 1.30^{**}$	^f $35.80 \pm 1.20^{***}$
Shelaza	^a $29.40 \pm 0.90^*$	^a $27.50 \pm 0.90^{**}$	^{c,d} $25.20 \pm 0.80^{***}$
Trwanish	^b $36.90 \pm 1.10^*$	^b $31.40 \pm 0.90^{**}$	^{d,e} $26.50 \pm 0.80^{***}$
Shahi	^a $28.50 \pm 1.00^*$	^a $26.50 \pm 0.80^{**}$	^{a,b} $21.30 \pm 0.80^{***}$
Charput	^a $28.40 \pm 0.90^*$	^a $25.20 \pm 0.90^{**}$	^{b,c} $22.60 \pm 0.80^{***}$
Suleymania	^d $51.50 \pm 1.50^*$	^c $42.40 \pm 1.30^{**}$	^f $36.60 \pm 1.20^{***}$
Kadana	^a $27.70 \pm 0.90^*$	^a $26.00 \pm 0.90^{**}$	^a $19.30 \pm 0.80^{***}$
Derishke	^b $36.00 \pm 1.10^*$	^b $30.80 \pm 1.00^{**}$	^{d,e} $26.20 \pm 0.90^{***}$
Ranya	^b $35.70 \pm 1.10^*$	^b $32.30 \pm 1.00^{**}$	^e $28.30 \pm 0.90^{***}$
Sheladize	^d $51.80 \pm 1.50^*$	^c $41.40 \pm 1.30^{**}$	^f $37.80 \pm 1.10^{***}$

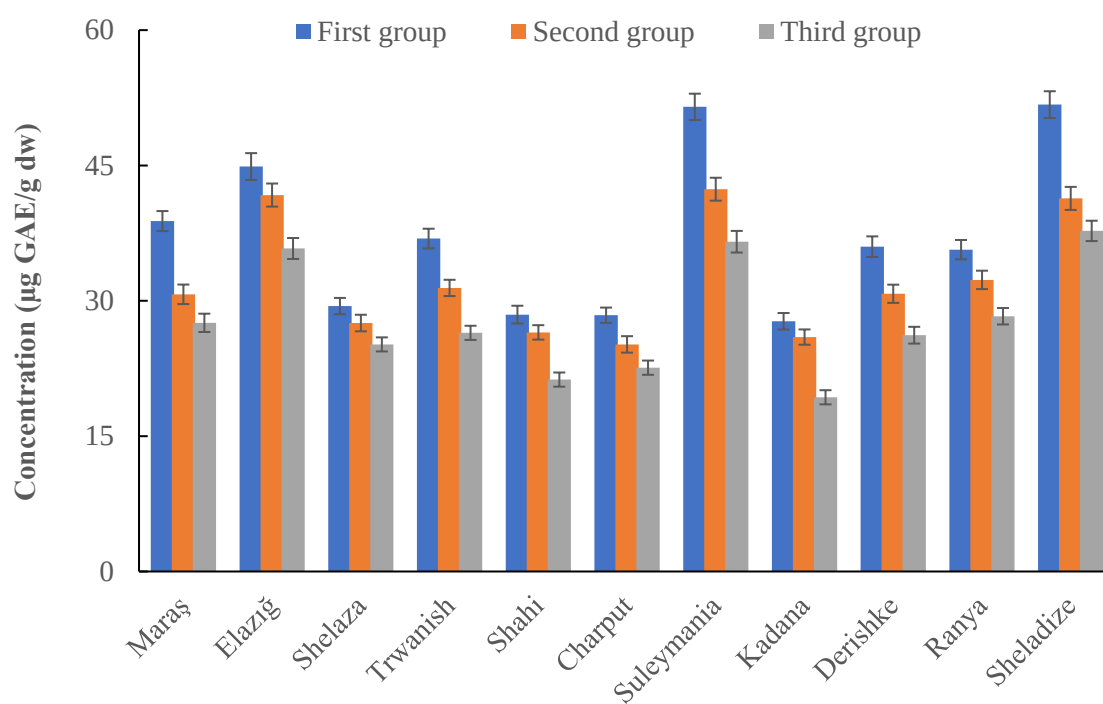


Figure 3.14. Interpretation column chart of total phenolic acid

Table 3.31. Loss percentage % of total phenolic acid

Region	Total phenolic acid	
	Second group	Third group
Maraş	20.90	29.04
Elazığ	7.04	20.20
Shelaza	6.40	14.40
Trwanish	14.80	28.30
Shahi	6.90	25.30
Charput	11.40	24.50
Suleymania	17.70	29.02
Kadana	6.30	30.40
Derishke	14.50	27.30
Ranya	9.40	20.70
Sheladize	20.10	27.10

Phenolic compounds are the secondary phytochemicals present in plants. The majority of the health advantages derived from plants may be attributed to their properties. They consist of phenolic substances, including flavonoids, phenolic acids, lignin precursors, tannins, benzoic acid, and cinnamic acid derivatives. Their antioxidant properties make them highly desirable, as they effectively preserve and protect food quality. Additionally, they play a crucial role in various protective functions, including anti-ageing, anti-inflammatory, capillary protection, inhibition of tumour growth at different stages, and prevention of metabolic disorders caused by oxidative stress [169].

The spectrometric techniques were used to analyse and compare the total phenolic contents in aliquot quantities of methanolic extracts obtained from eleven different species of sumac fruits originating from Iraq and Turkey, which were treated using various conservative procedures.

The methanolic extracts obtained from eleven different species of first group, second group, and third group sumac fruits were analysed for total phenolic compounds. The results showed that the range of phenolic compounds varied from 27.70 ± 0.90 to 51.80 ± 1.50 μg gallic acid equivalent (GAE)/g, 25.20 ± 0.90 to 42.40 ± 1.30 μg gallic acid equivalent (GAE)/g, and 19.30 ± 0.80 to 37.80 ± 1.10 μg gallic acid equivalent (GAE)/g for the respective extracts (Table 3.30).

In terms of total phenolic compound concentrations, it can be concluded that the Shahi, Shelaza, Charput, and Kadana areas do not vary significantly from each other ($p > 0.05$), and the same holds true for the first group Maraş, Trwanish, Derishke, and Ranya regions (Table 3.30).

The sumac samples from the Kadana region that were belong to the third group showed the maximum reduction in phenolic compound concentrations, with a value of 30.4%. On the other hand, the sumac sample belong to the second group in the Kadana area showed the lowest reduction

in concentrations, with a value of 6.3% (Table 3.31). Comparison data between the three groups of total phenolic contents shown in (Figure 3.14).

The proportion of phenolic compounds was reduced by aerobic and enzymatic oxidation processes, as well as by time and mechanical grinding, in comparison to the fresh model. The research done by Patil et al. (2019) determined that the phenolic content of prickly pears was 42.454 mg GAE/100g in a 50% methanol extract and 38.736 mg GAE/100g in a water extract [170].

According to previous research was conducted by Raodah et al. (2014), methanol extract of sumac samples contained 151.71(mg GAE/g extract), the ethyl acetate extract contained 65.31 (mg GAE/g extract) total phenolic substance [171].

In a study conducted by Mazzara et al. (2023), total phenolic and flavonoid substances in sumac samples taken from five different regions of Sicilian were between 35481- 473.08 (mg GAE/g DE), 38.06 – 55.56 (mg QE/g DE) respectively [172].

Yuksel et al. (2023) reported that the total amount of phenolic substances in the methanol extract of sumac samples grown in different regions of Tunceli varied between $797 \pm 50 - 1929 \pm 63$ (mg GAE/kg) [173].

The research done by Cha et al. (2013) [174], found that *Opuntia humifusa* has a total phenolic content of 125.10 (μg GAE/g) and a flavonoid content of 48.90 (μg CE/g). The total phenolic content in various seeds, fruits, and vegetables ranges from 169 to 1048 mg/100g of dry weight.

Various studies have been conducted to examine the impact of drying on the phenolic content of fruits. Several studies have found that the drying process leads to a reduction in the overall phenolic content [175,176], conversely, Carranza-Concha et al. (2012), found that drying led to an increase in the overall phenolic content [177]. As a result of the heat treatment, some phenolic compounds undergo conversion while others are liberated into the surrounding medium. Thus, it can be concluded that the drying process has varying effects on the total phenolic content of various goods [178].

According to previous research, the methanolic sumac extract had 151.71 mg/g of phenols, the ethyl acetate extract contained 65.31 mg/g, and the aqueous extract contained 6.10 mg/g [171]. Methanol is the best solvent for extracting phenolics from sumac, according to a study that compared three different extracts (aqueous, methanolic, and ethanolic) in Baghdad. This is because methanolic extracts contain more phenolics and flavonoids than ethanolic and aqueous extracts [179].

Table 3.32. Total flavonoids substance in sumac samples ($\mu\text{g QE/g dw}$)

Region	First group	Second group	Third group
Maraş	^{d,e} 25.84 ± 1.20 *	^b 18.37 ± 0.90 **	^{b,c} 14.62 ± 0.70 ***
Elazığ	^{f,g} 30.37 ± 1.80 *	^d 27.75 ± 1.30 **	^{d,e} 19.84 ± 1.10 ***
Shelaza	^a 16.16 ± 0.80 *	^a 14.89 ± 0.70 **	^a 10.76 ± 0.70 ***
Trwanish	^{b,c} 20.21 ± 1.40 *	^b 18.55 ± 0.90 **	^c 16.23 ± 0.80 ***
Shahi	^{b,c} 20.11 ± 1.40 *	^a 14.34 ± 1.10 **	^{a,b} 12.54 ± 0.90 ***
Charput	^{a,b} 17.88 ± 0.90 *	^a 14.46 ± 0.80 **	^{a,b} 12.83 ± 0.60 ***
Suleymania	^g 33.50 ± 1.70 *	^e 30.88 ± 1.30 **	^{d,e} 20.37 ± 1.10 ***
Kadana	^{a,b} 18.40 ± 0.90 *	^{a,b} 16.76 ± 0.90 **	^a 11.57 ± 0.70 ***
Derishke	^{d,e} 25.82 ± 0.80 *	^c 23.79 ± 1.40 **	^d 19.22 ± 0.80 ***
Ranya	^{c,d} 22.60 ± 1.20 *	^b 19.42 ± 1.10 **	^{b,c} 14.27 ± 0.80 ***
Sheladize	^{e,f} 28.52 ± 1.90 *	^{c,d} 25.72 ± 1.10 **	^e 21.82 ± 1.00 ***

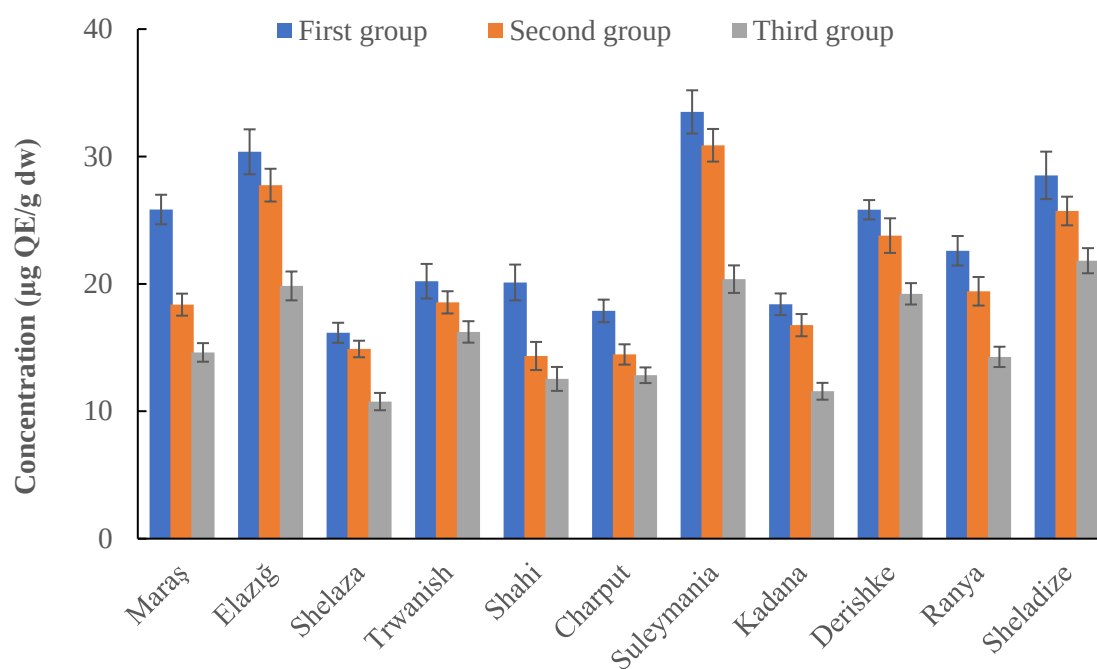


Figure 3.15. Interpretation column chart of total flavonoids

Table 3.33. Loss percentage % of total flavonoids

Region	Total flavonoids	
	Second group	Third group
Maraş	28.91	43.42
Elazığ	8.63	34.67
Shelaza	7.86	33.41
Trwanish	8.21	19.70
Shahi	28.70	37.64
Charput	19.13	28.24
Suleymania	7.82	39.19
Kadana	8.91	37.11
Derishke	7.86	25.56
Ranya	14.10	36.86
Sheladize	9.81	23.49

Plants generate a wide range of organic chemicals, most of which do not seem to directly contribute to their growth and development. These compounds, often known as secondary metabolites (flavonoids), are generally found in certain taxonomic groupings within the plant world. Flavonoids are classified into several categories, such as alkaloids, terpenoids, and phenolics. Flavonoids perform several defensive roles inside the human body. Several flavonoids have developed as bioactive substances that disrupt nucleic acids or proteins and exhibit antibacterial, insecticidal, and pharmacological characteristics. Flavonoids are of interest in medicine as medicines and in agriculture as insecticides [180].

Fruits and vegetables may be ingested in either their raw state or after undergoing processing. The preservation techniques used, such as drying, may have an impact on the flavonoid concentration found in fruits and vegetables [181].

From 16.16 ± 0.80 to 33.50 ± 1.70 $\mu\text{g/g dw}$, the total flavonoid component amounts varied in the first group. This diversity was detected in a number of regions. Quantity of total flavonoid component in the second group of samples varied from 14.34 ± 1.10 to 30.88 ± 1.30 $\mu\text{g/g dw}$. The third set of samples, however, showed a range of total flavonoid contents ranging from 10.76 ± 0.70 to 21.82 ± 1.00 $\mu\text{g/g dw}$. (Table 3.32).

If we look at the total flavonoid component, we can say that the areas of Elazığ, Shelaza, Maraş, and Trwanish have different concentrations ($p < 0.05$), and in the first group, we can see that the regions of Charput, Sheladize, and Ranya are different as well, see (Table 3.32). The rows of (Table 3.32) show that there is a statistically significant difference ($p < 0.05$) between the first, second, and third groups.

The sumac samples collected from the Maraş area and subjected to homogenization for a duration of 6 months exhibited the highest decrease in quantities of total flavonoid content

compounds, with a magnitude of 43.42 %. Conversely, the sumac sample that was covered with oil in the Suleymania region had the smallest decrease in concentrations, measuring at 7.82%, comparing to the first group (Table 3.33). This can be explained by oil film formed on the flakes of sumac samples preventing oxidation of sumac from air. Comparison data between the three groups of total flavonoid content shown in (Figure 3.15).

Fereidoonfar et al. (2019) reported that the amounts of total phenolic and flavonoid substances in the methanol extract of sumacs grown in various regions of Iran were determined to be in between 77.54-389.30 (mg GAE/g dw) and 2.19-7.54 (mg QE/g dw), respectively [182].

Özaydin et al. (2022) reported that the total phenolic and flavonoid substance in sumacs of the southeastern Anatolia region of Turkey were in the range of 26.3 - 82.2 (mg GAE/g sumac), 7.4 - 7.55 (mg catechin/g sumac), respectively [183].

Adelakun et al. (2016) report that essential oils have antimicrobial effects, so they can be applied on food products or incorporated into synthetic packaging films to extend the shelf life of foods [184].

Konfo et al. (2023) reported that essential oils, as an essential oils and natural antioxidants, are used in the preservation of foodstuffs [185].

Falowo et al. (2019) reported that 2% and 4% basil essential oil applied to ground beef increased oxidative stability and preserved color during storage [186].

Karatas et al. (2017) reported that vitamin loss was less in oiled samples then unoiled red pepper flakes for a certain period of time [187].

in prevouse study was conducted by Rahim and Mat (2012), reported that total flavonoids contenenent in Bell pepper, Chili pepper and Chili padi was 0.451 ± 0.001 , 0.306 ± 0.001 and 0.551 ± 0.003 ($\mu\text{mol Q/g}$) respectvily [188].

According to a study by Kamiloglu et al. (2015), freezing and drying of fresh vegetables and fruits have been shown to reduce the levels of flavonoids [181].

The overall flavonoid content of fruits may decrease as they undergo different preservation methods due to structural interactions. Heat treatment causes the degradation and depletion of some phenolic compounds antioxidant chemicals. In general, it is anticipated that the antioxidant activity and overall phenolic content will decrease when subjected to heat treatment.

Table 3.34. Total antioxidant capacity (IC₅₀ value) in sumac samples according to the DPPH method IC₅₀ (µg/mL)

Region	First group	Second group	Third group
Maraş	^b 18.81 ± 0.65 *	^b 22.69 ± 0.71 **	^e 28.03 ± 0.88 ***
Elazığ	^a 16.55 ± 0.61 *	^a 19.27 ± 0.64 **	^b 22.56 ± 0.69 ***
Shelaza	^{c,d} 20.83 ± 0.61 *	^b 22.20 ± 0.69 **	^{b,c} 24.24 ± 0.71 ***
Trwanish	^{b,c} 19.12 ± 0.61 *	^b 21.90 ± 0.66 **	^{b,c} 23.28 ± 0.67 ***
Shahi	^{d,e} 22.28 ± 0.57 *	^{c,d} 25.77 ± 0.80 **	^g 32.11 ± 0.90 ***
Charput	^e 23.04 ± 0.74 *	^d 27.70 ± 0.87 **	^{f,g} 30.37 ± 1.01 ***
Suleymania	^a 15.75 ± 0.56 *	^a 17.51 ± 0.62 **	^a 19.42 ± 0.67 ***
Kadana	^e 23.80 ± 0.72 *	^{c,d} 25.78 ± 0.72 **	^{d,e} 27.69 ± 0.78 ***
Derishke	^{b,c} 19.86 ± 0.58 *	^b 22.09 ± 0.67 **	^{c,d} 25.44 ± 0.77 ***
Ranya	^{c,d} 20.66 ± 0.65 *	^c 24.90 ± 0.70 **	^{e,f} 28.33 ± 0.76 ***
Sheladize	^a 14.79 ± 0.48 *	^a 17.81 ± 0.57 **	^a 19.37 ± 0.68 ***

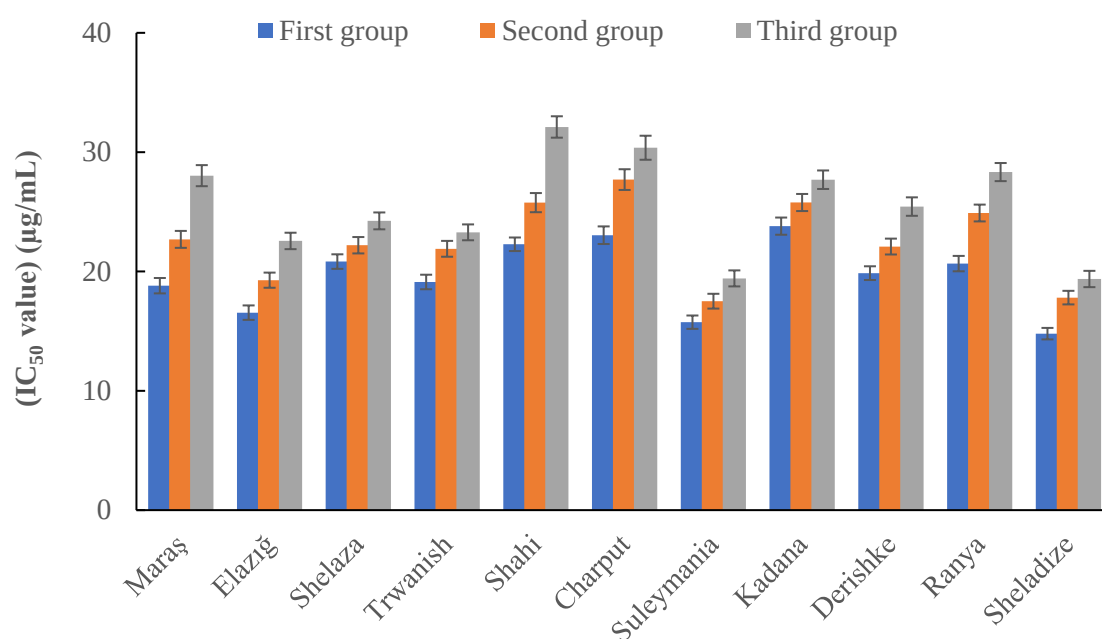


Figure 3.16. Interpretation column chart of DPPH

This study used two distinct methodologies, namely DPPH and TEAC, to assess the antioxidant capability of the samples. During the calculation of IC₅₀ values using the DPPH technique, the Trolox equivalent was determined using the TEAC method. The IC₅₀ value is the concentration of the antioxidant compound that effectively suppresses 50% of the DPPH radical in the medium. The antioxidant capacity is negatively correlated with the IC₅₀ value. The maximum IC₅₀ values obtained from our study for first, second and third groups samples were 14.79 ± 0.48 Sheladize, 17.51 ± 0.62 Suleymania and 19.37 ± 0.68 Sheladize µg/mL, respectively (Table 3.34).

The first group in Table 3.34 shows that there is no significant difference ($p > 0.05$) between the Sheladize and Süleymania and Elazığ areas, as well as between the Trawanish, Derişke, Ranya, and Shelaza regions, in terms of DPPH antioxidant capacity. Comparison data between the three groups of DPPH antioxidant capacity shown in (Figure 3.16).

Ereifej et al. (2016) reported that the total phenolic substance in the methanol extract of sumac and turmeric samples at 20°C were reported to be 271.4 and 187.1 (mg GAE/100g dw), respectively [189]. In the same study, they found the IC₅₀ values of sumac and turmeric methanol extracts found to be 0.15 and 0.16 mg/mL, respectively according to DPPH method.

In Cha et al.'s (2013) research, it was discovered that the methanol extract of *Opuntia humifusa* exhibited a radical scavenging activity (DPPH) of 72.5% [174].

Surinrut et al. (2005), discovered that the IC₅₀ values of mangosteen, orange, pomelo, grape, and papaya fruits varied between 11.18 and 32.80 mg/mL [190].

In a separate investigation, Reynertson et al. (2005), found that the IC₅₀ values ranged from 15.9 to 247 mg/mL in seven distinct fruits belonging to the Myrtle family [191].

Table 3.35. Total antioxidant capacity in sumac samples according to the TEAC method (μmol trolox/g dw)

Region	First group	Second group	Third group
Maraş	^{b,c} 544.27 ± 27.30 *	^b 448.77 ± 20.05 **	^b 332.90 ± 16.40 ***
Elazığ	^{c,d} 594.50 ± 26.30 *	^b 452.42 ± 18.17 **	^{b,c} 348.80 ± 17.11 ***
Shelaza	^b 515.81 ± 23.48 *	^b 433.73 ± 17.24 **	^b 326.37 ± 14.48 ***
Trwanish	^{b,c} 531.37 ± 26.60 *	^b 437.45 ± 16.03 **	^{b,c,d} 364.30 ± 16.82 ***
Shahi	^b 502.37 ± 25.71 *	^b 413.83 ± 19.31 **	^b 334.80 ± 18.23 ***
Charput	^b 488.31 ± 23.13 *	^b 414.90 ± 18.93 **	^b 324.33 ± 16.93 ***
Suleymania	^d 636.50 ± 25.00 *	^c 517.40 ± 20.17 **	^d 407.33 ± 18.30 ***
Kadana	^a 359.30 ± 15.82 *	^a 306.69 ± 13.13 **	^a 259.64 ± 11.83 ***
Derishke	^{b,c} 527.96 ± 24.61 *	^b 450.30 ± 17.50 **	^{c,d} 389.03 ± 17.06 ***
Ranya	^{b,c} 525.43 ± 24.50 *	^b 437.37 ± 20.14 **	^{b,c} 345.83 ± 14.51 ***
Sheladize	^d 665.62 ± 28.12 *	^c 510.00 ± 20.45 **	^{c,d} 389.63 ± 17.82 ***

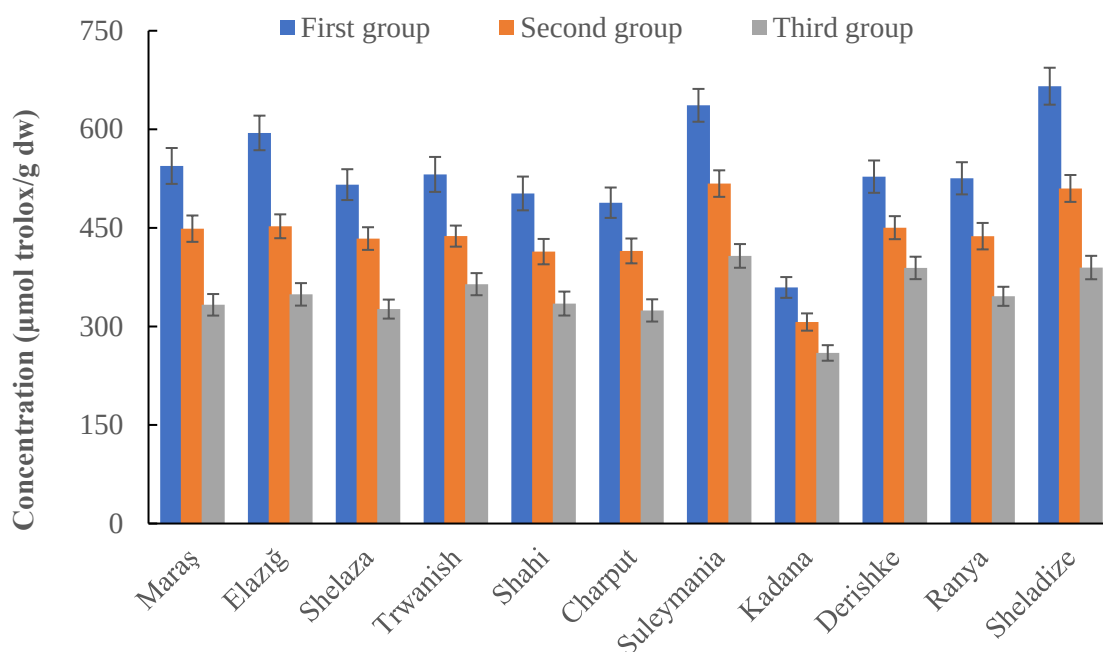


Figure 3.17. Interpretation column chart of ABTS

The TEAC technique is often used to assess the antioxidant potential of food samples since it can be easily applied to both aqueous and lipid phases. The investigation determined the highest level of free radical scavenging activity (TEAC) in first, second and third groups of sumac fruit samples. The specific values were 665.62 ± 28.12 µmol trolox/g dw Sheladize, 517.40 ± 20.17 and 407.33 ± 18.30 µmol trolox/g dw for Suleymania respectively (Table 3.35).

In contrast, the first, second and third groups sumac fruit samples from the Kadana region exhibited the lowest levels of free radical scavenging activity (TEAC), measuring 359.30 ± 15.82 , 306.69 ± 13.13 , and 259.64 ± 11.83 µmol trolox/g dw, respectively (Table 3.35).

When looking at the ABTS antioxidant capacity, the Maraş, Trwanish, Derishke, and Ranya areas do not vary significantly ($p > 0.05$), as well as the Sheladize and Suleymania regions, according to the first group in (Table 3.35). Comparison data between the three groups of free radical scavenging activity (TEAC) shown in (Figure 3.17).

Isgro et al. (2022), stated that the IC_{50} value of the sumac sample was 0.41 ± 0.02 mg/mL and the TEAC value was 1.76 ± 0.10 (mmol trolox E/g extract) [192].

Ayas et al. (2017), reported that the TEAC values of *Rhus coriaria*, *Nasturtium officinale* and *Scolymus hispanicus* were 3055.6 ± 20.4 , 903.0 ± 17.7 , 539.0 ± 6.4 (µmole trolox equivalent/g), respectively [193].

Fereidoonfar et al. (2019), reported that the total antioxidant capacity in the methanol extract of Iranian sumac was between 1.55-11.09 mg AAE/g dw [182].

In their study, Su et al. (2007), determined that the antioxidant activity level of rosehip fruit extracts, obtained using 80% methanol, was measured to be $190 \pm 4.81 \mu\text{mol TEAC/g}$ [194]. The trolox equivalent antioxidant capacities were higher in all categories of sumac fruit samples compared to rosehip fruit. As seen in (Figure 3.17), The antioxidant capacity diminished due to the occurrence of air and enzymatic oxidation, which were facilitated by the passage of time and mechanical force. The experimental findings indicate that the use of mechanical force and oxidation processes during grinding leads to a reduction in the overall antioxidant capacity of the fruits. This reduction may be attributed to a drop in the levels of total phenolic compounds, flavonoids, and antioxidant vitamins. in comparison to the newly obtained specimen. This research has also shown that oil has a role in preserving nutritional content to a certain degree.

3.5. Reducid glutathion, oxidased glutathion, malondialdehyde and hydroxynonenal

Table 3.36. Amount of GSH in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^e $1912.20 \pm 37.20^*$	^e $1810.10 \pm 29.80^*$	^d $1706.40 \pm 33.90^*$
Elazığ	^c $1588.60 \pm 32.40^*$	^c $1441.10 \pm 25.00^*$	^c $1375.10 \pm 27.90^*$
Shelaza	ⁱ $2550.40 \pm 31.90^*$	^h $2426.60 \pm 31.20^*$	^g $2314.90 \pm 30.40^*$
Trwanish	^b $1285.10 \pm 24.00^*$	^b $1178.70 \pm 23.60^*$	^b $1125.40 \pm 25.00^*$
Shahi	^a $1004.10 \pm 21.70^*$	^a $913.50 \pm 20.10^*$	^a $877.50 \pm 21.10^*$
Charput	^d $1759.30 \pm 27.20^*$	^d $1559.10 \pm 25.10^*$	^c $1408.10 \pm 26.10^*$
Suleymanian	^h $2390.10 \pm 28.60^*$	^g $2187.40 \pm 30.30^*$	^f $2098.40 \pm 29.40^*$
Kadana	^b $1362.10 \pm 22.00^*$	^b $1215.70 \pm 23.10^*$	^b $1169.70 \pm 23.20^*$
Derishke	^g $2152.10 \pm 27.60^*$	^f $2014.10 \pm 28.70^*$	^e $1943.10 \pm 29.50^*$
Ranya	^{f,g} $2109.70 \pm 27.40^*$	^f $2016.00 \pm 29.40^*$	^e $1916.00 \pm 30.30^*$
Sheladize	^f $2050.30 \pm 25.90^*$	^f $1969.10 \pm 27.80^*$	^e $1883.50 \pm 28.80^*$

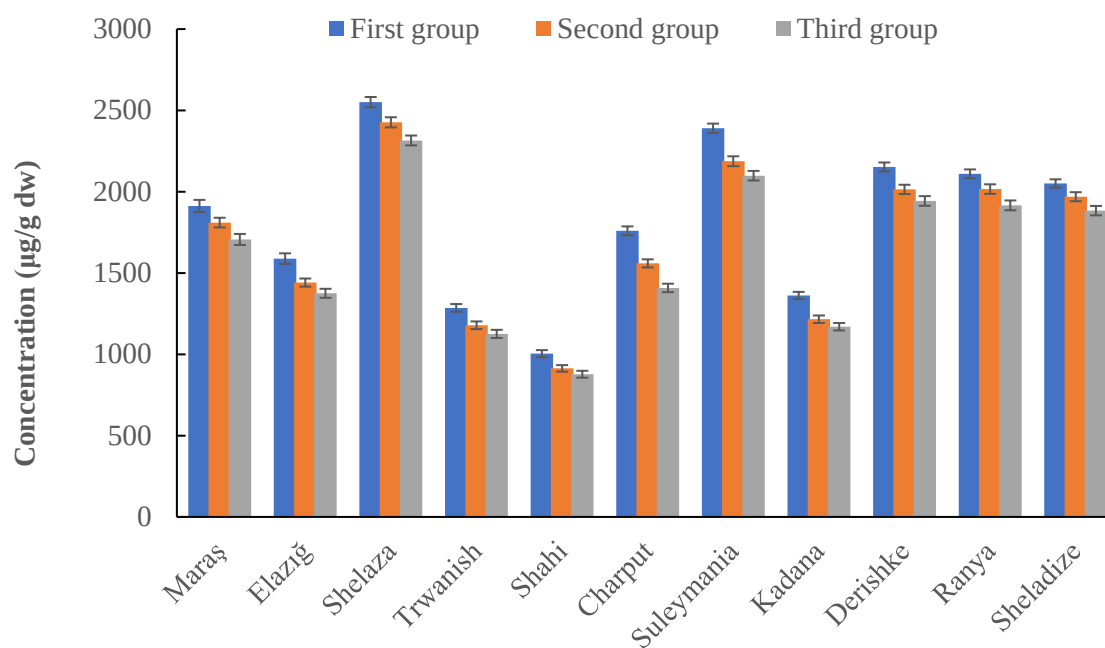


Figure 3.18. Interpretation column chart of GSH

Table 3.37. Loss percentage % of GSH

Region	GSH	
	Second group	Third group
Maraş	5.34	10.80
Elazığ	9.30	13.40
Shelaza	4.90	9.20
Trwanish	6.20	12.40
Shahi	9.02	11.60
Charput	11.40	20.00
Suleymania	8.50	12.20
Kadana	10.80	14.10
Derishke	6.40	9.70
Ranya	4.40	9.20
Sheladize	4.00	8.13

Glutathione, an essential component for cellular immune system function, has a peptide structure and serves as the primary intracellular antioxidant. Additionally, it plays a role in amino acid transport in metabolism and the reduction of sulfhydryl groups in proteins [195].

The research found that the highest levels of GSH were recorded in the Shelaza area for first, second and third groups samples, with values of 2550.40 ± 31.90 , 2426.60 ± 31.20 , and 2314.90 ± 30.40 µg/g dw, respectively. In contrast, the sumacs originating from the Shahi area exhibited the lowest GSH level in first, second and third groups samples, measuring at 1004.10 ± 21.70 , 913.50 ± 20.10 , and 877.50 ± 21.10 µg/g dw, respectively (Table 3.36).

In Table 3.36, we can see that the Maraş, Elazığ, Derishke, Sheladize, Shelaza, Trwanish, Shahi, Charput, and Suleymania areas have significantly different quantities of GSH ($p < 0.05$) in the first group. As seen in the rows of Table 3.36, there is no statistically difference between the first, second and third groups ($p > 0.05$). Loss percentage of GSH for the second and third group shown in (Table 3.37). Comparison data between the three groups of GSH shown in (Figure 3.18).

In study conducted by Palma et al. (2020), The quantity of glutathione (GSH) in the green and red (depending to the age of the fruit) Californian sweet pepper cultivar (Melchor) was discovered to be 84.4 and 58.3 $\mu\text{g/g}$ fw, respectively. According to the age of the fruit, the quantity of GSH in green and red Spain pungency pepper varieties (piquillo) was found to be 73.9 and 76.5 $\mu\text{g/g}$ fw respectively. This was determined by comparing the amount of GSH in green and red peppers [196].

Table 3.38. Amount of GSSG in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g}$ dw).

Region	First group	Second group	Third group
Maraş	^{e,f} 895.10 $\pm$ 24.00 *	^{e,f} 1014.40 $\pm$ 26.60 *	^f 1147.70 $\pm$ 30.40 *
Elazığ	ⁱ 1375.40 $\pm$ 32.30 *	^h 1272.60 $\pm$ 27.50 *	^h 1492.60 $\pm$ 33.50 *
Shelaza	^g 992.90 $\pm$ 21.00 *	^{e,f} 1027.30 $\pm$ 23.80 *	^f 1126.30 $\pm$ 24.70 *
Trwanish	^d 806.50 $\pm$ 19.10 *	^d 901.30 $\pm$ 19.80 *	^{d,e} 1017.00 $\pm$ 22.10 *
Shahi	^a 422.50 $\pm$ 13.10 *	^a 488.20 $\pm$ 13.10 *	^a 519.90 $\pm$ 14.20 *
Charput	^b 503.90 $\pm$ 15.50 *	^b 560.60 $\pm$ 15.60 *	^b 607.00 $\pm$ 15.60 *
Suleymania	^f 921.10 $\pm$ 19.10 *	^f 1052.20 $\pm$ 22.50 *	^f 1117.20 $\pm$ 22.50 *
Kadana	^c 693.60 $\pm$ 16.40 *	^c 715.90 $\pm$ 16.10 *	^c 745.20 $\pm$ 17.20 *
Derishke	^h 1075.40 $\pm$ 23.90 *	^g 1153.90 $\pm$ 24.00 *	^g 1227.20 $\pm$ 25.50 *
Ranya	^{d,e} 859.10 $\pm$ 19.40 *	^e 975.70 $\pm$ 21.10 *	^d 1015.70 $\pm$ 22.10 *
Sheladize	^{f,g} 949.90 $\pm$ 20.40 *	^{e,f} 1005.10 $\pm$ 22.10 *	^{e,f} 1084.80 $\pm$ 21.30 *

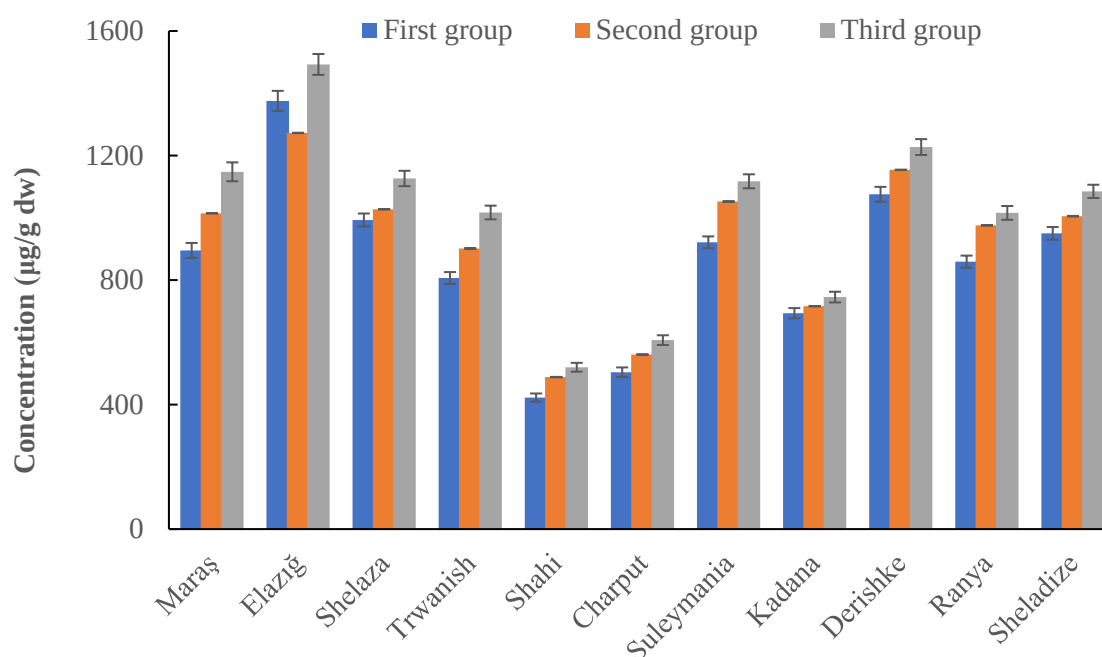


Figure 3.19. Interpretation column chart of GSSG

Table 3.39. GSH/GSSG ratio

	First group	Second group	Third group
Maraş	2.14	1.80	1.50
Elazığ	1.20	1.13	0.92
Shelaza	2.60	2.40	2.10
Trwanish	1.60	1.31	1.11
Shahi	2.40	1.90	1.69
Charput	3.50	2.80	2.32
Suleymania	2.60	2.10	1.88
Kadana	2.00	1.70	1.60
Derishke	2.00	1.80	1.60
Ranya	2.50	2.10	1.90
Sheladize	2.20	2.00	1.74

The levels of GSSG in the samples of Shelaza and Shahi, both in first, second and third groups, were measured to be 992.90 ± 21.00 , 1027.30 ± 23.80 , and 1126.30 ± 24.70 µg/g dw, and 422.50 ± 13.10 , 488.20 ± 13.10 , and 519.90 ± 14.20 µg/g dw, respectively (Table 3.38).

The oxidation processes led to a reduction in the concentration of GSH, whereas the concentration of GSSG rose significantly (Table 3.36 and Table 3.38). Comparison data between the three groups of GSSG shown in (Figure 3.19).

In study conducted by Palma et al. (2020), The quantity of oxidized glutathione (GSSG) in the green and red (depending to the age of the fruit) Californian sweet pepper cultivar (Melchor)

was discovered to be 4.5 and 1.8 µg/g fw, respectively. According to the age of the fruit, the quantity of GSSG in green and red Spain pungency pepper varieties (piquillo) was found to be 4.9 and 2.3 µg/g fw respectively. This was determined by comparing the amount of GSSG in green and red peppers [196]. During the same research project, the researchers discovered that the GSH/GSSG ratio in the green and red sweet pepper varieties (Melchor) was 18.55 and 32.02 correspondingly. In contrast, the ratio of GSH to GSSG in green and red pungency pepper varieties (piquillo) was 15.04 and 33.71, respectively. Piquillo peppers are very pungent.

Tesoriere et al. (2005), discovered that the levels of GSH in three distinct cultures of prickly pears ranged from 3.40 to 8.10 mg/100g [197]. Glutathione is a kind of peptide. Preservation techniques used on food may have a substantial impact on the biological functionality of peptides.

Ultrasound, heat, mechanical impacts, and irradiation processing have the potential to alter the structure and activities of proteins. Furthermore, these activities have the potential to induce Millard responses in food. Consequently, the aforementioned conditions might cause variations in the quantity of peptides [198].

Table 3.40. Amount of MDA in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^{b,c} 18.60 ± 1.20 *	^b 20.50 ± 0.70 ***	^{b,c} 22.80 ± 0.80 **
Elazığ	^a 14.00 ± 0.90 *	^a 15.10 ± 0.40 ***	^a 16.50 ± 0.60 **
Shelaza	^{c,d} 22.80 ± 1.40 *	^c 24.90 ± 0.50 ***	^{c,d} 26.60 ± 1.30 **
Trwanish	^{e,f} 28.40 ± 1.50 *	^g 30.50 ± 0.60 ***	^{e,f} 32.10 ± 1.70 **
Shahi	^{e,f} 27.30 ± 1.70 *	^{f,g} 29.50 ± 0.70 ***	^{e,f} 32.30 ± 1.60 **
Charput	^{d,e} 26.20 ± 1.60 *	^{e,f} 28.50 ± 0.60 ***	^{d,e} 30.40 ± 1.80 **
Suleymania	^{d,e} 25.40 ± 1.50 *	^{d,e} 27.30 ± 0.60 ***	^{d,e} 29.40 ± 1.80 **
Kadana	^{d,e} 25.00 ± 1.70 *	^{c,d} 26.40 ± 0.50 ***	^{d,e} 28.60 ± 1.70 **
Derishke	^{d,e} 24.10 ± 1.70 *	^{c,d} 26.10 ± 0.60 ***	^{d,e} 29.70 ± 1.70 **
Ranya	^{a,b} 17.80 ± 1.10 *	^a 19.20 ± 0.40 ***	^b 21.20 ± 1.10 **
Sheladize	^f 31.30 ± 1.80 *	^h 33.20 ± 0.80 ***	35.60 ± 1.80 **

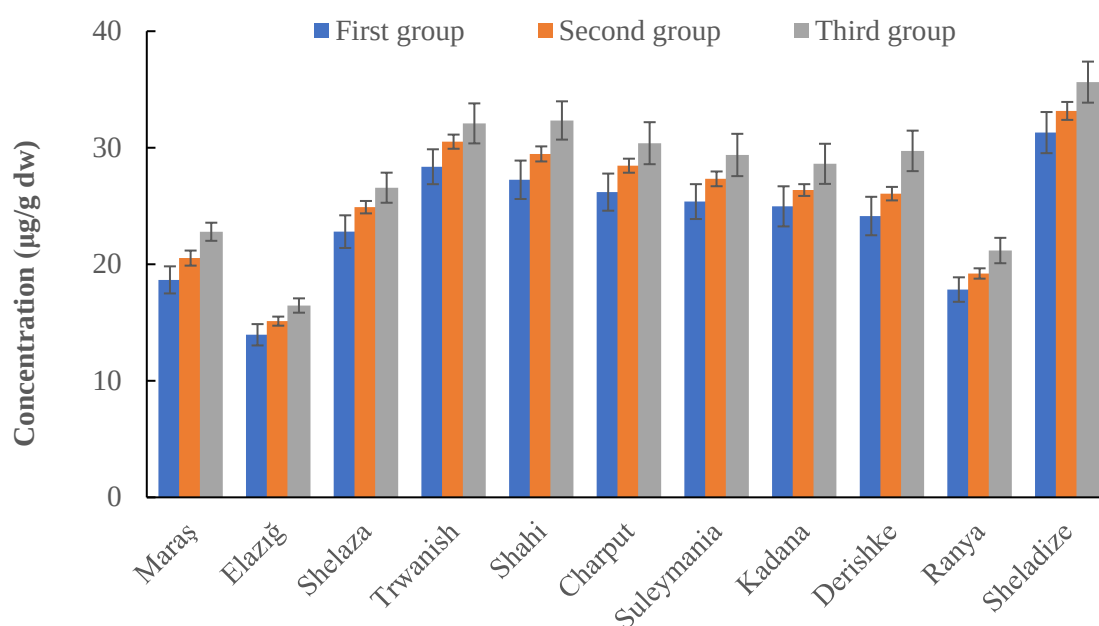


Figure 3.20. Interpretation column chart of MDA

The impact of free radicals on the unsaturated fatty acids in cell membranes leads to lipid peroxidation, resulting in the formation of MDA [199].

The research found that the highest levels of MDA concentration were recorded in the Sheladize area for first, second and third groups samples. The specific values were 31.30 ± 1.80 , 33.20 ± 0.80 , and 35.60 ± 1.80 µg/g dw, respectively. In contrast, the sumacs sourced from the Elazığ area exhibited the lowest MDA level in first, second and third groups samples, with values of 14.00 ± 0.90 , 15.10 ± 0.40 , and 16.50 ± 0.60 µg/g dw, respectively (Table 3.40).

Regarding the MDA component, it can be concluded that the areas of Elazığ, Shelaza, Maraş, and Shahi have significantly different concentrations ($p < 0.05$). On the other hand, in the first group, there is no significant difference in concentrations between the areas of Charput, Suleymania, Kadana, and Derishke ($p > 0.05$) (Table 3.40). Comparison data between the three groups of MDA shown in (Figure 3.20).

Based on a study conducted by Meltem Çakmak et al. (2023), the levels of malondialdehyde (MDA) in fresh, frozen, sun-dried, and microwave-dried wild black *Myrtus communis* L. fruits were measured to be 5.32 ± 0.23 , 6.00 ± 0.28 , 6.80 ± 0.20 , and 7.00 ± 0.14 µg/g dw, respectively [130].

The concentration of MDA in mature ber (*Ziziphus mauritiana* Lam) fruit was determined to be 4.498 nmol/g, according to Kumar et al. (2011) [200].

The GSH/GSSG ratio and MDA serve as indicators of stress (Table 3.39), (Table 3.40). The level of stress is inversely proportional to the ratio of reduced glutathione (GSH) to oxidised glutathione (GSSG) and directly proportional to the concentration of malondialdehyde (MDA). The

GSH/GSSG ratios for fresh, oil-coated, and 6-month homogenised samples of Shelaza sumac fruit were determined to be 2.6, 2.4, and 2.1, respectively. The rise in MDA levels in fruits and the decline in the GSH/GSSG ratio suggest that oxidative stress arises via oxidation facilitated by time and mechanical grinding procedures. These data indicate that the preservation procedures utilised exert stress on the fruits. The disparity in the quantity of pro-oxidant and antioxidant substances in diets causes enzymatic and non-enzymatic oxidation of polyunsaturated fatty acids. This process leads to the creation of peroxidation products, namely MDA and 4-HNE, which are recognised as indicators of oxidative stress [201].

Table 3.41. Amount of 4-HNE in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{b,c} 11.70 ± 0.40 *	^{b,c} 14.80 ± 1.10 **	^{b,c,d} 18.00 ± 1.10 ***
Elazığ	^a 7.10 ± 0.30 *	^a 9.30 ± 0.60 **	^a 12.10 ± 0.80 ***
Shelaza	^c 12.80 ± 0.60 *	^{b,c} 14.50 ± 0.80 **	^{b,c} 17.70 ± 1.10 ***
Trwanish	^{c,d} 13.40 ± 0.70 *	^{b,c,d} 15.20 ± 0.90 **	^{b,c,d} 18.30 ± 1.30 ***
Shahi	^b 9.90 ± 0.60 *	^b 13.10 ± 0.70 **	^b 16.80 ± 1.00 ***
Charput	^{c,d} 13.20 ± 0.70 *	^{c,d} 16.10 ± 0.90 **	^{b,c,d} 19.00 ± 1.30 ***
Suleymanıa	^{d,e} 14.60 ± 0.80 *	^d 17.50 ± 1.00 **	^{c,d} 20.10 ± 1.30 ***
Kadana	^a 7.30 ± 0.40 *	^a 9.50 ± 0.60 **	^a 11.60 ± 0.80 ***
Derishke	^a 8.10 ± 0.50 *	^a 10.50 ± 0.70 **	^a 12.10 ± 0.80 ***
Ranya	^e 15.40 ± 0.80 *	^d 17.60 ± 1.00 **	^d 21.10 ± 1.30 ***
Sheladize	^{c,d} 13.20 ± 0.70 *	^{c,d} 16.50 ± 1.10 **	^{b,c,d} 18.70 ± 1.10 ***

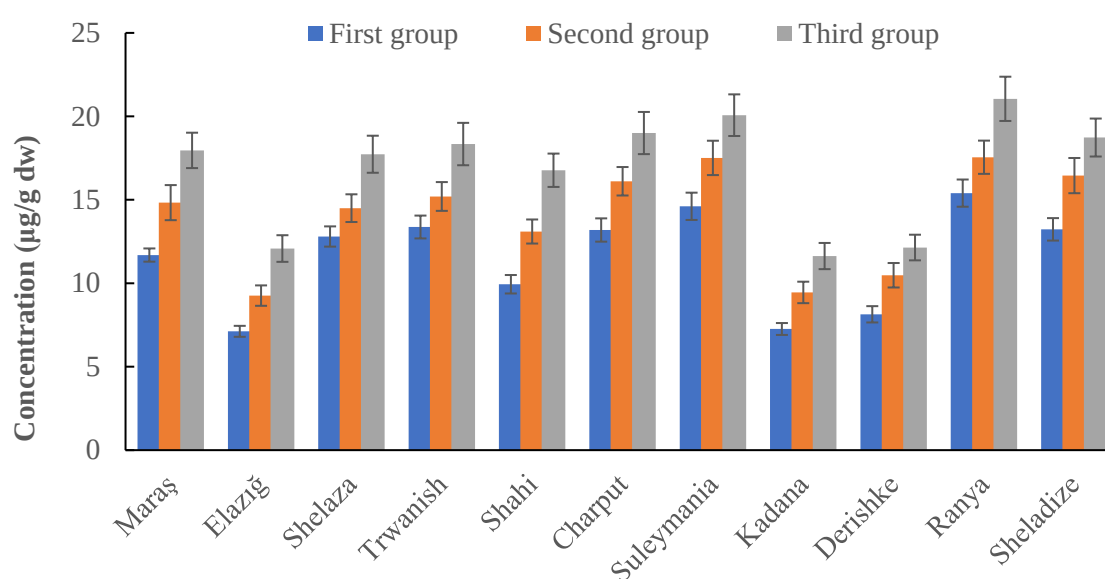


Figure 3.21. Interpretation column chart of 4-HNE

The investigation found that the highest levels of 4-HNE were recorded in the Ranya area for first, second and third groups samples. The specific values were 15.40 ± 0.80 , 17.60 ± 1.00 , and 21.10 ± 1.30 $\mu\text{g/g dw}$, respectively. In contrast, the sumacs sourced from the Elazığ area had the lowest 4-HNE concentration in both first and second groups samples, measuring at 7.10 ± 0.30 and 9.30 ± 0.60 $\mu\text{g/g dw}$, respectively. Kadana had the lowest result of 11.60 ± 0.80 $\mu\text{g/g dw}$ in the third group data (Table 3.41).

The concentration of 4-HNE was greatest in the third group samples and lowest in the first group samples (Table 3.41).

Table 3.41 shows that in the first group, the concentrations of Charput, Sheladize, and Trwanish regions are not significantly different from one another ($p > 0.05$). Based on the data, it can be inferred that Elazığ, Ranya, and Maraş exhibit substantially different concentrations ($p < 0.05$) for the 4-HNE component. Comparison data between the three groups of 4-HNE shown in (Figure 3.21).

The research done by Mukhtar et al. (2023), revealed that the White Garden Egg, Bitter Apple, Bitter Tomato, Dark Eggplant, and Light Eggplant had 4-HNE concentrations of 38.25 ± 1.55 , 36.29 ± 1.63 , 24.57 ± 1.38 , 31.81 ± 1.43 , and 33.56 ± 1.50 $\mu\text{g/g dw}$ accordingly [202].

3.6. Essential and non essential amino acids

Proteins, chemical compounds with intricate structures present in all living creatures, consist of amino acids. Amino acids have several activities, including metabolism, immunology, signal transduction, and growth. The precise balance of amino acids is crucial for optimal metabolic functioning. Amino acids can be classified into two groups: essential amino acids (histidine, arginine, threonine, valine, methionine, leucine, isoleucine, phenylalanine, tryptophan, and lysine) and non-essential amino acids (aspartic acid, glutamic acid, asparagine, serine, glycine, glutamine, alanine, pyrroline, tyrosine, and cysteine). Essential amino acids refer to the specific amino acids that are required to be obtained from external sources as they cannot be produced inside the human body. For protein synthesis, it is crucial to get essential amino acids from the diet. Therefore, it is important to have knowledge about the amino acid content of various meals [203,204].

Analysis results of the first, second and third groups sumac samples of amino acids taken from different regions are given in (Table 3.42) to (Table 3.84).

Table 3.42. Amount of aspartic acid in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^b 23.51 $\pm$ 0.99 *	^b 22.09 $\pm$ 0.79 *	^b 20.90 $\pm$ 0.81 *
Elazığ	^c 48.50 $\pm$ 2.07 *	^c 46.56 $\pm$ 0.91 *	^c 44.86 $\pm$ 0.91 *
Shelaza	^b 20.41 $\pm$ 0.75 *	^b 19.20 $\pm$ 0.67 *	^b 18.03 $\pm$ 0.72 *
Trwanish	^h 126.21 $\pm$ 4.25 *	^g 124.22 $\pm$ 1.82 *	^g 122.46 $\pm$ 2.09 *
Shahi	^g 80.49 $\pm$ 1.31 *	^f 78.50 $\pm$ 1.09 *	^f 77.00 $\pm$ 1.25 *
Charput	^d 65.81 $\pm$ 2.61 *	^d 63.50 $\pm$ 1.00 *	^d 62.27 $\pm$ 1.22 *
Suleymanlia	^{f,g} 74.71 $\pm$ 1.87 *	^e 73.20 $\pm$ 1.02 *	^e 71.37 $\pm$ 1.44 *
Kadana	ⁱ 170.51 $\pm$ 4.49 *	^h 166.83 $\pm$ 1.88 *	^h 164.17 $\pm$ 2.44 *
Derishke	^{d,e} 71.62 $\pm$ 2.63 *	^e 69.61 $\pm$ 1.14 *	^e 68.41 $\pm$ 1.26 *
Ranya	^{d,e,f} 71.92 $\pm$ 1.41 *	^e 69.50 $\pm$ 1.00 *	^e 68.00 $\pm$ 1.42 *
Sheladize	^a 10.32 $\pm$ 0.42 *	^a 9.20 $\pm$ 0.31 *	^a 8.50 $\pm$ 0.31 *

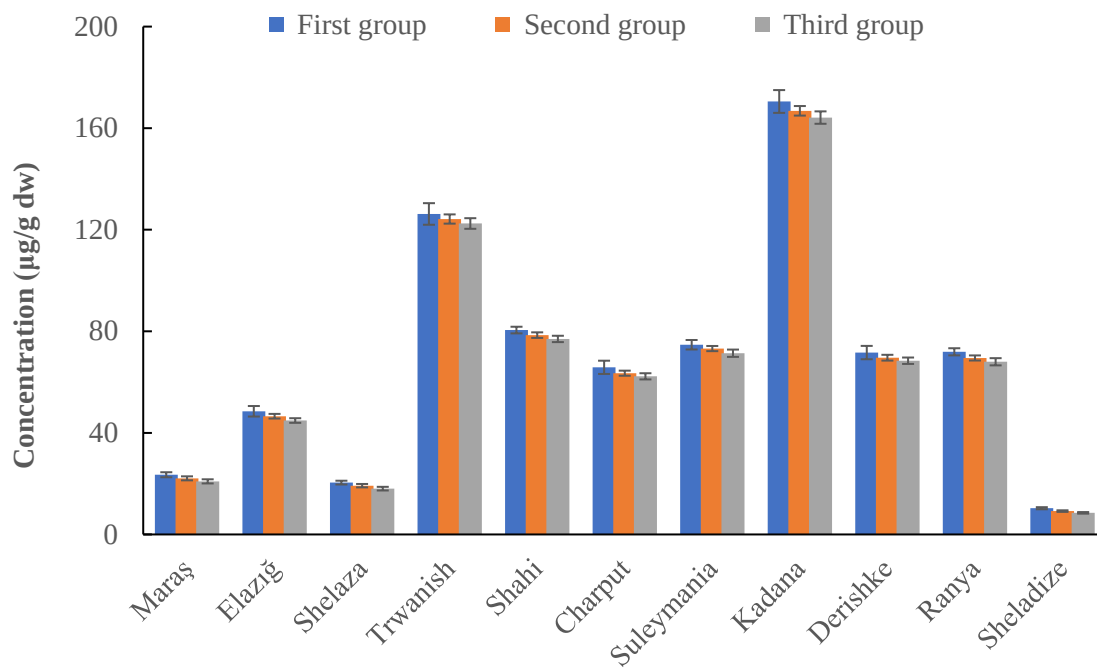


Figure 3.22. Interpretation column chart of aspartic acid

Table 3.43. Loss percentage % of aspartic acid

Region	Aspartic acid	
	Second group	Third group
Maraş	6.04	11.10
Elazığ	4.00	7.50
Shelaza	5.90	11.70
Trwanish	1.60	3.00
Shahi	2.50	4.30
Charput	3.50	5.40
Suleymania	2.00	4.50
Kadana	2.20	3.70
Derishke	2.80	4.50
Ranya	3.40	5.50
Sheladize	10.90	17.60

Table 3.44. Amount of glutamic acid in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 566.31 ± 39.86 *	^b 530.31 ± 21.19 *	^b 503.34 ± 22.89 *
Elazığ	^{e,f} 701.91 ± 15.86 *	^{e,f} 680.78 ± 15.85 *	^{e,f} 650.44 ± 24.35 *
Shelaza	^a 308.60 ± 7.94 *	^a 301.60 ± 9.56 *	^a 281.00 ± 11.94 *
Trwanish	^{d,e} 650.72 ± 4.48 *	^{d,e} 628.70 ± 12.55 *	^{d,e,f} 605.70 ± 16.62 *
Shahi	^{c,d} 630.12 ± 7.36 *	^{c,d} 605.10 ± 15.30 *	^{c,d} 590.10 ± 15.30 *
Charput	^{b,c} 579.50 ± 14.13 *	^{b,c} 550.50 ± 14.12 *	^{b,c} 532.50 ± 14.12 *
Suleymania	^{c,d,e} 639.98 ± 19.85 *	^d 610.98 ± 19.85 *	^{d,e} 593.87 ± 12.31 *
Kadana	^g 908.31 ± 13.96 *	^g 870.31 ± 13.96 *	^g 842.31 ± 13.96 *
Derishke	^b 534.11 ± 9.81 *	^b 515.11 ± 9.81 *	^b 492.11 ± 9.81 *
Ranya	^f 723.89 ± 5.72 *	^f 698.90 ± 13.62 *	^f 665.23 ± 16.06 *
Sheladize	^g 857.63 ± 24.01 *	^g 829.63 ± 20.17 *	^g 795.38 ± 20.38 *

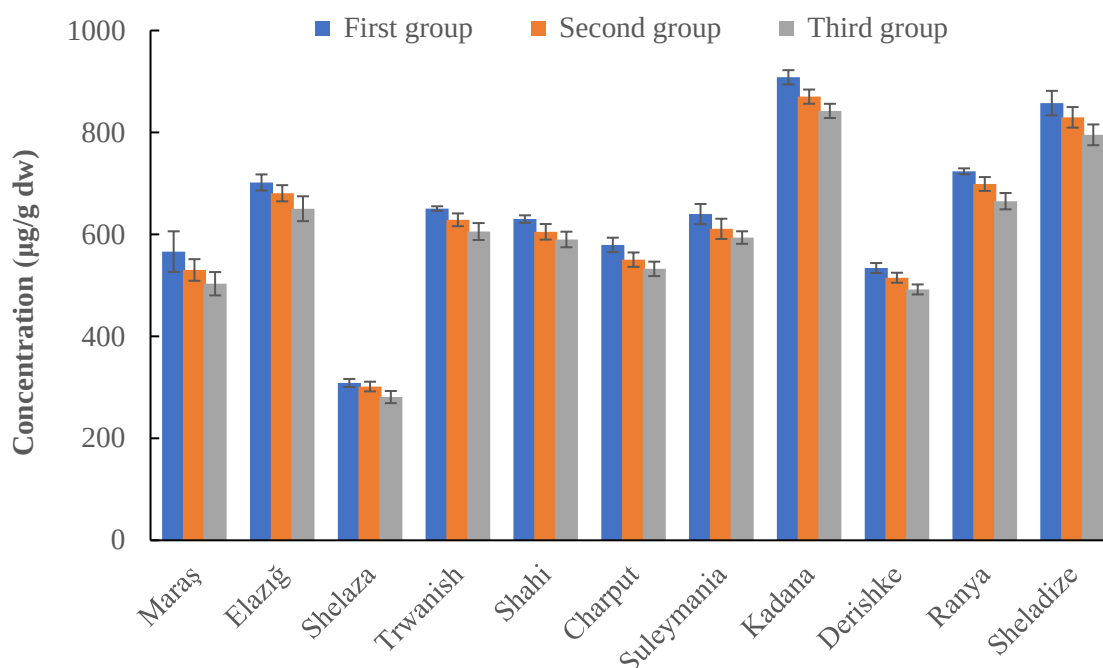


Figure 3.23. Interpretation column chart of glutamic acid

Table 3.45. Loss percentage % of glutamic acid

Region	Glutamic acid	
	Second group	Third group
Maraş	6.40	11.10
Elazığ	3.00	7.30
Shelaza	2.30	8.90
Trwanish	3.40	6.90
Shahi	4.00	6.40
Charput	5.00	8.10
Suleymania	4.50	7.20
Kadana	4.20	7.30
Derishke	3.60	7.90
Ranya	3.50	8.10
Sheladize	3.30	7.30

L-Aspartate is highly significant in the processes of urea synthesis, the purine-nucleotide cycle (PNC), the malate-aspartate shuttle (MAS), gluconeogenesis, and neurotransmission. It serves as the building block for the production of proteins, asparagine, arginine, nucleotides, and various substances involved in the growth of nervous tissue and neurotransmission [93]. Glutamic acid plays a crucial role in the production of proline and is very effective in the carbon and nitrogen metabolism cycle [205].

The first, second and third groups sumac samples cultivated in the Kadana area exhibited the greatest levels of aspartic acid and glutamic acid. The values were 170.51 ± 4.49 , 166.83 ± 1.88 , and 164.17 ± 2.44 $\mu\text{g/g dw}$ for aspartic acid and 908.31 ± 13.96 , 870.31 ± 13.96 , and 842.31 ± 13.96 $\mu\text{g/g dw}$ for glutamic acid, respectively. The lowest concentration of aspartic acid was identified in Sheladize, whereas the lowest concentration of glutamic acid was found in Shelaza (Table 3.42 and Table 3.44).

Regarding the aspartic acid component, it can be concluded that the areas of Elazığ, Shelaza, Maraş, and Charput have significantly different concentrations ($p < 0.05$), whereas the areas of Ranya and Derishke do not differ significantly ($p > 0.05$) in the first group (Table 3.42). As seen in the rows of (Table 3.44), there is no statistically difference between the first, second and third groups ($p > 0.05$) in the term of glutamic acid. Loss of aspartic acid substance in the third group is higher than the second group (Table 3.43). Loss of glutamic acid substance in the third group is higher than the second group (Table 3.45). Comparison data between the three groups of aspartic acid and glutamic acid shown in (Figure 3.22 and Figure 3.23).

According to a previous research carried out by Kossah et al. (2009), the quantity of aspartic acid found in Syrian and Chinese sumac was 1.70 ± 0.34 and 3.68 ± 0.49 mg/g, respectively. In terms of glutamic acid, the values obtained were 2.45 ± 0.15 and 7.46 ± 0.40 mg/g, respectively [31].

According to a previous research done by Abu-Izneid et al. (2022), the quantity of aspartic acid and glutamic acid in saffron (*Crocus sativus*) was determined to be 0.040–0.048 and 0.017–0.036 mg/100g respectively. This information was provided in a previous study [206].

In a previous research that was carried out by Adewole E. et al. (2022), it was stated that the quantity of aspartic acid found in flesh of red and green *Capsicum chinense* was 0.069 and 0.030 mg/g respectively. Glutamic acid, on the other hand, was determined to be 0.566 and 0.306 mg/g, respectively [207].

Table 3.46. Amount of asparagine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^{a,b} 106.69 $\pm$ 2.39 *	^{a,b} 95.39 $\pm$ 1.98 *	^{a,b} 91.69 $\pm$ 1.69 *
Elazığ	^c 176.51 $\pm$ 5.81 *	^c 161.17 $\pm$ 4.67 *	^c 151.84 $\pm$ 4.87 *
Shelaza	^a 85.91 $\pm$ 2.63 *	^a 80.24 $\pm$ 2.25 *	^a 74.57 $\pm$ 2.17 *
Trwanish	^f 453.00 $\pm$ 11.35 *	^f 430.10 $\pm$ 10.54 *	^f 407.03 $\pm$ 10.06 *
Shahi	^e 301.50 $\pm$ 4.57 *	^e 285.50 $\pm$ 5.30 *	^e 273.16 $\pm$ 6.96 *
Charput	^d 236.31 $\pm$ 4.91 *	^d 220.27 $\pm$ 4.85 *	^d 208.63 $\pm$ 5.48 *
Suleymania	^d 247.59 $\pm$ 6.46 *	^d 221.93 $\pm$ 4.76 *	^d 208.00 $\pm$ 4.96 *
Kadana	^g 586.41 $\pm$ 7.04 *	^g 546.07 $\pm$ 10.12 *	^g 531.41 $\pm$ 10.59 *
Derishke	^d 238.89 $\pm$ 8.33 *	^d 222.55 $\pm$ 6.75 *	^d 212.89 $\pm$ 6.17 *
Ranya	^b 116.62 $\pm$ 3.69 *	^b 106.27 $\pm$ 2.45 *	^b 101.60 $\pm$ 3.08 *
Sheladize	^d 229.52 $\pm$ 5.64 *	^d 213.17 $\pm$ 4.76 *	^d 204.84 $\pm$ 4.73 *

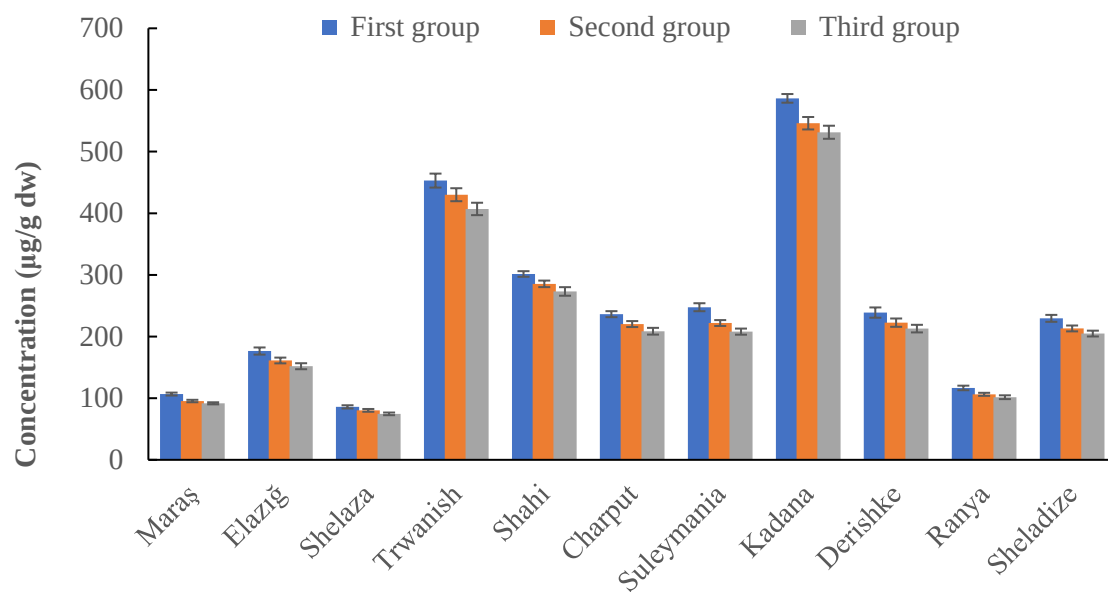


Figure 3.24. Interpretation column chart of asparagine

Table 3.47. Loss percentage % of asparagine

Region	Asparagine	
	Second group	Third group
Maraş	10.60	14.10
Elazığ	8.70	14.00
Shelaza	6.60	13.20
Trwanish	5.10	10.10
Shahi	5.30	9.40
Charput	6.80	11.70
Suleymania	10.40	16.00
Kadana	6.90	9.40
Derishke	6.80	10.90
Ranya	8.90	12.90
Sheladize	7.10	10.80

Asparagine has a crucial role in maintaining cellular glucose homeostasis and facilitates nitrogen buildup [208]. The asparagine levels in the first group samples ranged from 85.91 ± 2.63 to 586.41 ± 7.04 $\mu\text{g/g dw}$. In the second and third groups, the asparagine levels were found to be between 74.57 ± 2.17 - 531.41 ± 10.59 and 80.24 ± 2.25 - 546.07 ± 10.12 $\mu\text{g/g dw}$, respectively (Table 3.46).

As seen in the rows of Table 3.46, there is no statistically significant difference between the first, second, and third groups ($p > 0.05$). Loss of asparagine levels substance in the third group is higher than the second group (Table 3.47). Comparison data between the three groups of asparagine shown in (Figure 3.24).

Sabine sampels (2015), reported that when combined with antioxidant compounds, an optimised chilling or freezing process will result in the preservation of the general quality, sensory, and textural aspects of food, in addition to the preservation of the food's nutritional content [209]. In a previous research, done by Stankov et al. (2020), it was revealed that the quantity of asparagine found in Unripe Grecian Juniper from three different collecting locations in Bulgaria was 8.6 ± 0.1 , 5.9 ± 0.0 , and 3.4 ± 0.2 mg/g, respectively. Asparagine was found to be present in Ripe Grecian Juniper at a concentration of 7.2 ± 0.1 , 4.7 ± 0.1 , and 6.9 ± 0.1 mg/g, respectively [210].

Table 3.48. Amount of serine in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^a 207.52 ± 7.62 *	^{a,b} 189.50 ± 5.68 *	^a 171.50 ± 6.44 *
Elazığ	^a 223.93 ± 5.72 *	^{b,c} 212.10 ± 6.53 *	^b 203.31 ± 6.80 *
Shelaza	^a 222.81 ± 4.24 *	^c 213.40 ± 4.55 *	^b 203.01 ± 3.60 *
Trwanish	^c 403.71 ± 6.00 *	^e 386.28 ± 5.78 *	^d 368.04 ± 5.65 *
Shahi	^c 410.81 ± 8.10 *	^e 390.00 ± 7.25 *	^d 371.80 ± 7.39 *
Charput	^c 419.51 ± 8.24 *	^e 396.45 ± 6.38 *	^d 378.46 ± 7.63 *
Suleymania	^a 202.09 ± 3.83 *	^a 180.83 ± 2.99 *	^a 169.53 ± 3.35 *
Kadana	^c 394.92 ± 6.62 *	^e 379.64 ± 6.03 *	^d 364.91 ± 5.93 *
Derishke	^b 259.79 ± 6.87 *	^d 243.74 ± 4.43 *	^c 230.14 ± 4.99 *
Ranya	^b 264.78 ± 5.73 *	^d 249.41 ± 4.48 *	^c 233.40 ± 5.13 *
Sheladize	^d 461.22 ± 19.20 *	^f 437.89 ± 12.93 *	^e 407.89 ± 12.15 *

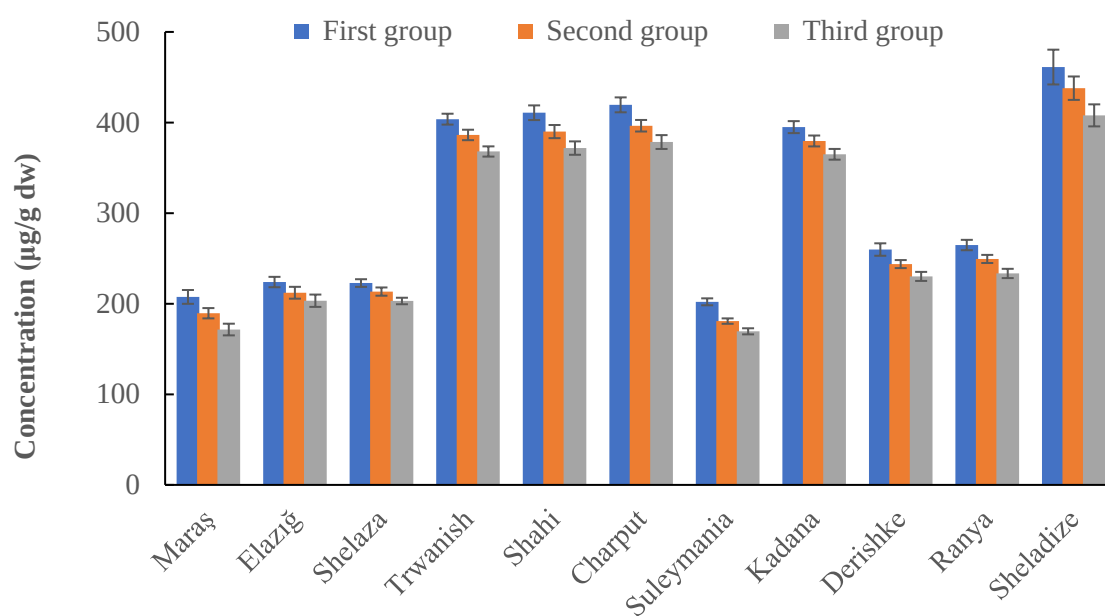


Figure 3.25. Interpretation column chart of serine

Table 3.49. Loss percentage % of serine

Region	Serine	
	Second group	Third group
Maraş	8.70	17.40
Elazığ	5.30	9.20
Shelaza	4.20	8.90
Trwanish	4.30	8.80
Shahi	5.10	9.50
Charput	11.90	9.80
Suleymania	10.50	16.10
Kadana	3.90	7.60
Derishke	6.20	11.40
Ranya	5.80	11.90
Sheladize	5.10	11.60

Table 3.50. Amount of glycine in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^{a,b,c} 1.61 ± 0.08 *	^{a,b,c} 1.47 ± 0.08 *	^{a,b,c} 1.35 ± 0.06 *
Elazığ	^{b,c,d} 1.81 ± 0.08 *	^{b,c,d} 1.62 ± 0.09 *	^{b,c,d} 1.41 ± 0.06 *
Shelaza	^{a,b} 1.40 ± 0.04 *	^{a,b} 1.23 ± 0.06 *	^{a,b} 1.12 ± 0.03 *
Trwanish	^a 1.20 ± 0.04 *	^a 1.07 ± 0.04 *	^a 1.03 ± 0.04 *
Shahi	^d 2.22 ± 0.08 *	^d 1.98 ± 0.08 *	^e 1.90 ± 0.07 *
Charput	^e 4.30 ± 0.17 *	^e 4.05 ± 0.20 *	^f 3.84 ± 0.13 *
Suleymania	^{c,d} 1.98 ± 0.04 *	^{c,d} 1.90 ± 0.07 *	^{d,e} 1.75 ± 0.06 *
Kadana	^{b,c,d} 1.81 ± 0.10 *	^{c,d} 1.69 ± 0.09 *	^{c,d,e} 1.59 ± 0.09 *
Derishke	^{b,c} 1.71 ± 0.09 *	^{b,c,d} 1.62 ± 0.08 *	^{c,d} 1.50 ± 0.07 *
Ranya	^{a,b,c} 1.63 ± 0.02 *	^{b,c} 1.51 ± 0.07 *	^{b,c,d} 1.42 ± 0.06 *
Sheladize	^f 5.02 ± 0.32 *	^f 4.62 ± 0.28 *	^g 4.30 ± 0.26 *

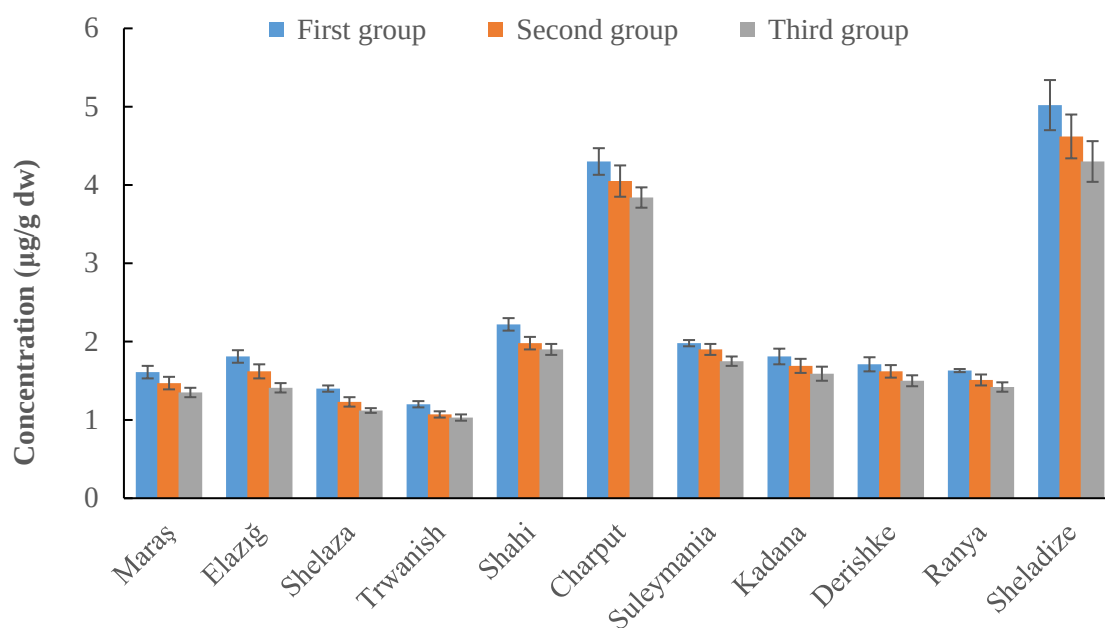


Figure 3.26. Interpretation column chart of glycine

Table 3.51. Loss percentage % of glycine

Region	Glycine	
	Second group	Third group
Maraş	8.70	16.10
Elazığ	10.50	22.10
Shelaza	12.10	20.00
Trwanish	10.80	14.20
Shahi	10.80	14.20
Charput	5.80	10.70
Suleymania	4.00	11.60
Kadana	6.60	12.20
Derishke	5.30	12.30
Ranya	7.40	12.90
Sheladize	8.00	14.30

Serine plays a crucial function in signalling, while glycine is beneficial in mitigating the impact of oxygen-dependent free radicals [211]. The sumac samples grown in Sheladize and subjected to different treatments exhibited the highest levels of serine and glycine, the concentrations of serine were measured at 461.22 ± 19.20 , 437.89 ± 12.93 , and 407.89 ± 12.15 µg/g dw for the first, second and third groups samples, respectively. Similarly, the concentrations of glycine were found to be 5.02 ± 0.32 , 4.62 ± 0.28 , and 4.30 ± 0.26 µg/g dw for the same samples, respectively (Table 3.48 and Table 3.50). Concerning the serine component, it can be inferred that

the concentrations in the regions of Elaziğ, Ranya, Trwanish, and Sheladize exhibit substantial differences ($p < 0.05$). In contrast, the concentrations in the regions of Shahi, Charput, and Trwanish in the first group do not show any significant variation ($p > 0.05$) (Table 3.48). Based on the data presented in (Table 3.48) and (Table 3.50), there is no statistically significant difference ($p > 0.05$) seen among the rows of the first, second, and third groups in terms of serine and glycine. Loss of serine and glycine levels substances in the third group is higher than the second group (Table 3.49 and Table 3.51). Comparison data between the three groups of serine and glycine shown in (Figure 3.25 and Figure 3.26).

Perumal et al. (2022) reported, A combination of essential oils and packaging film reduced weight loss, colour fluctuations, and respiration rate, and increased the shelf life of perishable fruits and vegetables [212]. An earlier study conducted by Hussah Abdullah Alshwyeh et al. (2022), revealed that the amount of serine present in raw *Nigella sativa* L. was measured to be 36.59 ± 1.40 mg/g. On the other hand, the amount of serine found in roasted *Nigella sativa* L. was measured to be 42.54 ± 1.13 mg/g. On the other hand, the reports indicated that the quantity of glycine was 49.58 ± 1.14 and 55.01 ± 0.28 mg/g, respectively [213].

Table 3.52. Amount of glutamine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^a $41.11 \pm 1.15^*$	^a $37.15 \pm 1.02^*$	^a $33.66 \pm 0.96^*$
Elaziğ	^{d,e} $101.30 \pm 2.30^*$	^{d,e} $94.84 \pm 2.08^*$	^{d,e} $90.10 \pm 2.04^*$
Shelaza	^a $47.90 \pm 1.07^*$	^a $43.76 \pm 1.10^*$	^a $39.80 \pm 0.99^*$
Trwanish	^g $159.02 \pm 5.26^*$	^f $143.00 \pm 5.10^*$	^f $131.00 \pm 5.04^*$
Shahi	^e $104.01 \pm 2.61^*$	^e $96.30 \pm 2.21^*$	^e $91.64 \pm 2.17^*$
Charput	^{c,d} $90.62 \pm 3.02^*$	^{c,d} $84.94 \pm 2.88^*$	^{c,d} $80.61 \pm 2.77^*$
Suleymania	^b $66.20 \pm 2.38^*$	^b $62.31 \pm 2.14^*$	^b $58.31 \pm 2.31^*$
Kadana	^h $190.88 \pm 4.18^*$	^g $180.90 \pm 3.89^*$	^g $168.56 \pm 3.71^*$
Derishke	^c $81.00 \pm 3.03^*$	^c $75.90 \pm 2.64^*$	^c $71.66 \pm 2.48^*$
Ranya	^e $104.49 \pm 2.53^*$	^e $97.32 \pm 2.45^*$	^e $90.86 \pm 2.11^*$
Sheladize	^f $116.62 \pm 4.61^*$	^e $104.20 \pm 4.33^*$	^e $96.93 \pm 4.08^*$

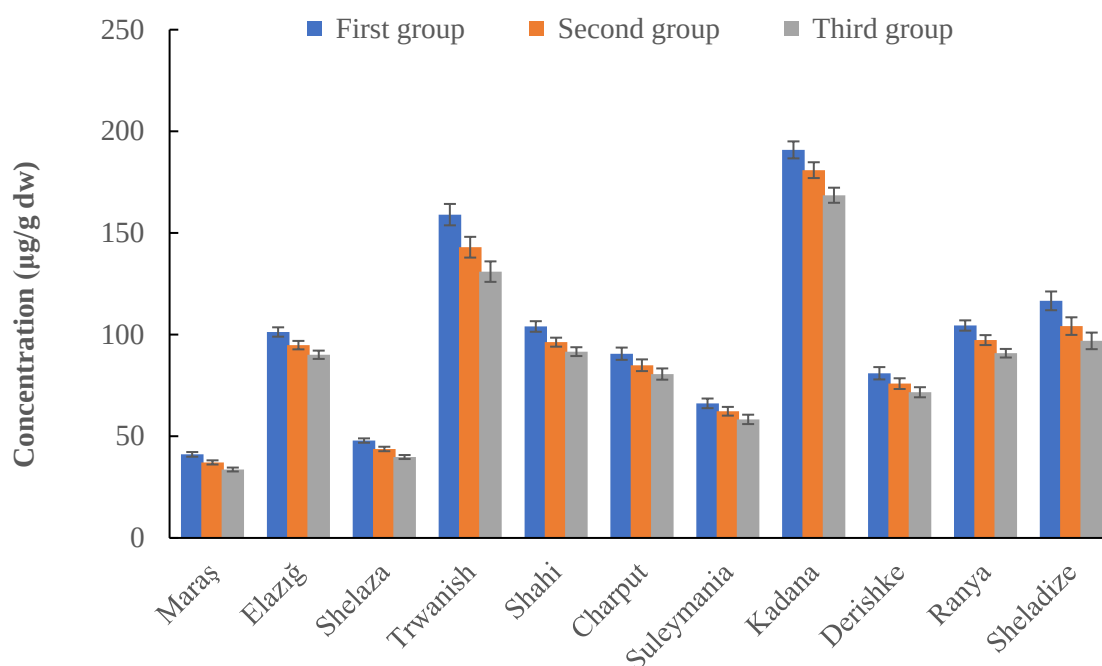


Figure 3.27. Interpretation column chart of glutamine

Table 3.53. Loss percentage % of glutamine

Region	Glutamine	
	Second group	Third group
Maraş	9.60	18.10
Elazığ	6.40	11.10
Shelaza	8.60	16.90
Trwanish	10.10	17.60
Shahi	7.40	11.90
Charput	6.30	11.00
Suleymania	5.90	11.90
Kadana	5.20	11.70
Derishke	6.30	11.50
Ranya	6.90	13.00
Sheladize	10.60	16.90

Glutamine has a role in controlling nitrogen metabolism inside the cell [214]. Primary functions Alanine inhibits the activity of pyruvate kinase and hepatic autophagy. It also affects processes such as gluconeogenesis, transamination, and the glucose-alanine cycle [215].

The first, second and third groups samples produced in the Maraş and Shelaza areas exhibited the lowest quantities of glutamine amino acid (A.A.) and alanine amino acid (A.A.), with values of $(41.11 \pm 1.15, 37.15 \pm 1.02 \text{ \& } 33.66 \pm 0.96)$ and $(316.22 \pm 4.66, 302.00 \pm 4.61 \text{ \& } 282.00 \pm 4.47)$ µg/g dw respectively (Table 3.52 and Table 3.54).

It can be said that there is a significant difference concentration between Trwanish and Shahi, Kadana, Derishke and Shelaza regions, as well as between Maraş and Elazığ regions in the term of glutamine (Table 3.52). It can be shown in (Table 3.53) that the third group has a greater decrease in the amount of glutamine levels than the second group. Comparison data between the three groups of glutamine shown in (Figure 3.27).

Based on the findings of a previous study conducted by Melo et al. (2022), it was determined that the amount of glutamine present in poppy seeds was 0.57 mg/g fw [216].

Essential oils have been recognised as natural food additives that have the potential to be used in a variety of applications within the realm of food preservation. In the field of food preservation, essential oils are being investigated as potential functional replacements to synthetic chemicals. These oils are ecologically safe and feature high levels of effectiveness. Essential oils extracted from plants are known to possess substantial repellent properties, and as a result, they have a number of applications in the field of pest management. In order to extend the shelf life of food goods, essential oils may be mixed into synthetic packaging sheets or coated onto them. This will have an antibacterial impact on the food products [217].

Table 3.54. Amount of alanine in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 348.94 ± 3.67 *	^{a,b} 325.25 ± 3.84 *	^{a,b} 297.91 ± 3.43 *
Elazığ	^c 385.01 ± 8.16 *	^b 339.66 ± 7.84 *	^b 314.00 ± 7.37 *
Shelaza	^a 316.22 ± 4.66 *	^a 302.00 ± 4.61 *	^a 282.00 ± 4.47 *
Trwanish	ⁱ 752.41 ± 9.15 *	^g 714.41 ± 9.15 *	^h 674.74 ± 8.82 *
Shahi	^h 616.71 ± 10.45 *	^f 589.24 ± 10.69 *	^g 553.38 ± 10.04 *
Charput	^{f,g} 542.82 ± 9.50 *	^{d,e} 509.97 ± 9.07 *	^{e,f} 483.94 ± 8.96 *
Suleymanian	^d 426.83 ± 7.61 *	^c 402.47 ± 7.64 *	^c 380.80 ± 7.37 *
Kadana	^j 889.72 ± 6.68 *	^h 846.27 ± 6.87 *	ⁱ 800.94 ± 6.91 *
Derishke	^e 506.99 ± 13.63 *	^d 490.00 ± 12.37 *	^d 451.00 ± 12.87 *
Ranya	^g 568.91 ± 7.68 *	^e 532.24 ± 7.22 *	^f 505.91 ± 7.01 *
Sheladize	^{e,f} 514.50 ± 10.20 *	^d 489.50 ± 10.15 *	^{d,e} 459.52 ± 9.98 *

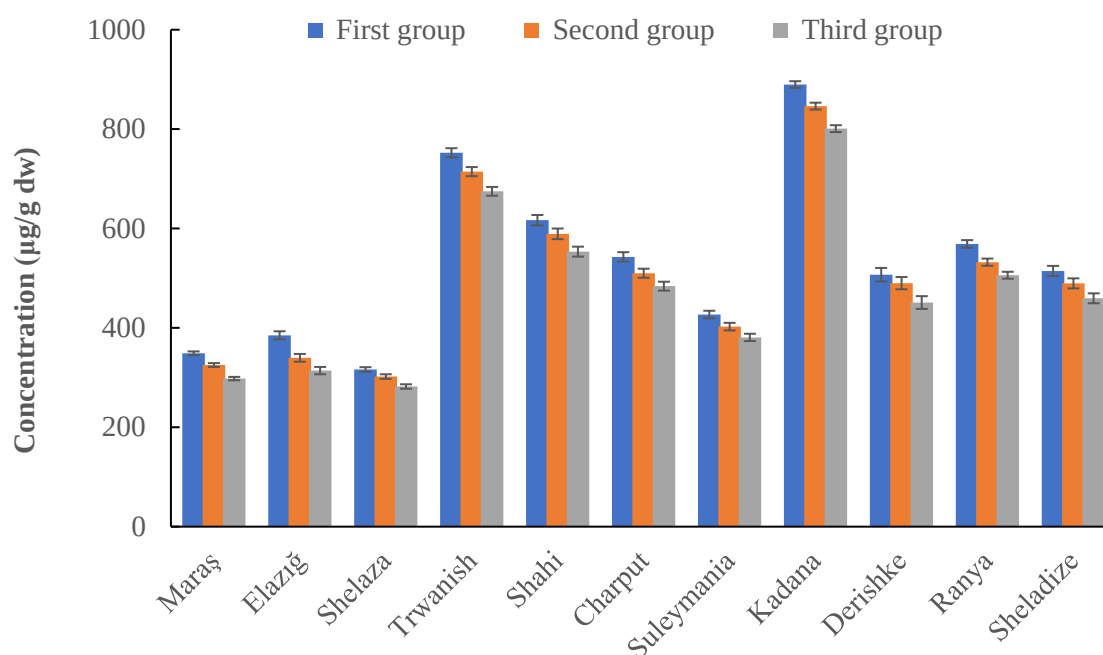


Figure 3.28. Interpretation column chart of alanine

Table 3.55. Loss percentage % of alanine

Alanine		
Region	Second group	Third group
Maraş	6.80	14.60
Elazığ	11.80	18.40
Shelaza	4.50	10.80
Trwanish	5.10	10.30
Shahi	4.50	10.30
Charput	6.10	10.80
Suleymania	5.70	10.80
Kadana	4.90	10.00
Derishke	3.40	11.00
Ranya	6.40	11.10
Sheladize	4.90	10.70

In the first group of samples, the levels of alanine varied from 316.22 ± 4.66 to 889.72 ± 6.68 µg/g dw within the prescribed range. When examining the amounts of alanine in the second and third groups, it was discovered that the levels ranged from 302.00 ± 4.61 to 846.27 ± 6.87 µg/g dw and 282.00 ± 4.47 to 800.94 ± 6.91 µg/g dw within the respective groups (Table 3.54).

When it comes to the alanine component, it is possible to assert that there is a notable disparity in concentrations between Elazığ, Shelaza, Suleymania, Kadana, and Sheladize ($p < 0.05$). Similarly, in the first group, we can observe that there is a difference between Charput, Maraş, and

Shahi (Table 3.54) and that this distinction is significant. According to the rows of (Table 3.54), there is no statistically significant difference between the first, second, and third groups ($p > 0.05$). This is shown by the observations. It can be shown in (Table 3.55) that the third group has a greater decrease in the amount of alanine levels than the second group. Comparison data between the three groups of alanine shown in (Figure 3.28).

Essential oils, sometimes known as EOs, are liquid mixes of volatile chemicals that are extracted from aromatic plants. Ever since it was discovered that some synthetic antioxidants, such as BHA and BHT, may be potentially hazardous to human health, there has been an increasing interest in the utilisation of essential oils (EOs) as natural antioxidants. This is due to the fact that many EOs possess antioxidant qualities. In order to avoid the autoxidation of edible goods and to extend their shelf life, the addition of essential oils (EOs) to edible products, either by direct mixing or through active packaging and edible coatings, may thus provide a viable option [218].

According to a prior study conducted by Kossah et al. (2009), the amount of alanine that was discovered in Syrian and Chinese sumac was 0.96 ± 0.26 and 1.98 ± 0.18 mg/g, respectively [31].

Table 3.56. Amount of proline in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^a $12.69 \pm 0.57^*$	^a $10.94 \pm 0.52^*$	^a $9.63 \pm 0.48^*$
Elazığ	^b $49.82 \pm 2.07^*$	^b $44.20 \pm 1.80^*$	^b $40.13 \pm 1.72^*$
Shelaza	^d $90.71 \pm 3.12^*$	^d $84.76 \pm 2.92^*$	^d $79.00 \pm 2.71^*$
Trwanish	^d $95.49 \pm 2.77^*$	^d $90.32 \pm 2.85^*$	^d $81.02 \pm 2.81^*$
Shahi	^{b,c} $60.62 \pm 2.39^*$	^{b,c} $56.97 \pm 2.10^*$	^{b,c} $52.85 \pm 2.41^*$
Charput	^c $69.02 \pm 2.20^*$	^c $62.36 \pm 2.12^*$	^c $56.29 \pm 1.99^*$
Suleymanian	^c $71.79 \pm 2.63^*$	^c $66.35 \pm 2.60^*$	^c $58.87 \pm 2.56^*$
Kadana	^e $159.71 \pm 3.98^*$	^e $148.54 \pm 3.97^*$	^e $140.78 \pm 3.84^*$
Derishke	^c $67.70 \pm 3.04^*$	^c $61.97 \pm 3.14^*$	^c $57.10 \pm 2.97^*$
Ranya	^c $72.31 \pm 2.85^*$	^c $66.67 \pm 2.53^*$	^c $59.94 \pm 2.63^*$
Sheladize	^f $291.77 \pm 10.23^*$	^f $277.13 \pm 10.10^*$	^f $257.97 \pm 9.94^*$

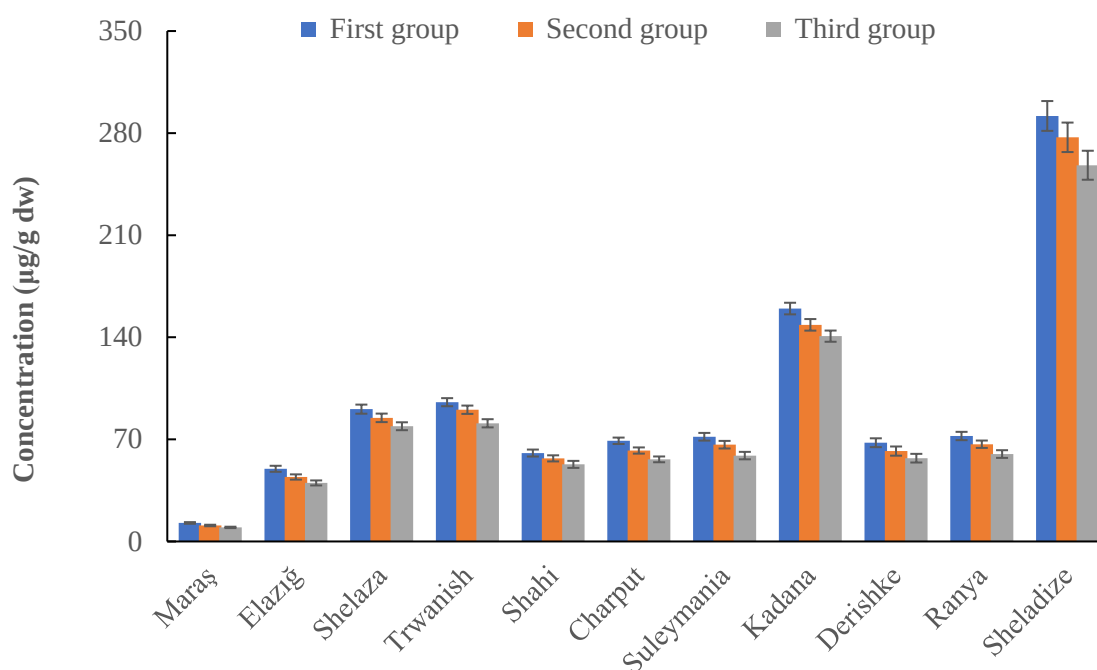


Figure 3.29. Interpretation column chart of proline

Table 3.57. Loss percentage % of proline

Region	Proline	
	Second group	Third group
Maraş	13.80	24.10
Elazığ	11.30	19.50
Shelaza	6.60	12.90
Trwanish	5.40	15.20
Shahi	6.00	12.80
Charput	9.60	18.40
Suleymania	7.60	18.00
Kadana	7.00	11.90
Derishke	8.50	15.70
Ranya	7.80	17.10
Sheladize	5.00	11.60

Proline plays a crucial role in several biological processes, such as protein synthesis, wound healing, antioxidant reactions, immunological responses, metabolism, and nutrition [219].

The Proline values in the first group samples ranged from 12.69 ± 0.57 to 291.77 ± 10.23 µg/g dw, it was found to be between 10.94 ± 0.52 to 277.13 ± 10.10 and 9.63 ± 0.48 to 257.97 ± 9.94 µg/g dw in the second and third group samples, respectively (Table 3.56). Loss of Proline levels substance in the third group is higher than the second group (Table 3.57).

Essential oils (EOs) are plant-based compounds often distilled from aromatic and therapeutic plants. Contributing to the safety and shelf-life extension of food items, these chemicals play a crucial role in food preservation. The development of spoilage bacteria is suppressed, leading to an increase in food safety by reducing biogenic amines and pathogenic microbes. This is especially true in meat and dairy products. The fundamental reason why enzymatic reduction may prolong the shelf-life of food items is because of their antioxidant activity. Essential oils are a valuable and healthy substitute for artificial preservatives and chemical additives; their efficacy is due to the presence of phenolic natural components [220].

As seen in the rows of (Table 3.56), there is no statistically difference between the first, second and third groups ($p > 0.05$). Comparison data between the three groups of proline shown in (Figure 3.29).

The quantity of proline that was identified in green scotch bonnet pepper was determined to be 0.298 mg/g, according to the findings of a previous research that was carried out by Adewole and colleagues (2022) [221].

According to a previous research carried out by Kossah et al. (2009), it was discovered that the Syrian and Chinese sumac had 1.43 ± 0.27 mg/g of proline, whereas the Chinese sumac had 2.26 ± 0.24 mg/g of proline [31].

Table 3.58. Amount of tyrosine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^b $12.51 \pm 0.67^*$	^b $11.40 \pm 0.66^*$	^a $9.42 \pm 0.63^*$
Elazığ	^{a,b} $10.03 \pm 0.77^*$	^{a,b} $9.00 \pm 0.74^*$	^a $8.33 \pm 0.67^*$
Shelaza	^{a,b} $10.22 \pm 0.58^*$	^{a,b} $9.21 \pm 0.56^*$	^a $8.26 \pm 0.55^*$
Trwanish	^d $20.81 \pm 0.65^*$	^{d,e} $19.05 \pm 0.60^*$	^c $16.54 \pm 0.63^*$
Shahi	^a $9.08 \pm 0.33^*$	^a $8.07 \pm 0.31^*$	^a $6.45 \pm 0.28^*$
Charput	^e $25.10 \pm 1.08^*$	^e $22.10 \pm 1.12^*$	^d $19.97 \pm 1.10^*$
Suleymania	^c $17.30 \pm 0.75^*$	^{c,d} $15.98 \pm 0.70^*$	^{b,c} $14.30 \pm 0.69^*$
Kadana	^g $40.11 \pm 1.56^*$	^g $35.56 \pm 1.44^*$	^f $31.51 \pm 1.34^*$
Derishke	^f $32.51 \pm 1.23^*$	^f $29.63 \pm 1.24^*$	^e $27.04 \pm 1.22^*$
Ranya	^c $16.31 \pm 0.82^*$	^c $15.00 \pm 0.78^*$	^b $13.16 \pm 0.79^*$
Sheladize	^{d,e} $23.50 \pm 0.74^*$	^e $19.76 \pm 0.74^*$	^c $16.34 \pm 0.65^*$

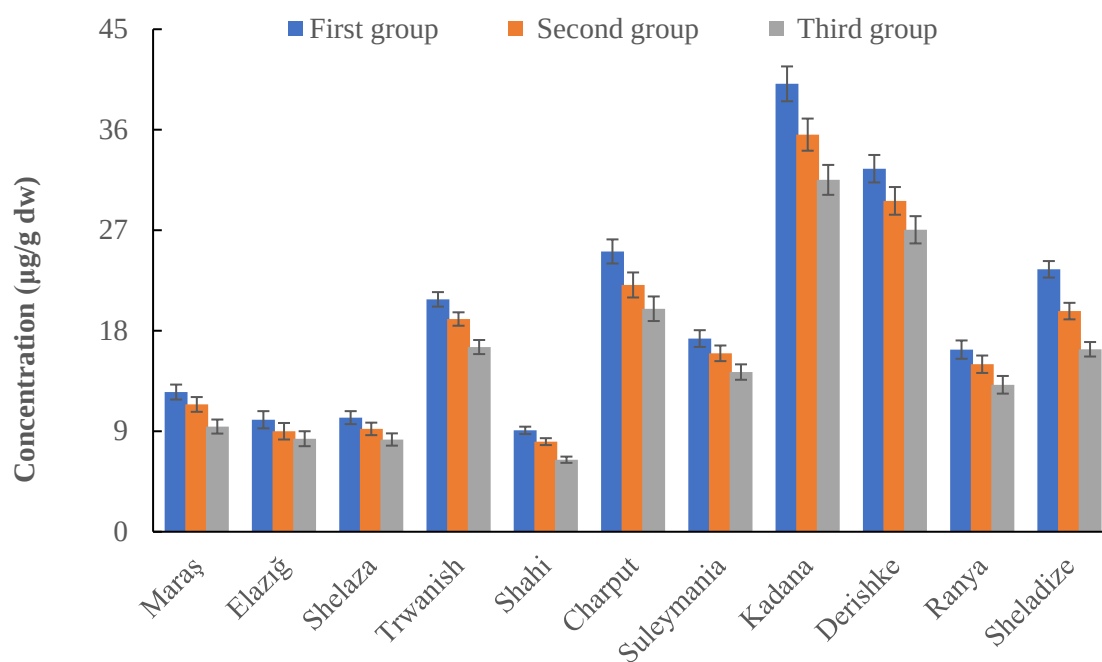


Figure 3.30. Interpretation column chart of tyrosine

Table 3.59. Loss percentage % of tyrosine

Tyrosine		
Region	Second group	Third group
Maraş	8.90	24.70
Elazığ	10.30	16.90
Shelaza	9.90	19.20
Trwanish	8.50	20.50
Shahi	11.10	29.00
Charput	12.00	20.40
Suleymania	7.60	17.30
Kadana	11.30	21.40
Derishke	8.90	16.80
Ranya	8.00	19.30
Sheladize	15.90	30.50

Tyrosine is essential for the biosynthesis of several organic chemicals in plants, including tocopherols, ubiquinone, betalains, and benzyloquinoline alkaloids. Metabolites generated from tyrosine, together with tocopherols and ubiquinone, play a crucial role in the survival of plants [222].

The sample cultivated in Kadana had the greatest concentration of tyrosine amino acid among the first, second and third groups samples with values of 40.11 ± 1.56 , 35.56 ± 1.44 and

31.51 ± 1.34, whereas the sample grown in Shahi had the lowest concentration with values of 9.08 ± 0.33, 8.07 ± 0.31 and 6.45 ± 0.28 µg/g dw respectively (Table 3.58).

There is a notable difference in tyrosine concentrations between the Trwanish and Shahi, Kadana and Charput areas, as well as between the Maraş, Derishke, and Sheladize regions (Table 3.58). It can be seen from the rows of Table 3.58 that there is not a statistically significant difference between the first, second, and third groups ($p > 0.05$). All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of tyrosine levels than the second group (Table 3.59). Comparison data between the three groups of tyrosine shown in (Figure 3.30).

In a prior study conducted by Kossah et al. (2009), it was discovered that the amount of Tyrosine present in Syrian and Chinese sumac was 0.51 ± 0.33 and 1.27 ± 0.19 mg/g, respectively [31].

A earlier research that was carried out by Muhammad et al. (2021), came to the conclusion that the quantity of tyrosine that was found in various types of poppy seeds was 4.23 g/100g of Dhawla Bada poppy seed type, 4.17 g/100g of Dhawla Chotta poppy seed type and 3.97 g/100g of commercial variety poppy seed type [223].

Previous research conducted by Ishtiaque et al. (2013), reveals that organic antioxidants may be preferable for use in the preservation of food and the protection of health impacts. This is due to the fact that organic antioxidants are just as powerful as synthetic antioxidants from a strength standpoint [224].

Table 3.60. Amount of arginine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^a 96.80 ± 1.49 *	^a 86.70 ± 1.35 *	^a 74.63 ± 1.26 *
Elaziğ	^c 246.17 ± 9.17 *	^c 228.64 ± 9.03 *	^{c,d} 205.30 ± 8.93 *
Shelaza	^a 117.22 ± 3.19 *	^a 102.21 ± 3.17 *	^a 86.32 ± 3.05 *
Trwanish	^e 371.43 ± 8.19 *	^e 351.09 ± 7.72 *	^f 306.46 ± 6.99 *
Shahi	^c 255.08 ± 5.64 *	^c 229.34 ± 5.34 *	^d 208.71 ± 4.91 *
Charput	^b 220.40 ± 5.88 *	^b 204.16 ± 5.65 *	^{c,d} 188.73 ± 5.43 *
Suleymania	^b 202.30 ± 5.15 *	^b 192.03 ± 4.88 *	^b 164.70 ± 4.62 *
Kadana	^f 500.31 ± 6.15 *	^f 460.54 ± 5.79 *	^g 404.74 ± 5.59 *
Derishke	^b 219.80 ± 6.52 *	^b 202.14 ± 6.06 *	^{b,c} 183.81 ± 5.85 *
Ranya	^d 302.70 ± 6.19 *	^d 281.40 ± 6.22 *	^e 242.37 ± 5.97 *
Sheladize	^d 314.71 ± 12.26 *	^d 289.38 ± 12.12 *	^e 253.71 ± 11.51 *

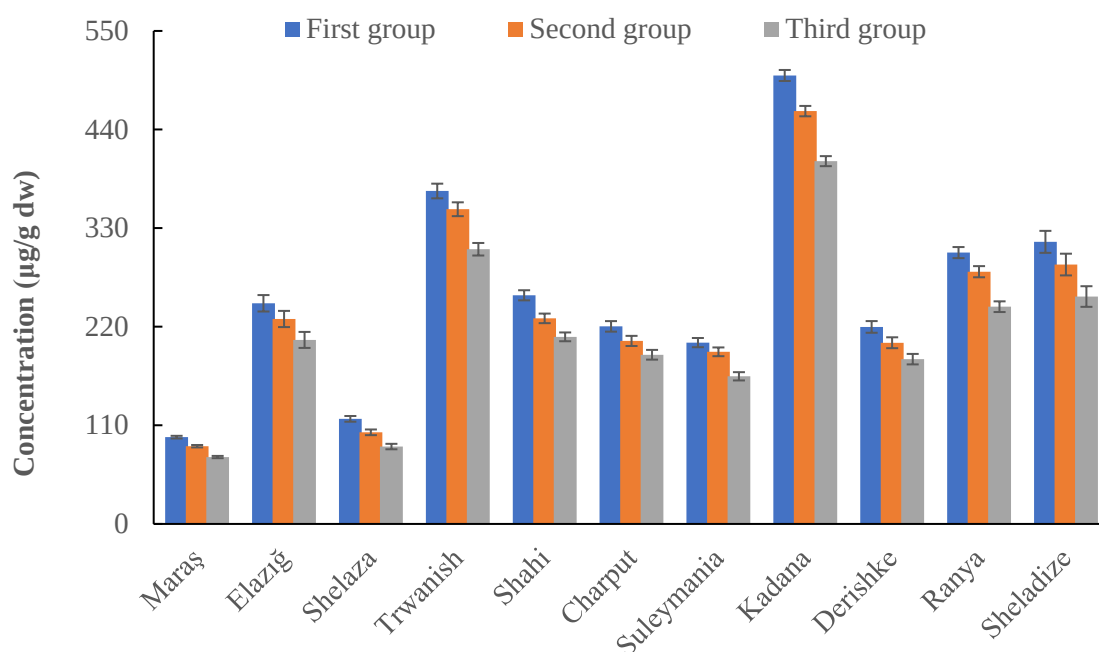


Figure 3.31. Interpretation column chart of arginine*

Table 3.61. Loss percentage % of arginine*

Arginine*		
Region	Second group	Third group
Maraş	10.40	22.90
Elazığ	7.10	16.60
Shelaza	12.80	26.40
Trwanish	5.50	17.50
Shahi	10.10	18.20
Charput	7.40	14.40
Suleymania	5.10	18.60
Kadana	7.90	19.10
Derishke	8.00	16.40
Ranya	7.00	19.90
Sheladize	8.00	19.40

Within the human body, arginine serves as a free amino acid, a component of the majority of proteins, and a building block for a number of nitrogen-containing molecules that are not compounds that are proteins. In the urea cycle, arginine serves as an intermediary since it is a free amino acid. One of the twenty α -amino acids that are often found, arginine is an essential constituent of proteins found in mammalian organisms. Through its role as a source for a number of nitrogen-containing molecules that are not proteins, arginine has an indirect role in the fast

regeneration of adenosine triphosphate, as well as in cell proliferation, vasodilation, neural communication, calcium release, and eventually immunology [225].

The values of arginine amino acid in the samples from the first group exhibited a range of 96.80 ± 1.49 to 500.31 ± 6.15 $\mu\text{g/g dw}$. Conversely, the arginine amino acid concentrations in the samples from the second and third groups were determined to be 74.63 ± 1.26 to 404.74 ± 5.59 and 86.70 ± 1.35 to 460.54 ± 5.79 $\mu\text{g/g dw}$, respectively (Table 3.60). In accordance with the rows of (Table 3.60), it can be shown that there is no statistically significant difference between the first, second, and third groups ($p > 0.05$). All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of arginine levels than the second group (Table 3.61). Comparison data between the three groups of arginine shown in (Figure 3.31).

phenolic antioxidants may be found in abundance in the oil from olive mill rubbish, which is a supply that is both inexpensive and renewable. As a way to promote the stability of foods by avoiding lipid peroxidation and to protect biological systems from oxidative damage by scavenging oxygen radicals, phenolic extracts from olive oil mill waste may be utilised as alternatives to synthetic antioxidants. This is accomplished by lowering the levels of oxygen radicals in the body [226].

Table 3.62. Amount of cysteine in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^a 11.79 ± 0.58 *	^a 10.00 ± 0.62 **,*	^a 8.11 ± 0.55 **
Elazığ	^c 23.80 ± 1.23 *	^b 19.22 ± 1.18 **,*	^b 15.60 ± 1.16 **
Shelaza	^a 12.81 ± 0.41 *	^a 10.11 ± 0.41 **,*	^a 8.52 ± 0.37 **
Trwanish	^e 34.91 ± 1.22 *	^{c,d} 29.24 ± 1.20 **,*	^{c,d} 23.57 ± 1.07 **
Shahi	^{d,e} 33.42 ± 0.74 *	^{c,d} 28.67 ± 0.72 **,*	^{c,d} 22.29 ± 0.66 **
Charput	^{b,c} 21.00 ± 0.83 *	^b 17.61 ± 0.80 **,*	^b 15.20 ± 0.75 **
Suleymanian	^d 30.60 ± 1.06 *	^c 26.64 ± 1.04 **,*	^c 20.64 ± 0.94 **
Kadana	^g 51.90 ± 1.40 *	^e 47.01 ± 1.35 **,*	^e 42.58 ± 1.33 **
Derishke	^b 20.31 ± 0.50 *	^b 17.30 ± 0.50 **,*	^b 15.11 ± 0.46 **
Ranya	^d 30.61 ± 0.76 *	^c 27.40 ± 0.67 **,*	^c 21.43 ± 0.62 **
Sheladize	^f 38.40 ± 1.16 *	^d 31.42 ± 1.16 **,*	^d 24.77 ± 1.04 **

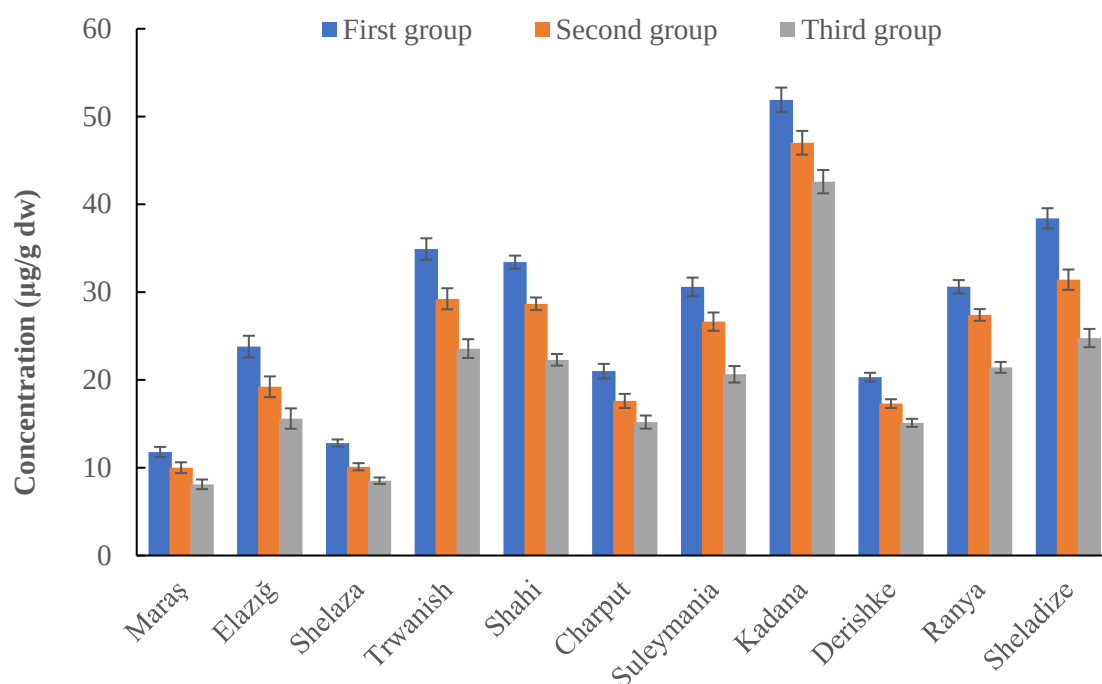


Figure 3.32. Interpretation column chart of cysteine

Table 3.63. Loss percentage % of cysteine

Cysteine		
Region	Second group	Third group
Maraş	15.20	31.20
Elazığ	19.20	34.50
Shelaza	21.10	33.50
Trwanish	16.20	32.50
Shahi	14.20	33.30
Charput	16.10	27.60
Suleymania	12.90	32.50
Kadana	9.40	18.00
Derishke	14.80	25.60
Ranya	10.50	30.00
Sheladize	18.20	35.50

L-Cysteine is a semiessential amino acid that is mostly found in the extracellular space in the form of L-cystine. Through a transportation mechanism, L-cystine from outside the cell is able to pass across the plasma membrane and undergo reduction to L-cysteine within the cells. This reduction process is facilitated by thioredoxin and reduced glutathione (GSH). Intracellular L-cysteine is crucial for maintaining cellular homeostasis as it serves as a precursor for protein synthesis and the creation of GSH, hydrogen sulphide (H₂S), and taurine [227].

The sample produced in Maraş exhibited the lowest cysteine amino acid content among the first, second and third groups samples with values of 11.79 ± 0.58 , 10.00 ± 0.62 & 8.11 ± 0.55 µg/g dw (Table 3.62).

We may conclude that Elazığ, Maraş, Trwanish, Kadana, and Sheladize have substantially different concentrations of the cysteine component in the first group ($p < 0.05$) (Table 3.62). The rows of (Table 3.62) show that there is a statistically significant difference ($p < 0.05$) between the first and third groups, but no statistical difference ($p > 0.05$) between the second and first groups or between the second and third groups. All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of cysteine levels than the second group (Table 3.63). Comparison data between the three groups of cysteine shown in (Figure 3.32).

Kutti Gounder and Lingamallu (2012) reported, in light of the decreased IC₅₀ values, it can be inferred that the turmeric oil derived from both dry and cured rhizome has a strong antioxidant potential. Because of its impressive antioxidant properties, turmeric oil has many potential uses in the food sector, including as a functional food and as a substitute for synthetic antioxidants [228].

Table 3.64. Amount of histidine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 635.31 ± 20.92 *	^b 584.64 ± 20.78 *	^b 543.20 ± 20.57 *
Elazığ	^a 496.01 ± 10.39 *	^a 454.00 ± 10.16 *	^a 424.67 ± 9.48 *
Shelaza	^a 469.82 ± 6.78 *	^a 422.69 ± 6.16 *	^a 400.16 ± 6.73 *
Trwanish	^g 1084.32 ± 24.02 *	^g 994.66 ± 22.23 *	^f 905.32 ± 23.02 *
Shahi	^e 837.92 ± 7.21 *	^e 784.22 ± 7.43 *	^e 705.26 ± 6.75 *
Charput	^f 981.70 ± 7.36 *	^f 921.43 ± 7.42 *	^f 880.43 ± 7.41 *
Suleymania	^d 772.94 ± 18.64 *	^d 710.61 ± 17.81 *	^{d,e} 668.94 ± 14.83 *
Kadana	^h 1303.43 ± 13.31 *	^h 1241.43 ± 13.68 *	^g 1156.76 ± 14.15 *
Derishke	^{c,d} 718.70 ± 11.11 *	^{c,d} 676.70 ± 11.24 *	^{c,d} 624.37 ± 10.67 *
Ranya	^c 693.88 ± 18.62 *	^{b,c} 629.12 ± 16.90 *	^c 595.55 ± 17.29 *
Sheladize	^g 1079.28 ± 16.15 *	^g 985.95 ± 16.30 *	^f 908.28 ± 15.54 *

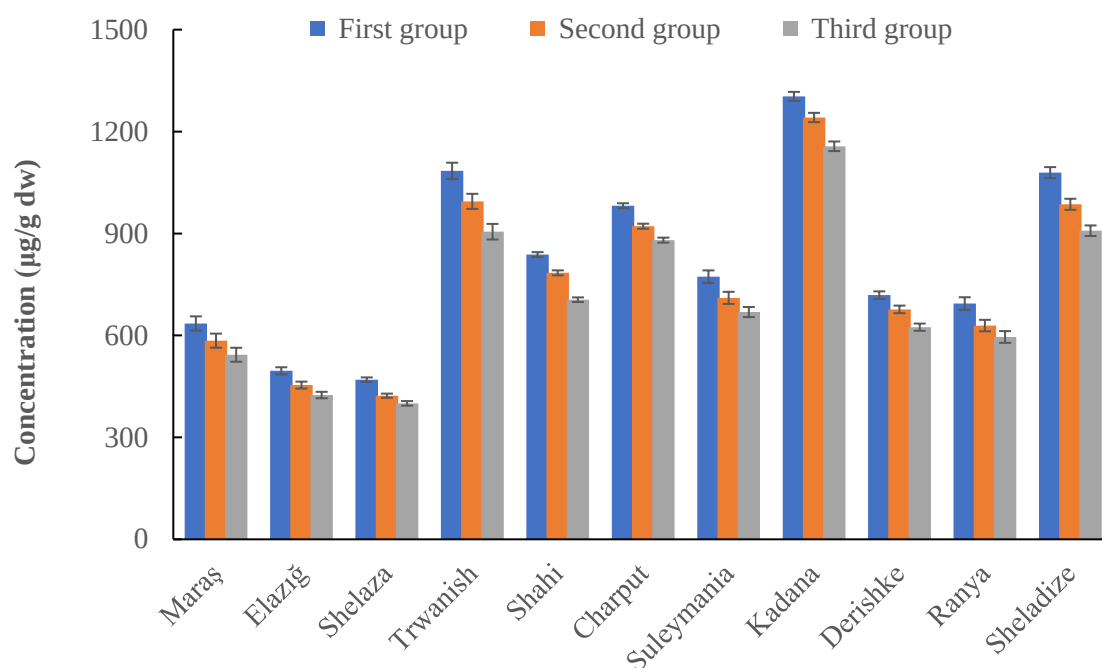


Figure 3.33. Interpretation column chart of histidine*

Table 3.65. Loss percentage % of histidine*

Region	Histidine*	
	Second group	Third group
Maraş	7.98	14.50
Elazığ	8.50	14.40
Shelaza	10.00	14.80
Trwanish	8.30	16.50
Shahi	6.40	15.80
Charput	6.10	10.30
Suleymania	8.10	13.50
Kadana	4.80	11.30
Derishke	5.80	13.10
Ranya	9.30	14.20
Sheladize	8.60	15.80

Histidine A.A. is essential for erythropoiesis and the development of the myelin sheath, whereas arginine A.A. plays a crucial role in growth hormone production and enhancing the immune system [229].

Results showed that histidine ranged from 469.82 ± 6.78 to 1303.43 ± 13.31 µg/g dw in the first group, but from 422.69 ± 6.16 to 1241.43 ± 13.68 and 400.16 ± 6.73 to 1156.76 ± 14.15 µg/g dw in the second and third groups, respectively (Table 3.64). As seen in the rows of (Table 3.64),

there is no statistically difference between the first, second and third groups ($p > 0.05$). All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of histidine levels than the second group (Table 3.65). Comparison data between the three groups of histidine shown in (Figure 3.33).

In a study conducted by Mukhtar et al. in 2022, the levels of histidine and arginine were measured in white garden eggs, bitter apples, dark eggplants, light eggplants, and bitter tomatoes. The amounts of histidine were found to be 6.910.46, 6.900.47, 6.840.48, 4.700.34, and 8.400.70 mg/g dw, respectively. The levels of arginine were measured as 0.240.01, 0.100.007, 0.100.007, 0.090.006, and 0.090.006 mg/g dw [230].

In accordance with the findings of a previous study conducted by Kossah et al. (2009), the amount of histidine that was discovered in Syrian and Chinese sumac was 0.68 ± 0.01 mg/g, and 1.03 ± 0.12 mg/g, among other values [31].

Previous research by Muhammad et al. (2021) found that different types of poppy seeds contained different amounts of histidine. For example, Dhawla Bada poppy seeds had 2.70 g/100g, Dhawla Chotta poppy seeds had 2.54 g/100g and commercial variety poppy seeds had 3.13 g/100g [223].

Singh et al. (2005) reported, it is possible to draw the conclusion that both the essential oil and its acetone extract of mace displayed a wide range of antibacterial activity against the microbial species that were tested. Furthermore, it has the potential to be a more effective natural antioxidant for stabilising rapeseed oil. When compared with synthetic antioxidants, it was found that both essential oil and extract showed antioxidative activity that was comparable to or even greater than that of the synthetic antioxidants. This gives a method for screening antioxidants for use in foods, cosmetics, and medicine [231].

Table 3.66. Amount of threonine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 283.41 ± 5.39 *	^{c,d} 265.94 ± 5.41 *	^c 243.41 ± 4.62 *
Elazığ	^a 211.22 ± 4.43 *	^b 198.84 ± 4.33 *	^b 186.20 ± 4.24 *
Shelaza	^b 295.31 ± 4.25 *	^d 279.78 ± 4.19 *	^c 250.35 ± 4.07 *
Trwanish	^d 449.21 ± 3.78 *	^f 416.54 ± 3.54 *	^e 383.87 ± 3.38 *
Shahi	^f 613.20 ± 7.77 *	ⁱ 575.20 ± 7.05 *	^h 517.53 ± 6.30 *
Charput	^f 588.30 ± 6.86 *	^h 542.53 ± 6.82 *	^g 493.30 ± 6.72 *
Suleymania	^a 187.90 ± 3.77 *	^a 159.93 ± 3.72 *	^a 141.90 ± 3.62 *
Kadana	^e 515.50 ± 4.03 *	^g 485.67 ± 4.02 *	^f 433.50 ± 3.93 *
Derishke	^c 368.31 ± 6.05 *	^e 351.64 ± 5.34 *	^d 309.64 ± 4.80 *
Ranya	^b 277.63 ± 4.00 *	^c 255.23 ± 3.57 *	^c 232.63 ± 3.27 *
Sheladize	^f 612.12 ± 16.52 *	ⁱ 580.77 ± 15.84 *	^{g,h} 509.10 ± 14.74 *

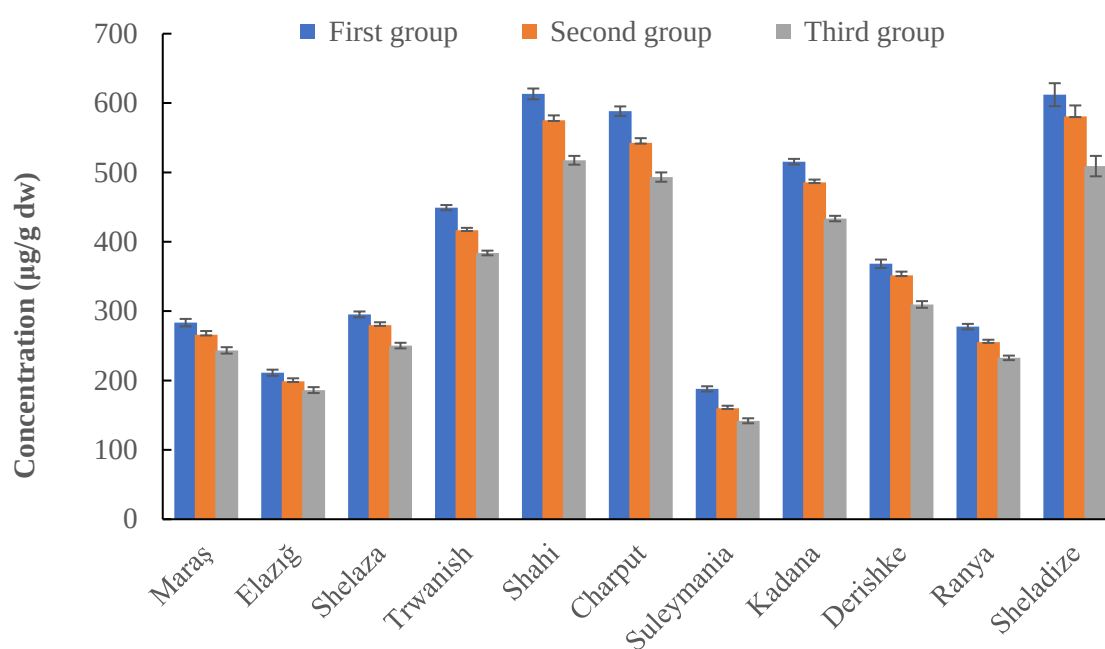


Figure 3.34. Interpretation column chart of threonine*

Table 3.67. Loss percentage % of threonine*

Region	Threonine*	
	Second group	Third group
Maraş	6.20	14.10
Elazığ	5.90	11.80
Shelaza	5.30	15.20
Trwanish	7.30	14.50
Shahi	6.20	15.60
Charput	7.80	16.10
Suleymania	14.90	24.50
Kadana	5.80	15.90
Derishke	4.50	15.90
Ranya	8.10	16.20
Sheladize	5.10	16.80

Threonine (Thr.), often referred to as α -amino- β -hydroxybutyric acid, is a vital amino acid in animals that is necessary to be acquired from food. Threonine primarily functions as a building block for the production of proteins, namely mucin. Furthermore, threonine has the ability to participate in the catabolic pathway, where it may undergo metabolism to produce many significant products (such as glycine, acetyl CoA, and pyruvate) that have a vital impact on the metabolism of the host. Threonine is subject to three distinct metabolic processes. [232].

While the values of threonine in the samples from the first group ranged from 187.90 ± 3.77 to 613.20 ± 7.77 , it was found that the threonine concentration in the samples from the second and third groups was between 159.93 ± 3.72 to 580.77 ± 15.84 and 141.90 ± 3.62 to 517.53 ± 6.30 $\mu\text{g/g}$ dw, respectively (Table 3.66). It is possible to demonstrate, in accordance with the rows of (Table 3.66), that there is not a statistically significant difference between the first, second, and third groups due to the fact that the p-value is greater than 0.05.

All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of threonine levels than the second group (Table 3.67). Comparison data between the three groups of threonine shown in (Figure 3.34).

According to the results of a previous research that was carried out by Kossah et al. (2009), the quantity of threonine that was found in Syrian and Chinese sumac was 0.70 ± 0.08 and 1.57 ± 0.06 mg/g respectively [31].

A previous research by Bleiziffer et al. (2017), found that sage (*Salvia officinalis*), basil (*Ocimum basilicum*), and mint (*Mentha piperita*) contained 0.04, 0.01 and 0.09 mg/g of threonine, respectively [233].

Table 3.68. Amount of valine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^d 14.88 ± 0.56 *	^d 13.10 ± 0.55 ***	^e 11.52 ± 0.51 **
Elazığ	^c 9.72 ± 0.41 *	^c 8.85 ± 0.43 ***	^d 7.35 ± 0.39 **
Shelaza	^c 8.70 ± 0.43 *	^c 7.90 ± 0.41 ***	^{c,d} 6.33 ± 0.33 **
Trwanish	^b 6.00 ± 0.41 *	^b 5.25 ± 0.40 ***	^b 4.50 ± 0.35 **
Shahi	^c 9.41 ± 0.49 *	^c 8.33 ± 0.47 ***	^d 7.17 ± 0.41 **
Charput	^c 8.71 ± 0.33 *	^c 8.28 ± 0.30 ***	^d 7.26 ± 0.31 **
Suleymania	^b 7.00 ± 0.34 *	^b 6.43 ± 0.32 ***	^{b,c} 5.60 ± 0.31 **
Kadana	^a 3.20 ± 0.17 *	^a 2.90 ± 0.17 ***	^a 2.30 ± 0.14 **
Derishke	^c 9.49 ± 0.49 *	^c 8.16 ± 0.47 ***	^d 7.29 ± 0.42 **
Ranya	^c 9.62 ± 0.33 *	^c 8.55 ± 0.36 ***	^d 7.38 ± 0.33 **
Sheladize	^e 17.41 ± 0.49 *	^e 16.07 ± 0.39 ***	^f 13.41 ± 0.41 **

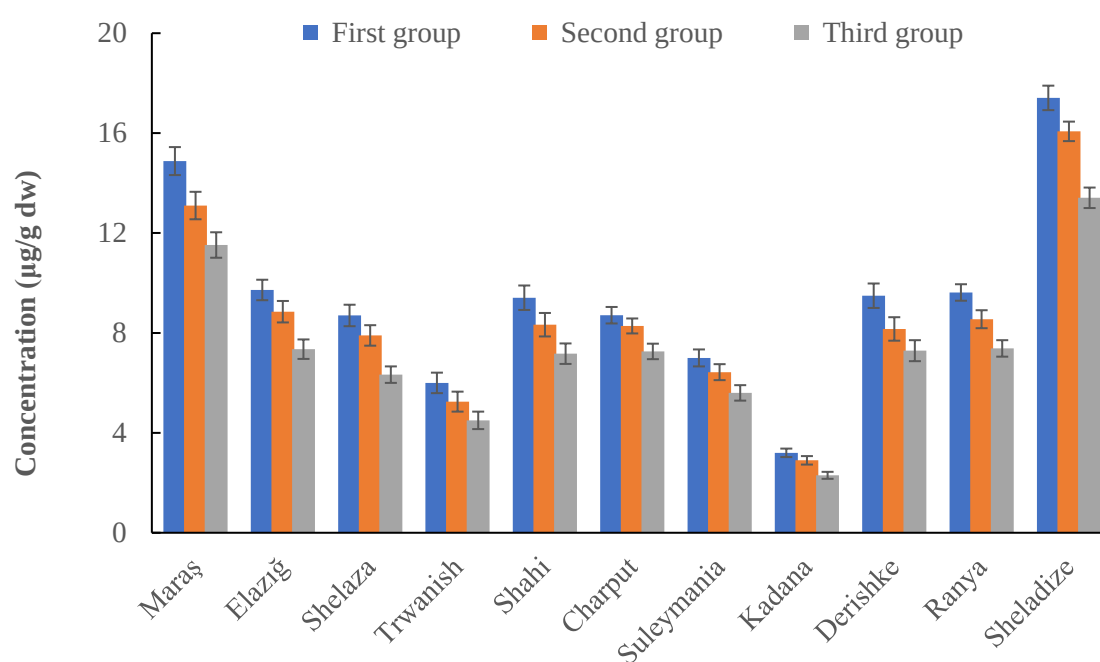


Figure 3.35. Interpretation column chart of valine*

Table 3.69. Loss percentage % of valine*

Region	Valine*	
	Second group	Third group
Maraş	12.00	22.60
Elazığ	9.00	24.40
Shelaza	9.20	27.20
Trwanish	12.50	25.00
Shahi	11.50	23.80
Charput	4.90	16.60
Suleymania	8.10	20.00
Kadana	9.40	28.10
Derishke	14.00	23.20
Ranya	11.10	23.30
Sheladize	7.70	23.00

Proteins that include high levels of proline, glycine, leucine, and methionine have a significant impact on the formation of the cell wall. Additionally, leucine, isoleucine, and valine have been shown to provide protection to the cell when it is exposed to osmotic stress. Phenylalanine, tyrosine, and tryptophan are aromatic amino acids that originate from the shikimate pathway. They play a crucial role in protein synthesis and the creation of aromatic secondary metabolites, such as anthocyanin. Tryptophan, a crucial component in cellular growth, is recognised as the precursor of neurotransmitter chemicals [234].

While the values of valine in the first group samples varied between 3.20 ± 0.17 - 17.41 ± 0.49 $\mu\text{g/g dw}$, it was determined that valine was between 2.90 ± 0.17 - 16.07 ± 0.39 and 2.30 ± 0.14 - 13.41 ± 0.41 $\mu\text{g/g dw}$ in the second and third group samples, respectively (Table 3.68). As seen in the rows of (Table 3.68), the difference between the first and third groups is statistically significant ($p < 0.05$), while there is no statical difference between second group and first group as well as between second group and third group ($p > 0.05$). All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of valine levels than the second group (Table 3.69). Comparison data between the three groups of valine shown in (Figure 3.35).

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 0.71 ± 0.06 and 2.24 ± 0.30 mg/g of valine, respectively [31].

Table 3.70. Amount of methionine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^b 71.91 ± 2.78 *	^b 66.86 ± 2.73 *	^b 60.37 ± 2.71 *
Elazığ	^{b,c} 81.70 ± 2.05 *	^{b,c} 75.67 ± 2.02 *	^{b,c} 65.90 ± 1.98 *
Shelaza	^d 103.49 ± 3.19 *	^d 94.19 ± 2.93 *	^d 88.89 ± 2.81 *
Trwanish	^e 130.22 ± 2.61 *	^e 121.96 ± 2.75 *	^e 103.53 ± 2.35 *
Shahi	^f 163.81 ± 6.36 *	^f 154.13 ± 6.18 *	^f 140.46 ± 6.02 *
Charput	^h 223.02 ± 6.71 *	^h 207.53 ± 6.41 *	^g 183.49 ± 6.36 *
Suleymania	^a 29.51 ± 1.55 *	^a 26.54 ± 1.51 *	^a 22.58 ± 1.47 *
Kadana	^{c,d} 92.31 ± 2.05 *	^{c,d} 83.80 ± 1.97 *	^c 74.64 ± 1.79 *
Derishke	^{c,d} 94.90 ± 1.96 *	^{c,d} 85.10 ± 1.93 *	^c 73.97 ± 1.91 *
Ranya	^b 69.30 ± 1.09 *	^b 64.16 ± 1.02 *	^b 58.36 ± 0.99 *
Sheladize	^g 204.80 ± 6.05 *	^g 193.83 ± 6.02 *	^g 174.60 ± 5.79 *

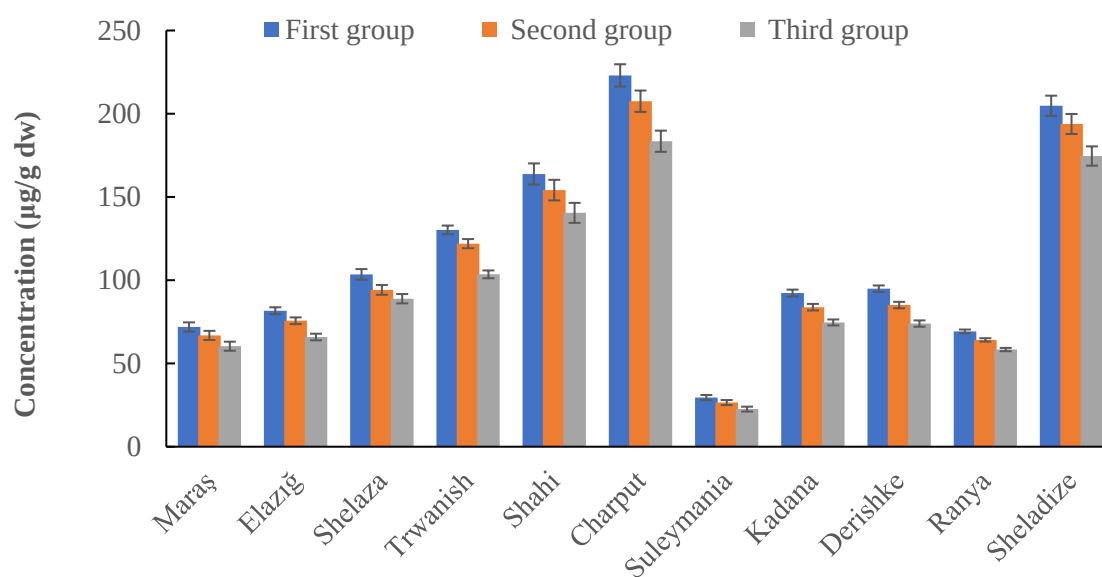


Figure 3.36. Interpretation column chart of methionine*

Table 3.71. Loss percentage % of methionine*

Region	Methionine*	
	Second group	Third group
Maraş	7.00	16.00
Elazığ	7.40	19.30
Shelaza	9.00	14.10
Trwanish	6.30	20.50
Shahi	5.90	14.30
Charput	6.90	17.70
Suleymania	10.10	23.50
Kadana	9.20	19.10
Derishke	10.30	22.10
Ranya	7.40	15.80
Sheladize	5.40	14.70

Amount of methionine in the first group grown in different regions varies in between 29.51 ± 1.55 - 223.02 ± 6.71 $\mu\text{g/g dw}$. While the amount of methionine substances in the second group samples varies in between 26.54 ± 1.51 to 207.53 ± 6.41 $\mu\text{g/g dw}$, on the other hand in third group of samples it varied between 22.58 ± 1.47 - 183.49 ± 6.36 $\mu\text{g/g dw}$. As seen in the rows of (Table 3.70), there is no statistically difference between the first, second and third groups ($p > 0.05$). Loss of methionine A.A. in the third group is greater than the second group (Table 3.71). Comparison data between the three groups of methionine shown in (Figure 3.36).

In a previous research done by Kossah et al. (2009), it was discovered that Syrian and Chinese sumac contain 0.15 ± 0.07 and 0.05 ± 0.02 mg/g of methionine, respectively [31].

Table 3.72. Amount of leucine* in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^a 162.20 ± 3.52 *	^a 151.24 ± 3.50 *	^a 132.27 ± 3.46 *
Elazığ	^b 266.72 ± 5.64 *	^b 249.39 ± 5.54 *	^b 222.66 ± 5.59 *
Shelaza	^a 181.93 ± 3.95 *	^a 172.23 ± 4.12 *	^a 151.83 ± 3.87 *
Trwanish	^f 730.49 ± 15.7 *	^f 688.50 ± 14.95 *	^f 620.40 ± 15.36 *
Shahi	^e 565.11 ± 13.96 *	^e 495.11 ± 13.80 *	^e 461.11 ± 13.18 *
Charput	^c 383.40 ± 9.56 *	^c 360.07 ± 9.38 *	^c 325.40 ± 8.82 *
Suleymania	^d 485.12 ± 12.26 *	^d 440.44 ± 11.62 *	^d 401.44 ± 11.00 *
Kadana	^g 1040.64 ± 7.39 *	^g 989.64 ± 6.65 *	^g 901.60 ± 7.02 *
Derishke	^c 413.21 ± 4.59 *	^c 388.20 ± 3.83 *	^c 347.53 ± 4.07 *
Ranya	^e 531.68 ± 5.73 *	^e 492.70 ± 5.04 *	^e 447.70 ± 4.97 *
Sheladize	^d 495.59 ± 14.13 *	^d 448.59 ± 13.52 *	^d 398.59 ± 13.36 *

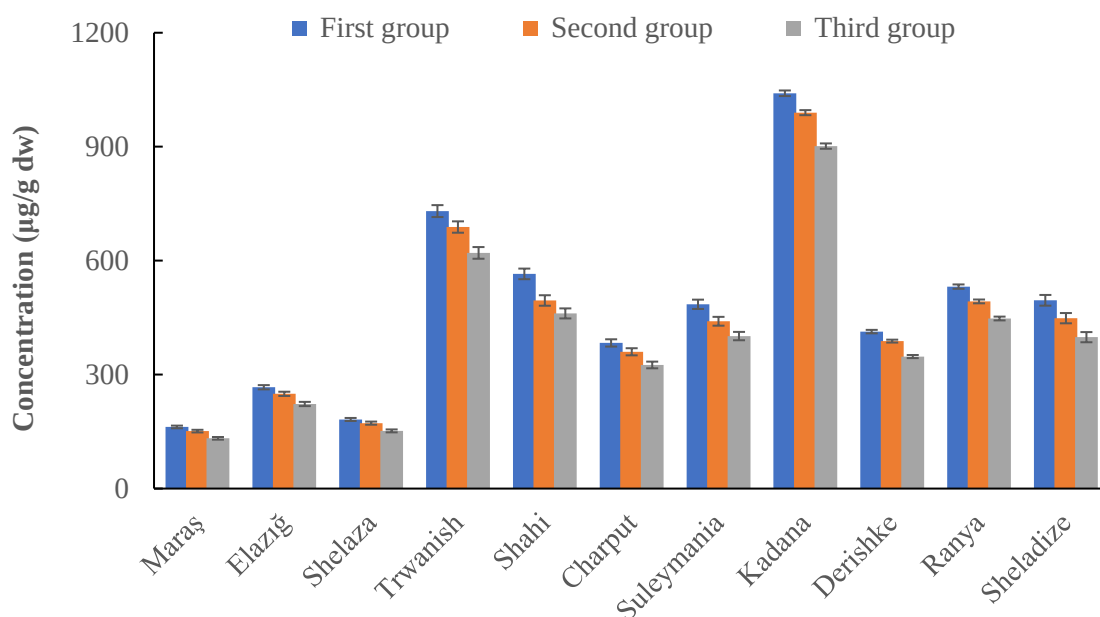


Figure 3.37. Interpretation column chart of leucine*

Table 3.73. Loss percentage % of leucine*

Region	Leucine*	
	Second group	Third group
Maraş	6.80	18.50
Elazığ	6.50	16.50
Shelaza	5.30	16.50
Trwanish	5.70	15.10
Shahi	12.40	18.40
Charput	6.10	15.10
Suleymania	9.20	17.20
Kadana	4.90	13.40
Derishke	6.10	15.90
Ranya	7.30	15.80
Sheladize	9.50	19.60

Between 162.20 ± 3.52 and 1040.64 ± 7.39 µg/g dw, the amount of leucine A.A. in the first group that is cultivated in various places varies. Leucine A.A. levels in the samples of the second group range from 151.24 ± 3.50 to 989.64 ± 6.65 µg/g dw. On the other hand, the levels of leucine A.A. in the samples of the third group ranged from 132.27 ± 3.46 to 901.60 ± 7.02 µg/g dw (Table 3.72). According to the rows of (Table 3.72), there is no statistically significant difference between the first, second, and third groups ($p > 0.05$). This is evident from the evidence presented. The amount of leucine A.A. that is lost in the second group is somewhat lower than that of the third group (Table 3.73). Comparison data between the three groups of leucine shown in (Figure 3.37).

In a previous research by Kossah et al. (2009), it was discovered that Syrian sumac had 1.25 ± 0.16 mg/g of leucine A.A., whereas Chinese sumac had 3.16 ± 0.19 mg/g [31].

Table 3.74. Amount of isoleucine* in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^b $149.12 \pm 5.17^*$	^b $128.42 \pm 5.13^*$	^b $112.43 \pm 5.06^*$
Elazığ	^c $175.69 \pm 4.67^*$	^c $158.94 \pm 3.29^*$	^c $140.27 \pm 3.86^*$
Shelaza	^b $151.61 \pm 4.10^*$	^b $140.50 \pm 3.80^*$	^b $120.60 \pm 3.87^*$
Trwanish	^g $388.10 \pm 5.14^*$	^g $358.57 \pm 4.26^*$	^h $315.57 \pm 4.37^*$
Shahi	^f $335.31 \pm 4.25^*$	^f $311.58 \pm 4.08^*$	^{f,g} $285.64 \pm 4.26^*$
Charput	^f $351.22 \pm 5.17^*$	^f $319.92 \pm 4.11^*$	^g $296.46 \pm 4.72^*$
Suleymania	^a $42.90 \pm 1.15^*$	^a $35.71 \pm 1.05^*$	^a $31.63 \pm 1.12^*$
Kadana	^h $421.21 \pm 6.69^*$	^h $384.73 \pm 6.27^*$	ⁱ $340.46 \pm 6.52^*$
Derishke	^d $217.21 \pm 4.33^*$	^d $197.21 \pm 3.57^*$	^d $183.54 \pm 3.86^*$
Ranya	^e $266.37 \pm 2.80^*$	^e $237.63 \pm 2.43^*$	^e $201.73 \pm 2.65^*$
Sheladize	^f $347.81 \pm 5.62^*$	^f $310.33 \pm 4.61^*$	^f $280.76 \pm 4.97^*$

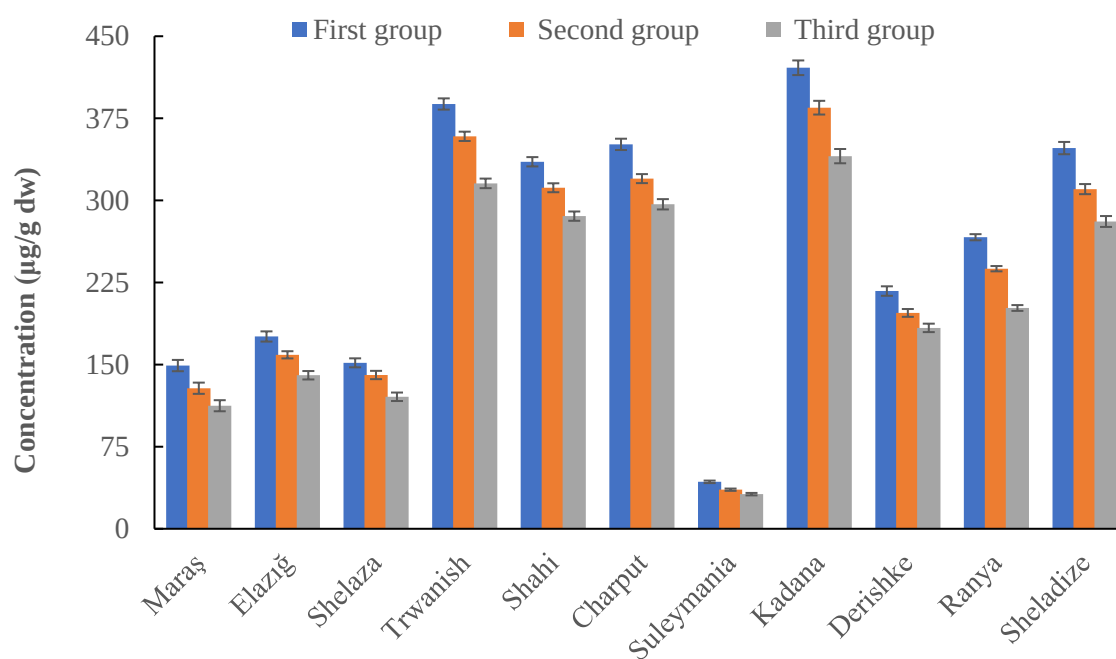


Figure 3.38. Interpretation column chart of isoleucine*

Table 3.75. Loss percentage % of isoleucine*

Region	Isoleucine*	
	Second group	Third group
Maraş	13.90	24.60
Elazığ	9.50	20.20
Shelaza	7.30	20.50
Trwanish	7.60	18.70
Shahi	7.10	14.80
Charput	8.90	15.60
Suleymanlia	16.80	26.30
Kadana	8.70	19.20
Derishke	9.20	15.50
Ranya	10.80	24.30
Sheladize	10.80	19.30

Within the first group, the amount of isoleucine A.A. that is cultivated in various places ranges from 42.90 ± 1.15 to 421.21 ± 6.69 $\mu\text{g/g dw}$. When comparing the samples from the second group, the quantity of isoleucine A.A. ranges between 35.71 ± 1.05 to 384.73 ± 6.27 $\mu\text{g/g dw}$. On the other hand, the samples from the third group ranged from 31.63 ± 1.12 to 340.46 ± 6.52 $\mu\text{g/g dw}$ (Table 3.74).

Based on the rows in (Table 3.74), it can be concluded that there is no statistically significant difference between the first, second, and third groups ($p > 0.05$). The data that was given makes this quite clear. When compared to the third group, the quantity of isoleucine A.A. that is lost in the second group is slightly less than what is lost in both groups (Table 3.75). Comparison data between the three groups of isoleucine shown in (Figure 3.38).

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 0.63 ± 0.08 and 1.79 ± 0.17 mg/g of isoleucine A.A., respectively [31].

Table 3.76. Amount of phenylalanine* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^a 8.71 ± 0.34 *	^a 7.40 ± 0.31 *	^a 6.13 ± 0.26 *
Elazığ	^b 16.80 ± 0.82 *	^b 14.79 ± 0.77 *	^b 13.46 ± 0.65 *
Shelaza	^{a,b} 12.41 ± 0.42 *	^{a,b} 10.24 ± 0.39 *	^{a,b} 8.80 ± 0.31 *
Trwanish	^{e,f} 66.90 ± 2.55 *	^e 59.10 ± 2.48 *	^e 53.87 ± 2.09 *
Shahi	^d 57.10 ± 1.73 *	^d 51.34 ± 1.63 *	^d 45.47 ± 1.33 *
Charput	^{d,e} 62.49 ± 2.76 *	^{d,e} 57.53 ± 2.74 *	^{d,e} 51.66 ± 2.24 *
Suleymania	^f 72.80 ± 2.93 *	^f 68.77 ± 2.86 *	^f 60.94 ± 2.26 *
Kadana	^g 167.59 ± 3.60 *	^g 149.23 ± 3.47 *	^g 135.90 ± 2.77 *
Derishke	^c 29.00 ± 1.23 *	^c 26.00 ± 1.17 *	^c 22.00 ± 0.92 *
Ranya	^{e,f} 69.79 ± 2.62 *	^e 60.13 ± 2.59 *	^e 52.80 ± 2.11 *
Sheladize	^b 18.81 ± 0.84 *	^b 16.42 ± 0.74 *	^b 14.22 ± 0.56 *

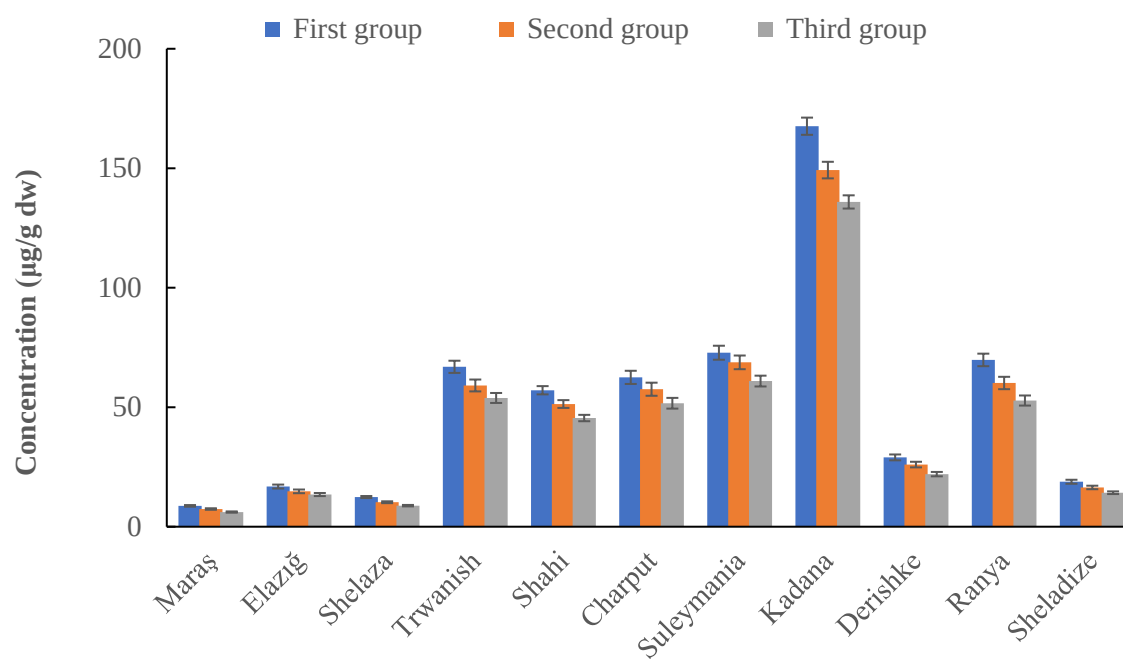


Figure 3.39. Interpretation column chart of phenylalanine*

Table 3.77. Loss percentage % of phenylalanine*

Region	Phenylalanine*	
	Second group	Third group
Maraş	15.00	29.60
Elazığ	12.00	19.90
Shelaza	17.50	29.10
Trwanish	11.70	19.50
Shahi	10.10	20.40
Charput	7.90	17.30
Suleymania	5.50	16.30
Kadana	11.00	18.90
Derishke	10.30	24.10
Ranya	13.80	24.30
Sheladize	12.70	24.40

Within the first group, the quantity of phenylalanine A.A. that is grown in different locations varies from 8.71 ± 0.34 to 167.59 ± 3.60 $\mu\text{g/g dw}$. This range of phenylalanine A.A. concentrations is observed. When comparing the samples from the second group, it is seen that the amount of phenylalanine A.A. varies from 7.40 ± 0.31 to 149.23 ± 3.47 $\mu\text{g/g dw}$. At the opposite end of the spectrum, the samples that were obtained from the third group exhibited a range of 6.13 ± 0.26 to 135.90 ± 2.77 $\mu\text{g/g dw}$ (Table 3.76).

It is possible to draw the conclusion that there is no statistically significant difference between the first, second, and third groups of individuals based on the rows that are shown in (Table 3.76) ($p > 0.05$). The information that was provided makes this point quite obvious. The amount of phenylalanine A.A. that is lost in the second group is somewhat less than what is lost in the third group when compared to the first group (Table 3.77). This is because the third group is different from the second group. Comparison data between the three groups of phenylalanine shown in (Figure 3.39).

In a study conducted by Mukhtar et al. (2022), the bitter apple sample cultivated in Nigeria was found to have the following levels of amino acids, valine 1.41 mg/g dw, methionine 3.10 mg/g dw, leucine 0.09 mg/g dw, and phenylalanine 2.33 mg/g dw [230].

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 0.75 ± 0.13 and 2.00 ± 0.13 mg/g of phenylalanine, respectively [31].

A prior study that was conducted by Adewole et al. (2022), found that the amount of phenylalanine that was present in red scotch bonnet pepper was 0.048 mg/g [221].

Table 3.78. Amount of tryptophan* in sumac samples (*Rhus coriaria* L.) grown in different regions (µg/g dw).

Region	First group	Second group	Third group
Maraş	^a 46.80 ± 1.88 *	^a 41.34 ± 1.85 *	^a 37.27 ± 1.76 *
Elazığ	^a 51.10 ± 2.04 *	^{a,b} 46.77 ± 2.00 *	^{a,b} 41.43 ± 1.90 *
Shelaza	^{b,c} 66.91 ± 2.14 *	^c 58.86 ± 2.10 *	^c 53.30 ± 1.98 *
Trwanish	^d 99.30 ± 2.38 *	^f 91.36 ± 2.31 *	^f 85.12 ± 2.25 *
Shahi	^e 110.11 ± 4.43 *	^g 100.77 ± 4.32 *	^f 90.43 ± 4.08 *
Charput	^d 90.59 ± 1.56 *	^e 82.43 ± 1.50 *	^e 73.60 ± 1.33 *
Suleymania	^a 42.60 ± 1.41 *	^a 38.29 ± 1.39 *	^a 33.50 ± 1.22 *
Kadana	^d 91.09 ± 1.81 *	^e 82.43 ± 1.73 *	^e 74.06 ± 1.69 *
Derishke	^c 75.41 ± 1.97 *	^d 68.08 ± 1.89 *	^d 63.31 ± 1.84 *
Ranya	^b 60.20 ± 2.28 *	^{b,c} 54.13 ± 2.21 *	^{b,c} 49.20 ± 2.04 *
Sheladize	^f 194.61 ± 3.36 *	^h 183.27 ± 3.32 *	^g 176.57 ± 3.24 *

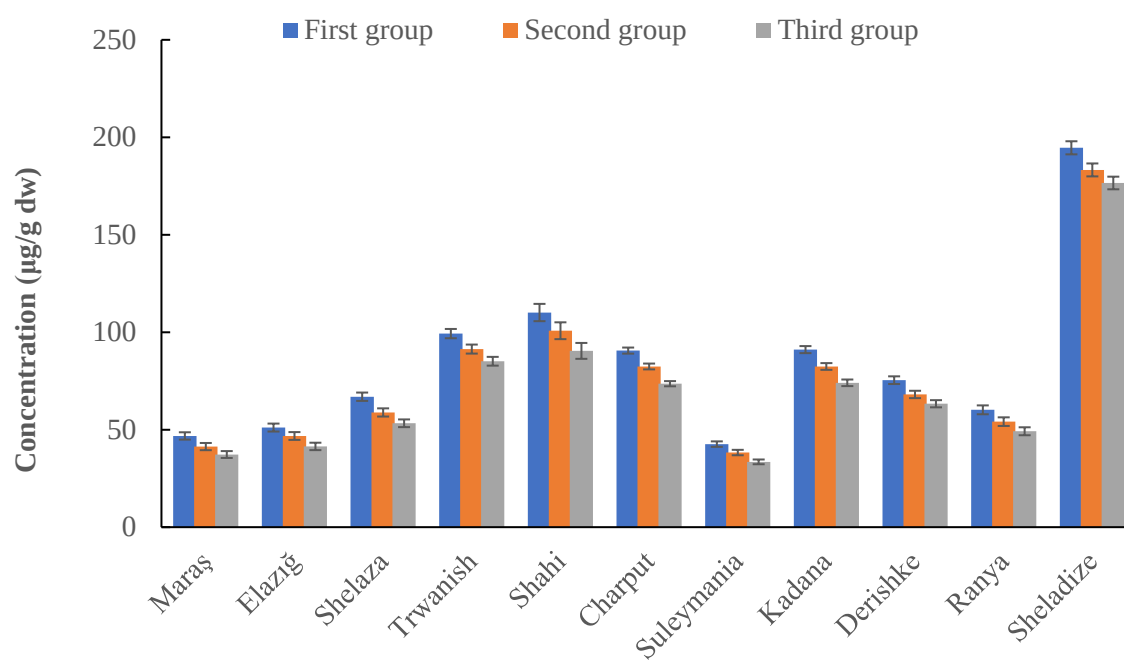


Figure 3.40. Interpretation column chart of tryptophan*

Table 3.79. Loss percentage % of tryptophan*

Region	Tryptophan*	
	Second group	Third group
Maraş	11.70	20.40
Elazığ	8.50	18.90
Shelaza	12.00	20.30
Trwanish	8.00	14.30
Shahi	8.50	17.90
Charput	9.00	18.80
Suleymania	10.10	21.40
Kadana	9.50	18.70
Derishke	9.70	16.00
Ranya	10.10	18.30
Sheladize	5.80	9.30

Tryptophan is an essential amino acid that must be obtained from dietary protein. In addition to being used in the formation of body proteins, tryptophan serves as the precursor for serotonin, a crucial neurotransmitter, as well as kynurenine, an intermediate metabolite in a complicated metabolic pathway that ultimately produces niacin, CO₂, and kynurenic and xanthurenic acids. The metabolism of tryptophan in many organs is linked to a wide range of physiological processes. The liver maintains tryptophan homeostasis by breaking down excessive amounts of tryptophan. The conversion of tryptophan into kynurenine by immune cells is essential for controlling the immunological response in the context of infections, inflammations, and pregnancy. Serotonin is produced from tryptophan in both the gastrointestinal tract and the brain. The availability of tryptophan in the brain is recognised to impact susceptibility to mood disorders [235].

The amount of tryptophan A.A. cultivated in various places within the first group ranges from 42.60 ± 1.41 to 194.61 ± 3.36 µg/g dw. These quantities of tryptophan A.A. are noted. Examining the samples from the second group reveals that the concentration of tryptophan A.A. ranges from 38.29 ± 1.39 to 183.27 ± 3.32 µg/g dw. Contrasting with the first two groups, the third group's samples showed a range of 33.50 ± 1.22 to 176.57 ± 3.24 µg/g dw (Table 3.78).

When it comes to tryptophan A.A., it is possible to assert that there is a statistically significant difference in concentrations between the regions of Elazığ, Shelaza, Trwanish, and Sheladize ($p < 0.05$). However, it is worth noting that there is no statistically significant difference in concentrations between the regions of Maraş, Elazığ, and Suleymania ($p > 0.05$) in the first group, as indicated by (Table 3.78). All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of tryptophan levels than the second group (Table 3.79). Comparison data between the three groups of tryptophan shown in (Figure 3.40).

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 0.51 ± 0.18 and 3.10 ± 0.15 mg/g of Tryptophan, respectively [31].

Table 3.80. Amount of lysine* in sumac samples (*Rhus coriaria* L.) grown in different regions ($\mu\text{g/g dw}$).

Region	First group	Second group	Third group
Maraş	^b 28.50 ± 0.85 *	^b 24.80 ± 0.96 *	^b 21.83 ± 0.92 *
Elazığ	^d 38.62 ± 0.79 *	^d 34.27 ± 0.81 *	^d 30.60 ± 0.76 *
Shelaza	^e 48.99 ± 1.85 *	^e 43.64 ± 2.02 *	^e 39.24 ± 1.97 *
Trwanish	^f 57.90 ± 2.97 *	^f 52.24 ± 1.89 *	^f 46.24 ± 1.73 *
Shahi	^g 68.09 ± 1.69 *	^g 61.77 ± 1.01 *	^g 56.44 ± 1.49 *
Charput	^g 64.40 ± 1.92 *	^g 58.06 ± 2.05 *	^g 51.73 ± 1.79 *
Suleymania	^a 16.60 ± 0.65 *	^a 15.23 ± 0.64 *	^a 13.23 ± 0.56 *
Kadana	^{b,c} 32.20 ± 1.20 *	^{b,c} 28.86 ± 1.24 *	^{b,c} 25.20 ± 1.16 *
Derishke	^{c,d} 37.50 ± 1.21 *	^{c,d} 33.07 ± 1.34 *	^{c,d} 29.30 ± 1.25 *
Ranya	^b 30.42 ± 1.01 *	^b 26.73 ± 1.12 *	^b 23.20 ± 1.07 *
Sheladize	^h 110.51 ± 1.27 *	^h 101.19 ± 1.33 *	^h 90.51 ± 1.25 *

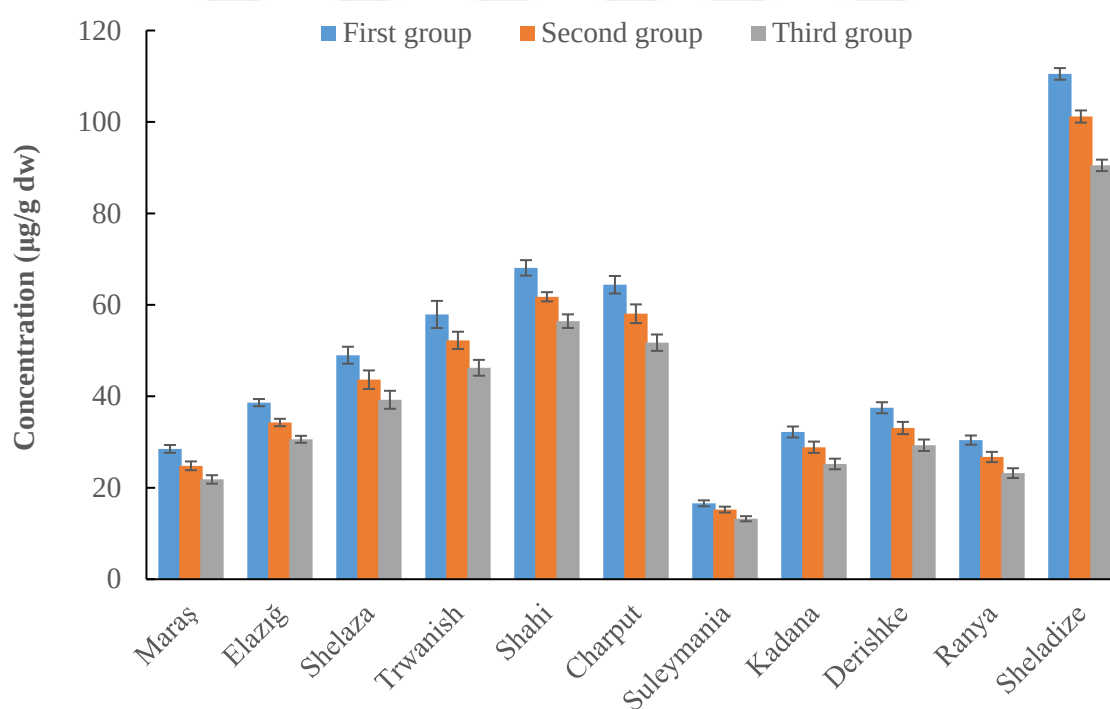


Figure 3.41. Interpretation column chart of lysine*

Table 3.81. Loss percentage % of lysine*

Region	Lysine*	
	Second group	Third group
Maraş	13.00	23.40
Elazığ	11.30	20.80
Shelaza	10.90	19.90
Trwanish	9.80	20.10
Shahi	9.30	17.10
Charput	9.80	19.70
Suleymania	8.30	20.30
Kadana	10.30	21.70
Derishke	10.10	21.90
Ranya	12.10	23.70
Sheladize	8.40	18.10

Lysine plays a crucial function in metabolism by facilitating the production of glutamic acid and enhancing stress resistance [236].

The amount of lysine A.A. cultivated in various places within the first group ranges from 16.60 ± 0.65 to 110.51 ± 1.27 $\mu\text{g/g dw}$. The detected concentrations of lysine A.A. fall within this range. The amounts of lysine A.A. range from 15.23 ± 0.64 to 101.19 ± 1.33 $\mu\text{g/g dw}$, as seen when comparing the samples from the second group. Contrasting with the first two groups, the third group's samples showed a range of 13.23 ± 0.56 to 90.51 ± 1.25 $\mu\text{g/g dw}$ (Table 3.80).

From the data in the three rows of (Table 3.80) ($p > 0.05$), we may infer that the sumac samples from the first, second, and third groups do not vary significantly. Based on the data given, this is clearly the case. In comparison to the first group, the second group loses a little less lysine A.A. than the third group. The reason for this is the dissimilarity between the second and third groups. All of the observations point in this direction. A comparison of the third group with the second group reveals that the third group has had a more significant reduction in the quantity of lysine levels than the second group (Table 3.81). Comparison data between the three groups of lysine shown in (Figure 3.41).

Based on a prior study conducted by Kossah et al. (2009), the Syrian and Chinese sumac were found to have 0.98 ± 0.02 and 2.65 ± 0.07 mg/g of lysine A.A., respectively [31].

Table 3.82. TA: Total amino acid, TE: Total essential amino acid and TNE: Total non-essential amino acid for first group ($\mu\text{g/g dw}$).

	TA	TE	TNE	TE/TNE%	TE/TA%
Maraş	^{cd} 3830.00 $\pm$ 84.8*	^a 1497.50 $\pm$ 48.3*	^f 2332.40 $\pm$ 51.8*	64	39
Elazığ	^b 3316.00 $\pm$ 68.6*	^a 1593.70 $\pm$ 26.4*	^b 1722.30 $\pm$ 42.7*	93	48
Shelaza	^a 2573.30 $\pm$ 32.2*	^a 1456.30 $\pm$ 16.6*	^a 1117.00 $\pm$ 16.8*	130	57
Trwanish	^g 6081.00 $\pm$ 93.2*	^e 3383.70 $\pm$ 51.1*	^g 2697.40 $\pm$ 47.4*	125	56
Shahi	^f 5264.00 $\pm$ 29.9*	^d 3015.00 $\pm$ 33.0*	^{ef} 2249.00 $\pm$ 3.20*	134	57
Charput	^f 5028.10 $\pm$ 38.0*	^d 2974.20 $\pm$ 9.5*	^{de} 2053.90 $\pm$ 37.8*	145	59
Suleymania	^c 3638.60 $\pm$ 69.9*	^b 1859.60 $\pm$ 46.6*	^{bc} 1779.00 $\pm$ 30.2*	105	51
Kadana	^h 7561.70 $\pm$ 59.6*	^f 4167.30 $\pm$ 28.7*	^h 3394.40 $\pm$ 31.2*	123	55
Derishke	^{de} 3998.10 $\pm$ 45.1*	^c 2183.50 $\pm$ 26.1*	^{bc} 1814.60 $\pm$ 34.7*	120	55
Ranya	^e 4283.00 $\pm$ 29.5*	^c 2311.60 $\pm$ 30.9*	^{cd} 1971.50 $\pm$ 17.9*	117	54
Sheladize	^g 5944.20 $\pm$ 93.7*	^e 3395.70 $\pm$ 17.9*	^g 2548.50 $\pm$ 75.9*	133	57

Table 3.83. TA: Total amino acid, TE: Total essential amino acid and TNE: Total non-essential amino acid for second group ($\mu\text{g/g dw}$).

	TA	TE	TNE	TE/TNE%	TE/TA%
Maraş	^b 2603.94 $\pm$ 79.0*	^a 1370.44 $\pm$ 42.6*	^b 1233.50 $\pm$ 36.4*	111	53
Elazığ	^c 3079.31 $\pm$ 80.1*	^b 1470.16 $\pm$ 38.4*	^c 1609.15 $\pm$ 41.7*	91	48
Shelaza	^a 2397.75 $\pm$ 56.0*	^a 1332.24 $\pm$ 29.3*	^a 1065.51 $\pm$ 26.7*	125	56
Trwanish	^j 5705.66 $\pm$ 112.2*	^f 3139.27 $\pm$ 62.5*	^h 2566.39 $\pm$ 49.6*	122	55
Shahi	^h 4912.12 $\pm$ 96.4*	^e 2771.79 $\pm$ 51.3*	^f 2140.33 $\pm$ 45.1*	129	56
Charput	^g 4693.69 $\pm$ 88.9*	^e 2761.94 $\pm$ 46.4*	^e 1931.75 $\pm$ 42.5*	143	59
Suleymania	^d 3356.57 $\pm$ 88.6*	^c 1693.98 $\pm$ 45.8*	^{c,d} 1662.59 $\pm$ 42.8*	101	50
Kadana	^k 7132.05 $\pm$ 94.6*	^g 3909.23 $\pm$ 45.0*	ⁱ 3222.82 $\pm$ 49.6*	121	55
Derishke	^e 3763.73 $\pm$ 78.9*	^d 2036.30 $\pm$ 36.8*	^d 1727.43 $\pm$ 42.1*	118	54
Ranya	^f 3974.00 $\pm$ 76.7*	^d 2109.78 $\pm$ 41.5*	^e 1864.22 $\pm$ 35.3*	113	53
Sheladize	^l 5542.32 $\pm$ 139.1*	^f 3125.80 $\pm$ 74.2*	^g 2416.52 $\pm$ 64.9*	129	56

Table 3.84. TA: Total amino acid, TE: Total essential amino acid and TNE: Total non-essential amino acid for third group ($\mu\text{g/g dw}$).

	TA	TE	TNE	TE/TNE%	TE/TA%
Maraş	^b 2390.57 $\pm$ 79.1*	^a 1243.06 $\pm$ 41.1*	^b 1147.51 $\pm$ 37.9*	108	52
Elazığ	^c 2857.86 $\pm$ 87.7*	^b 1337.84 $\pm$ 37.8*	^c 1520.02 $\pm$ 50.0*	88	47
Shelaza	^a 2201.13 $\pm$ 56.5*	^a 1205.82 $\pm$ 29.0*	^a 995.31 $\pm$ 27.6*	121	55
Trwanish	^l 5256.01 $\pm$ 114.7*	^f 2824.88 $\pm$ 61.9*	^h 2431.13 $\pm$ 52.8*	116	54
Shahi	^h 4558.79 $\pm$ 95.3*	^e 2518.22 $\pm$ 48.7*	^f 2040.57 $\pm$ 46.5*	123	55
Charput	^g 4393.77 $\pm$ 89.3*	^e 2552.06 $\pm$ 45.1*	^e 1841.71 $\pm$ 44.2*	139	58
Suleymania	^d 3121.90 $\pm$ 77.0*	^c 1544.46 $\pm$ 41.0*	^{c,d} 1577.44 $\pm$ 36.0*	98	49
Kadana	^j 6637.92 $\pm$ 94.9*	^g 3549.16 $\pm$ 44.8*	ⁱ 3088.76 $\pm$ 50.1*	115	53
Derishke	^e 3471.72 $\pm$ 77.9*	^d 1844.76 $\pm$ 35.6*	^d 1626.96 $\pm$ 42.3*	113	53
Ranya	^f 3671.87 $\pm$ 79.6*	^d 1910.92 $\pm$ 40.7*	^e 1760.95 $\pm$ 38.9*	109	52
Sheladize	^l 5096.19 $\pm$ 134.9*	^f 2819.75 $\pm$ 71.4*	^g 2276.44 $\pm$ 63.5*	124	55

The total amino acid values ranged between 2573.30 $\pm$ 32.2 to 7561.70 $\pm$ 59.6 $\mu\text{g/g dw}$. While total essential amino acid amounts ranged between 1456.30 $\pm$ 16.6 to 4167.30 $\pm$ 28.7 $\mu\text{g/g dw}$ in fresh samples.

In their study, Prasad and Chandra (2018) determined the concentrations of essential amino acids in *P. indica*, *E. thymifolia*, and *P. hirta* to be 33.58, 57.99, and 145.82 mg/g dw, respectively. Additionally, the total amino acid concentrations were reported as 58.8, 123.92, and 225.73 mg/g dw for the corresponding plants [237].

The grown *Nitraria tangutorum* Bobr fruit in Nuomuhong has a total of 53.51 mg/g dw of essential amino acids and 71.33 mg/g dw of non-essential amino acids. It has been noted that a good protein source should have TE/TA and TE/TNE ratios above 40% and 60%, respectively [238].

According to the data shown in Table 3.82, Table 3.83 and Table 3.84 the TE/TA and TE/TNE ratios of all sumac samples exceed 40% and 60% respectively, except in Maraş region the TE/TA ratio are less than 40% for the first group. Based on these findings, it can be concluded that the ratios of essential amino acids in all the samples examined exceed the necessary quantity.

4. CONCLUSIONS

From the findings, it might be said that sumac samples can be considered a good source for major elements except phosphorus. In terms of nutrition, it is seen that all sumac samples are sufficiently rich in zinc, copper, iron, selenium, manganese, nickel, and molybdenum. From the findings, it can be said that the arsenic, cadmium, mercury, and lead contents of the sumac samples do not pose a health risk when it is taken with food as a flavor-enhancing spice. It can be said that THQ and TTHQ values calculated for minor, toxic, and heavy metals in sumac samples are much less than 1.0, so it does not pose a health risk in terms of nutrition.

It was observed that all parameters (Amino acids, Vitamin C and Water-soluble vitamins, vitamin A, vitamin E, β -carotene, Lycopene, GSH, total phenolic, flavonoid substance and total antioxidant capacity) of all sumac samples decreased significantly compared to freshly ground ones. However, the amount of decrease is lower in the oiled samples. The reason why the loss in the parameters examined in oiled samples is less can be explained by the fact that the oil forms a film layer on the sumac surface.

In terms of vitamin content, all the examined sumac samples are a good source of vitamin other than ascorbic acid. Third group samples show a loss percentage greater than other groups. This demonstrates the efficacy of using oil as a preservative. The levels of phenolic compounds, flavonoids, and antioxidant capacity were greater in both first and second group fruit sample compared to the quantities found in third group samples fruits.

It was found that Shalidize, Süleymania and Elazığ regions were richer than other regions in terms of total phenolic and flavonoid substances. It was concluded that the richest regions in terms of antioxidant capacity were Süleymania and Shalidize, while the poorest regions were Charput and Kadana. In regions where the total amount of phenolic and flavonoid substances is high, antioxidant capacity was also found to be high. The loss of measured values in an oiled samples less than in the samples kept without oil. Sumac is thought to be a potential source for functional food production due to its high amount of phenolic compounds and antioxidant capacity. Differences in total phenolic, flavonoid substance and antioxidant capacity amounts between regions might be depending on geographical and ecological conditions.

Furthermore, the concentration of reduced glutathione in third group sample fruits showed a decline, whereas the levels of oxidised glutathione, 4-HNE, and malondialdehyde showed a rise. In the context of amino acids, sumac has significant potential for utilisation in critical industries such as medicines and food additives, particularly sumac sourced from the Kadana region, which exhibits a total essential amino acid content of 3667.17 $\mu\text{g/g dw}$. The second group fruit samples experienced a percentage loss of less than 20% for most examined biochemical parameters, this indicates that oil is a beneficial factor for preserving food and its biochemical components.

Additionally, oil is odourless and has a pleasant taste. By incorporating these oils into foods, the growth of bacteria and other microorganisms can be hindered, thereby prolonging the product's shelf life. Moreover, oil may provide a protective barrier that effectively inhibits oxidation and food decomposition. The variation of examined parameters among the samples could be made by geographical and ecological condition in addition to differences of sumac species grown in different regions.

The Kadana region exhibited the highest levels of aspartic acid, glutamic acid, asparagine, glutamine, alanine, tyrosine, arginine, cysteine, histidine, leucine, isoleucine, and phenylalanine among all other regions. Conversely, the concentration of valine in the Kadana region was found to be the lowest.

In the Maraş area, the concentrations of phenylalanine, leucine, cysteine, glutamine, arginine, and proline were the lowest. Similarly, in the Suleymania region, the quantities of serine, threonine, methionine, isoleucine, tryptophane, and lysine were found to be the lowest. Additionally, in the shelaza region, the concentrations of aspartic acid, asparagine, alanine, and histidine were found to be the lowest.

Sumacs from the areas of Kadana and Sheladize have been found to have a high concentration of non-essential amino acids, while sumacs from the regions of Shelaza and Maraş have been found to contain a low concentration. In terms of the necessary essential amino acids, the sumac that was collected from the areas of Kadana and Sheladize was found to be more abundant, while the sumac that was taken from the regions of Suleymania and Maraş was found to be deficient. It is possible to assert that all of the sumac samples that were analysed had a high concentration of glutamic acid, histidine, and alanine, but a low concentration of glycine. While the overall number of essential amino acids varied from 1456.30 to 4167.30, 1332.24 to 3909.23, and 1205.82 to 3549.16 µg/g dw for the first, second, and third groups, respectively, the sumac of the Kadana area was found to have the largest amount of these amino acids. When it came to the sumac samples that were analysed, the TE/TNE ratio varied from 64% to 145%, 91% to 143%, and 88% to 139% for the first, second, and third groups, respectively. The ratio of TE/TA ranges from 39% to 59% for the first group, 48% to 59% for the second group, and 47% to 58% for the third group. Taking into consideration these findings, it is possible to assert that sumac samples are an excellent supplier of necessary amino acids. There may be a connection between the variances in the quantity of essential and non-essential amino acids found in various samples and the geographical and ecological differences that exist between them.

RECOMMENDATIONS

Vitamins, total antioxidant capacity, and amino acids are some biochemical parameters in sumac that are influenced by ecological and storage conditions. Sumac is commercially distributed in local markets in ground form. To determine how oxidation affects certain biochemical parameters in ground sumac, samples of ground sumac were stored at 4°C for six months in both oiled coated and unoled coated conditions. Consequently, a reduction in losses was observed in the samples that were maintained in a lubricated state. As a consequence, it is advisable to prepare sumac for use as a spice immediately prior to ingestion by grinding it. When pulverised sumac is to be stored for an extended period of time, it is advisable to subject it to oiling. The development of sumac cultivation in appropriate regions can be facilitated by considering the parameters that are assessed in sumac samples.

Further biochemical investigations are required to enhance the marketing of sumac which is used as a spice.

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APPENDICES

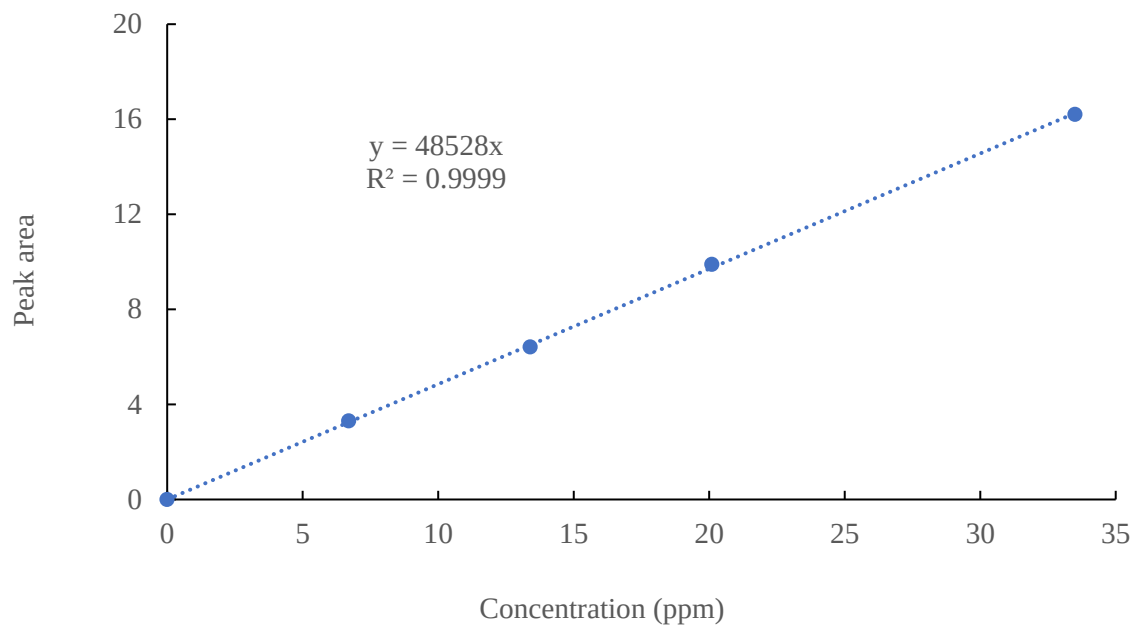


Figure A 1. Working graph for the correct equation of vitamin C

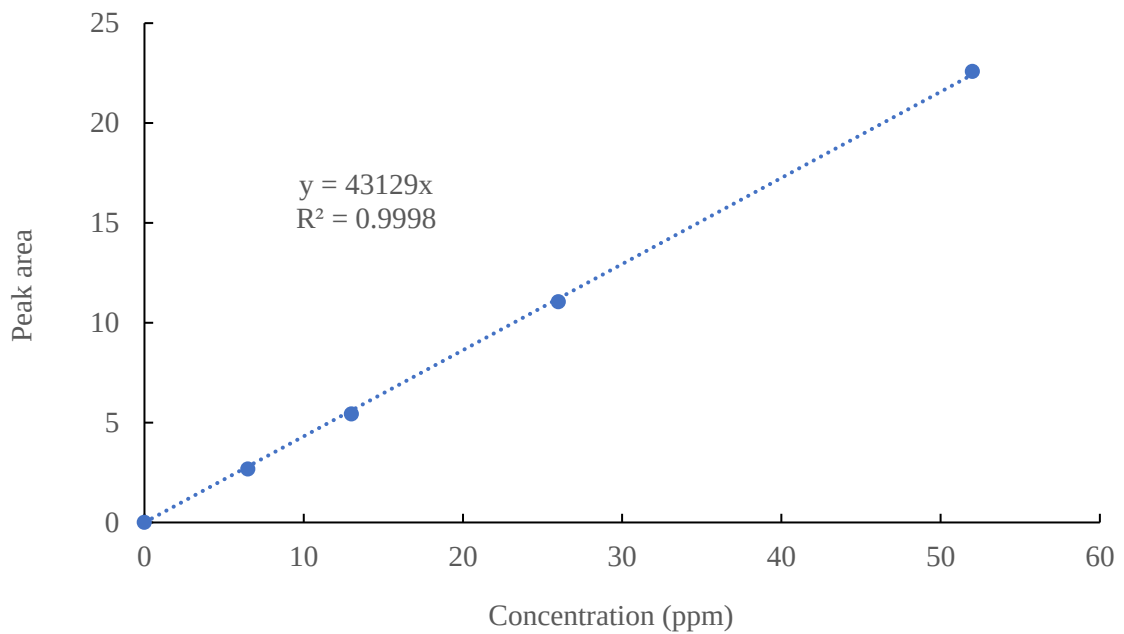


Figure A 2. Working graph for the correct equation of vitamin B1

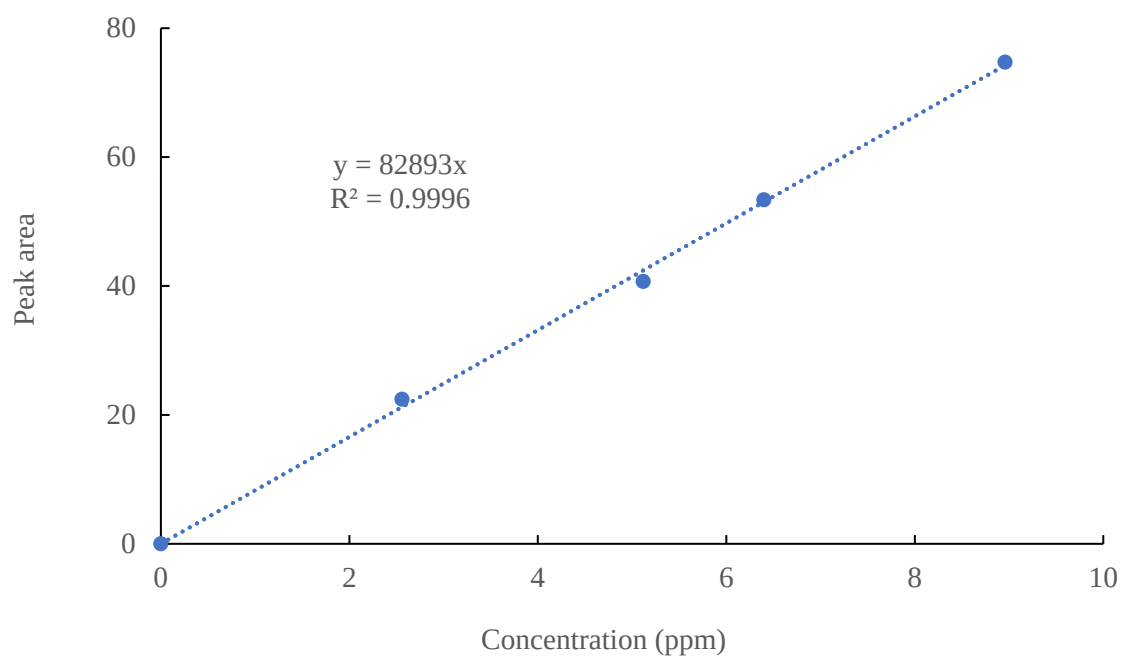


Figure A 3. Working graph for the correct equation of vitamin B2

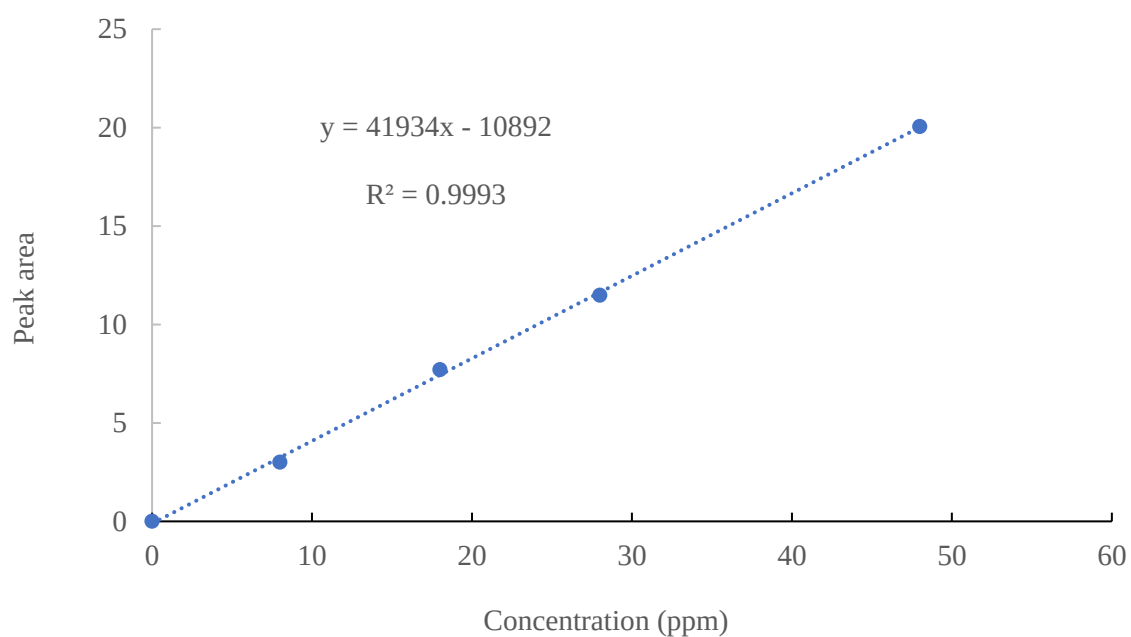


Figure A 4. Working graph for the correct equation of nicotinic acid

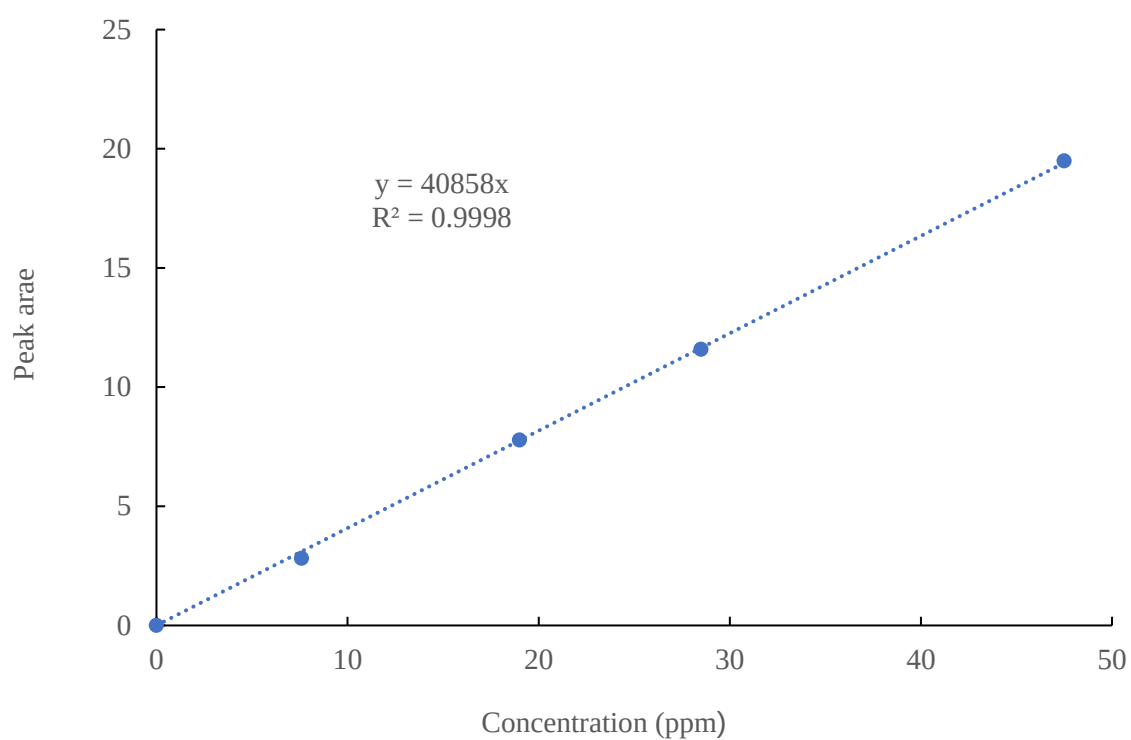


Figure A 5. Working graph for the correct equation of nicotinamide

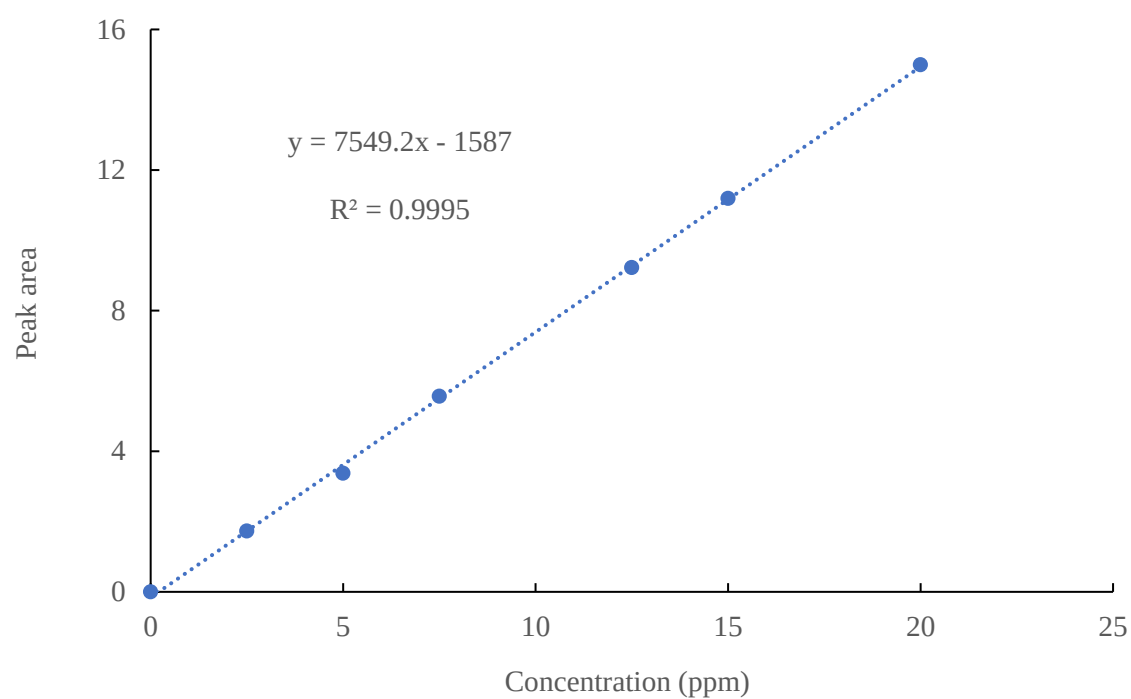


Figure A 6. Working graph for the correct equation of vitamin B5

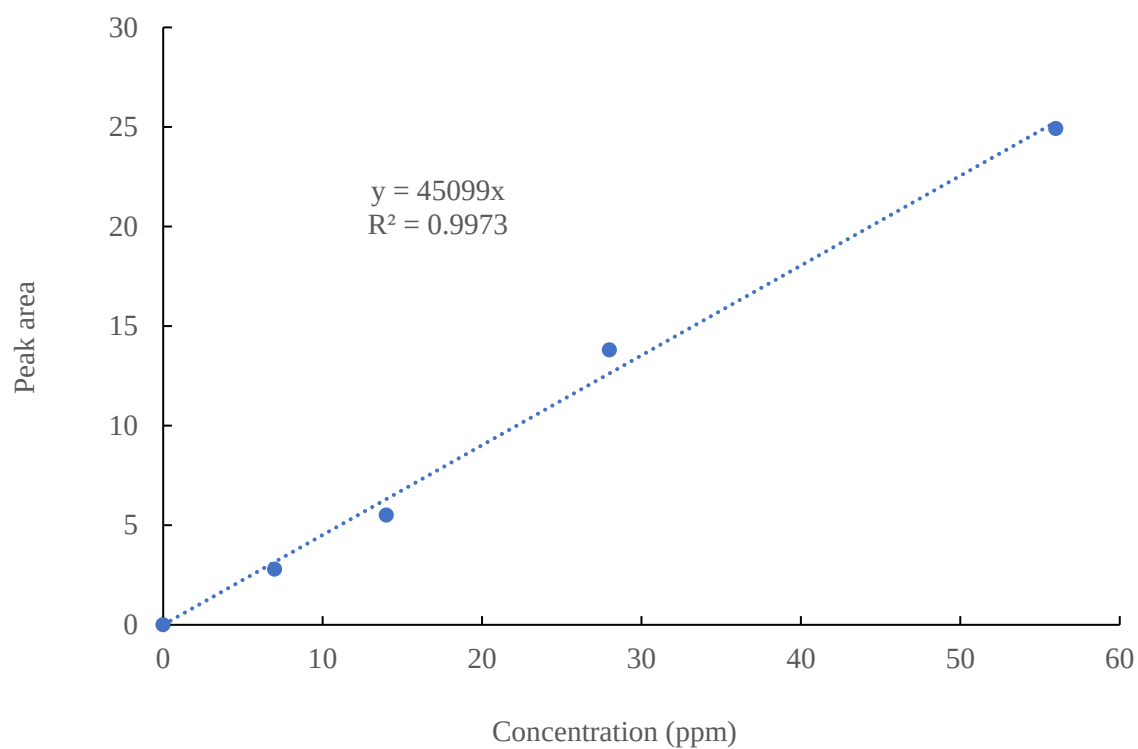


Figure A 7. Working graph for the correct equation of vitamin B6

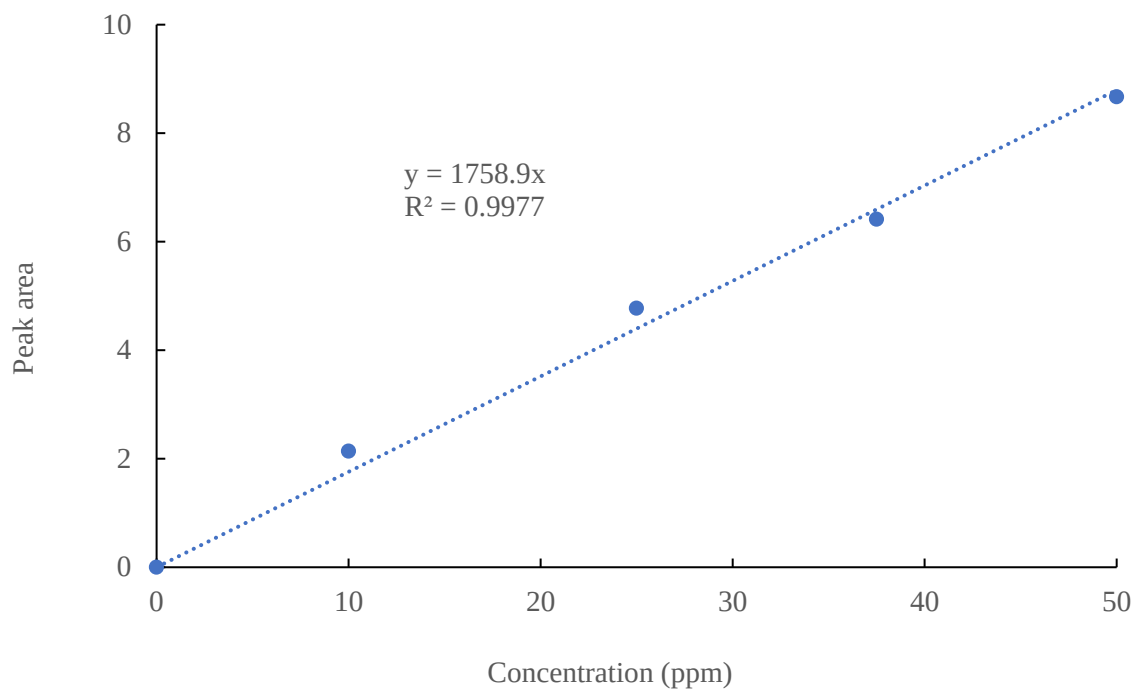


Figure A 8. Working graph for the correct equation of vitamin B

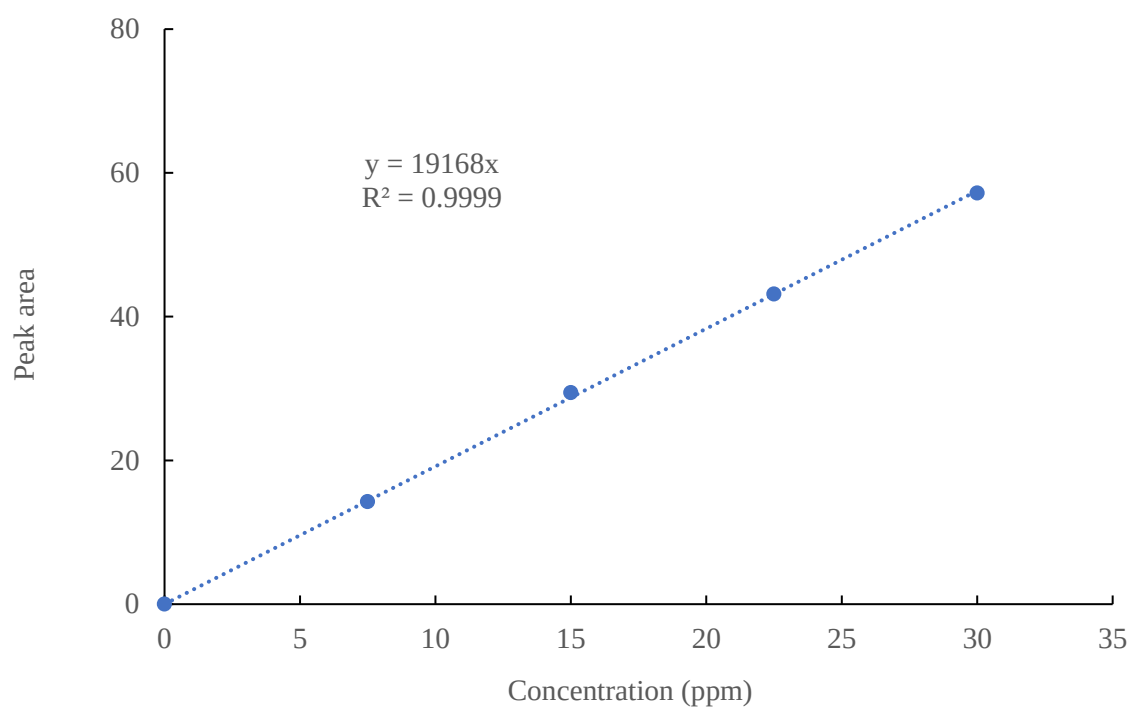


Figure A 9. Working graph for the correct equation of vitamin B12

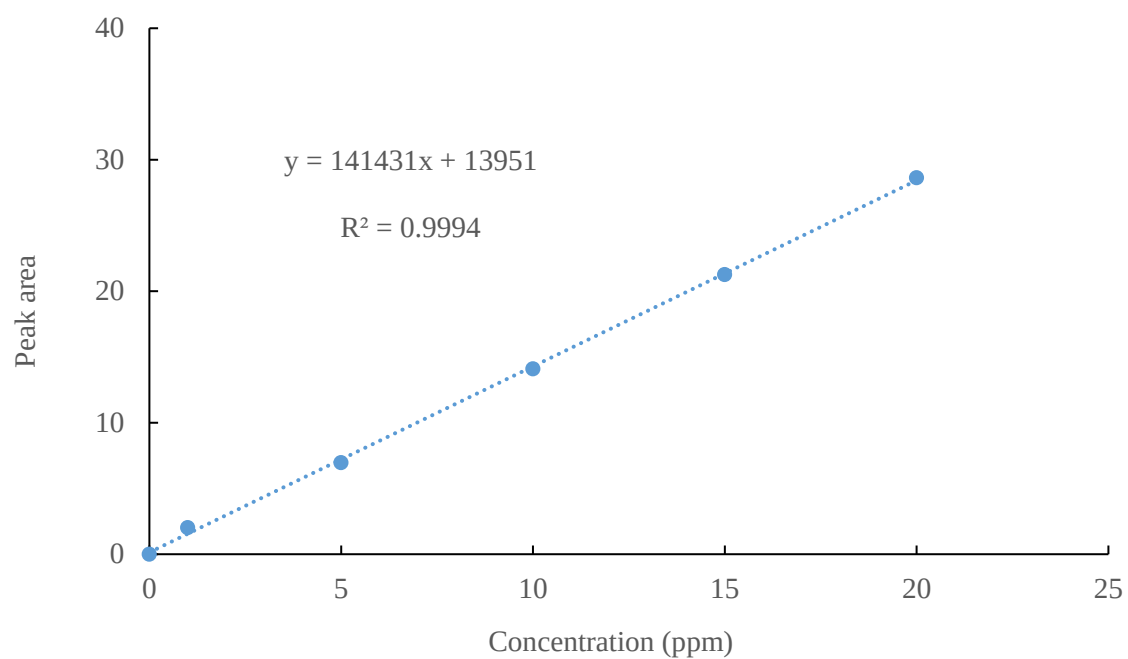


Figure A 10. Working graph for the correct equation of vitamin A

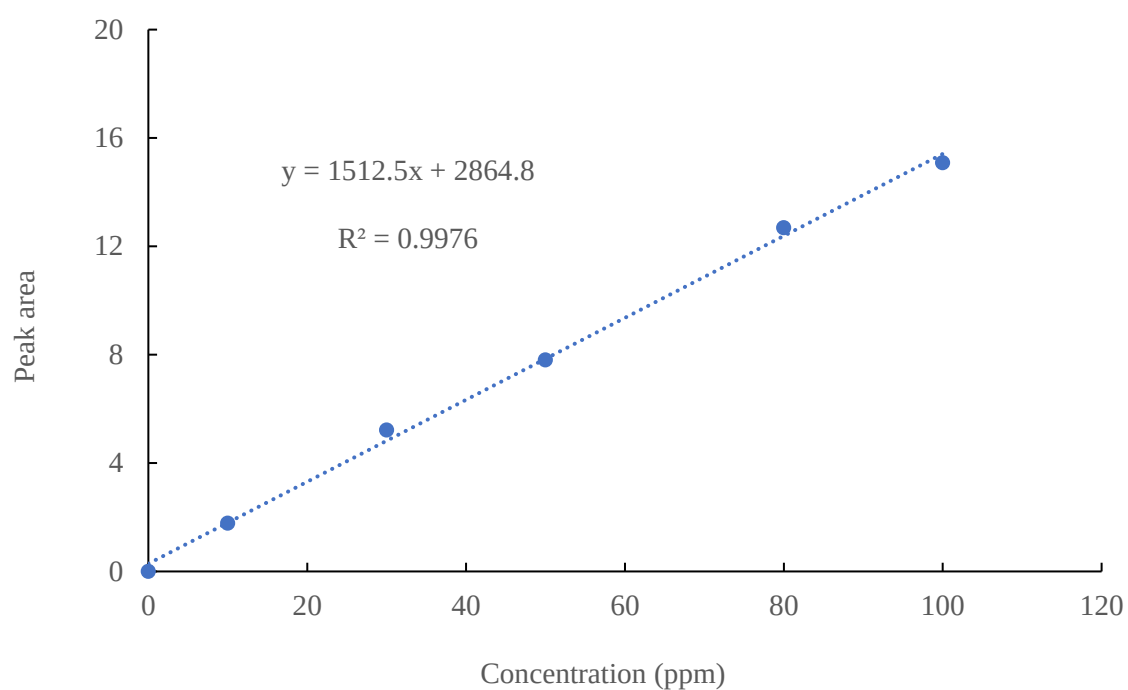


Figure A 11. Working graph for the correct equation of vitamin E

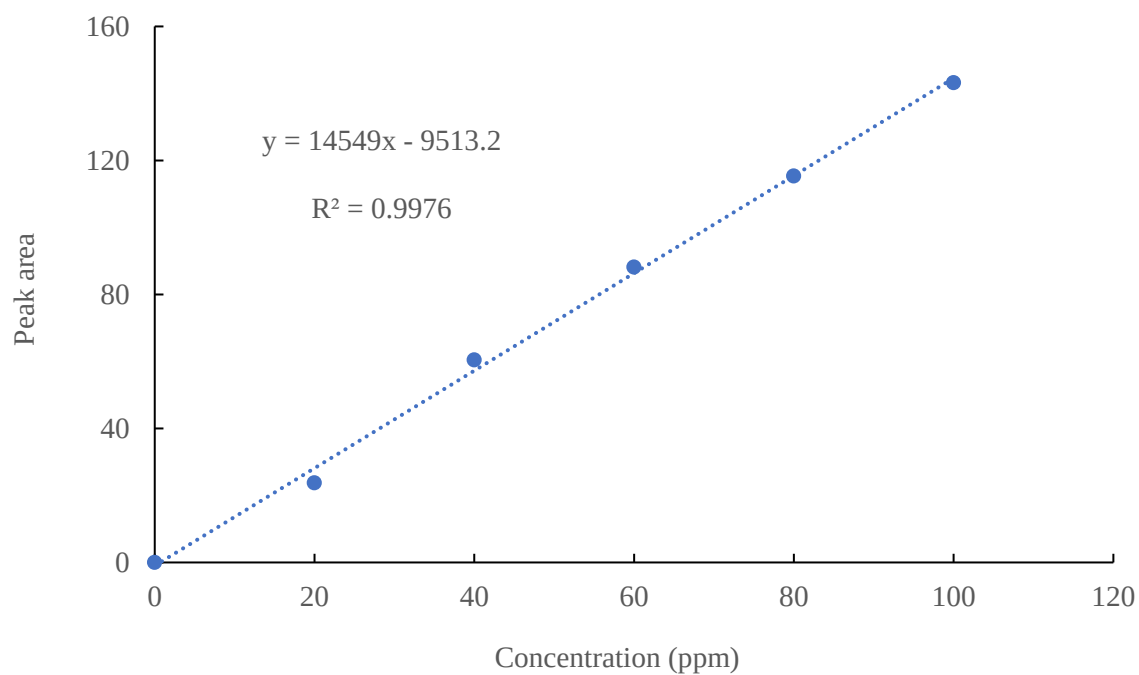


Figure A 12. Working graph for the correct equation of β -carotene

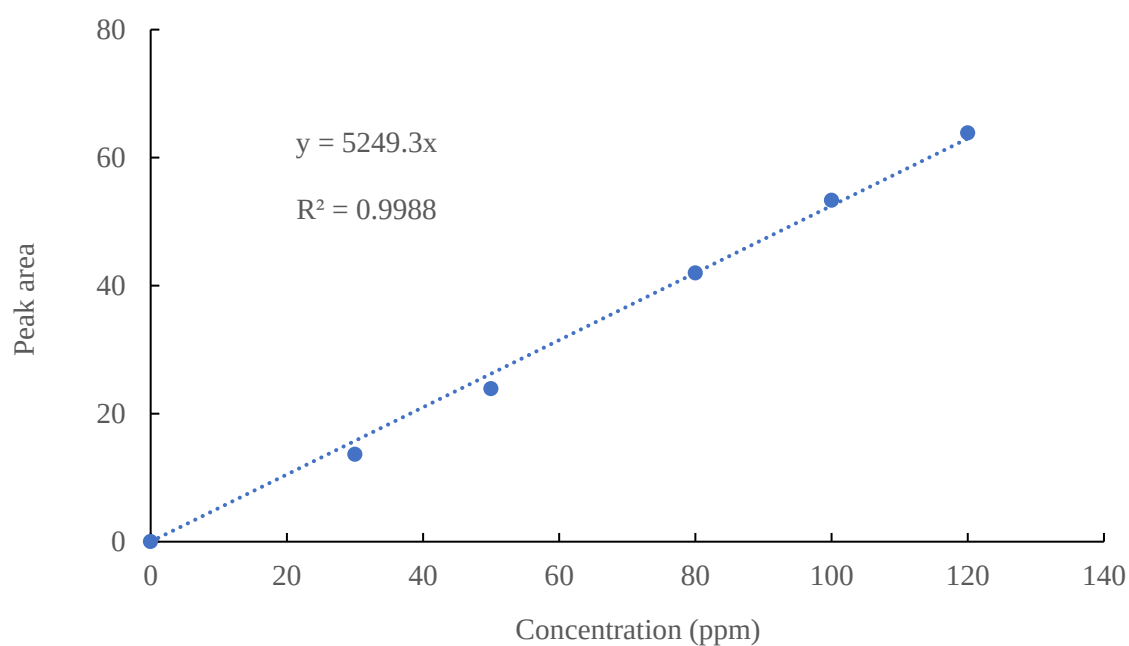


Figure A 13. Working graph for the correct equation of lycopene

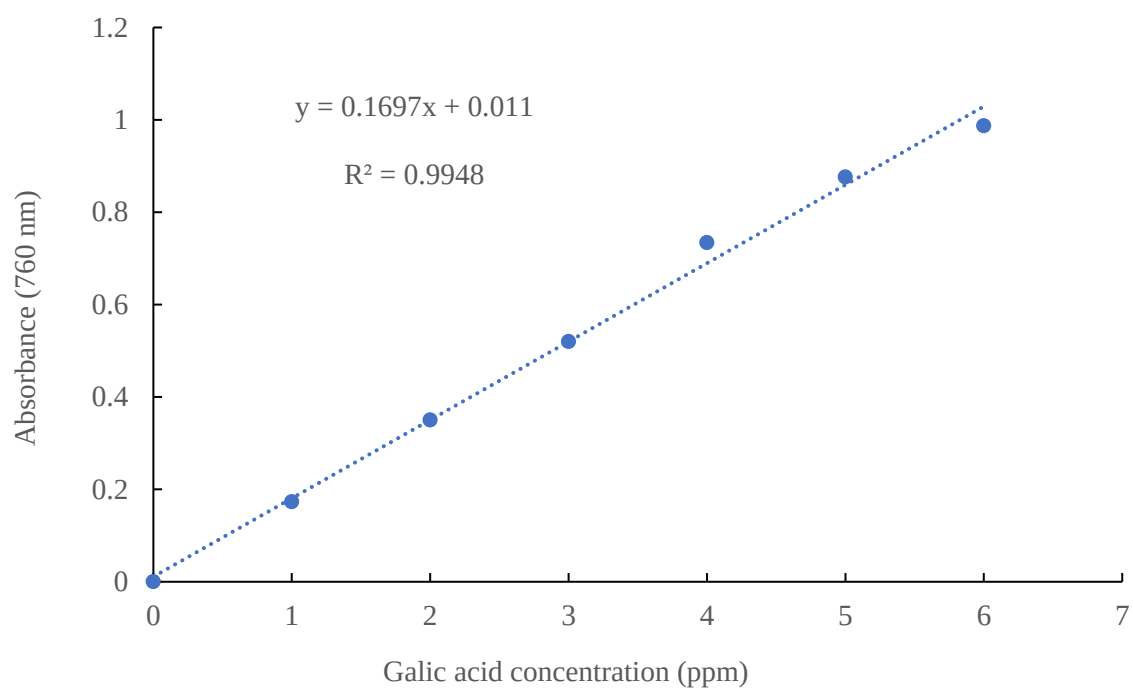


Figure A 14. Working graph for the correct equation of total phenolic acid

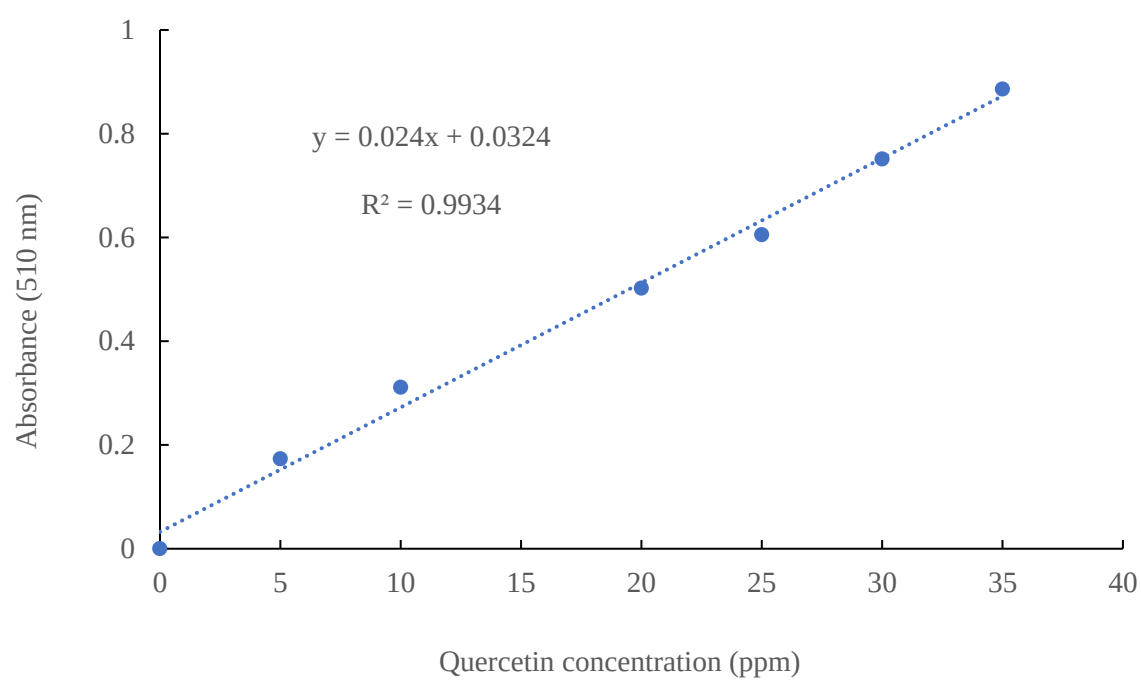


Figure A 15. Working graph for the correct equation of total flavonoids

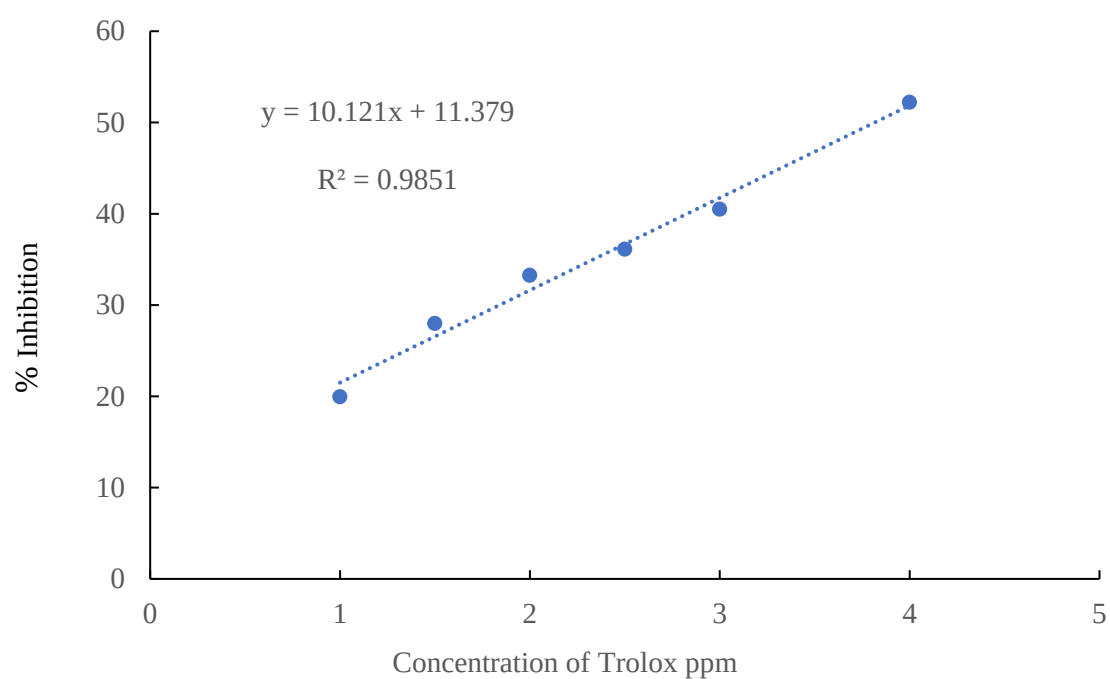


Figure A 16. Working graph for the correct equation of trolox

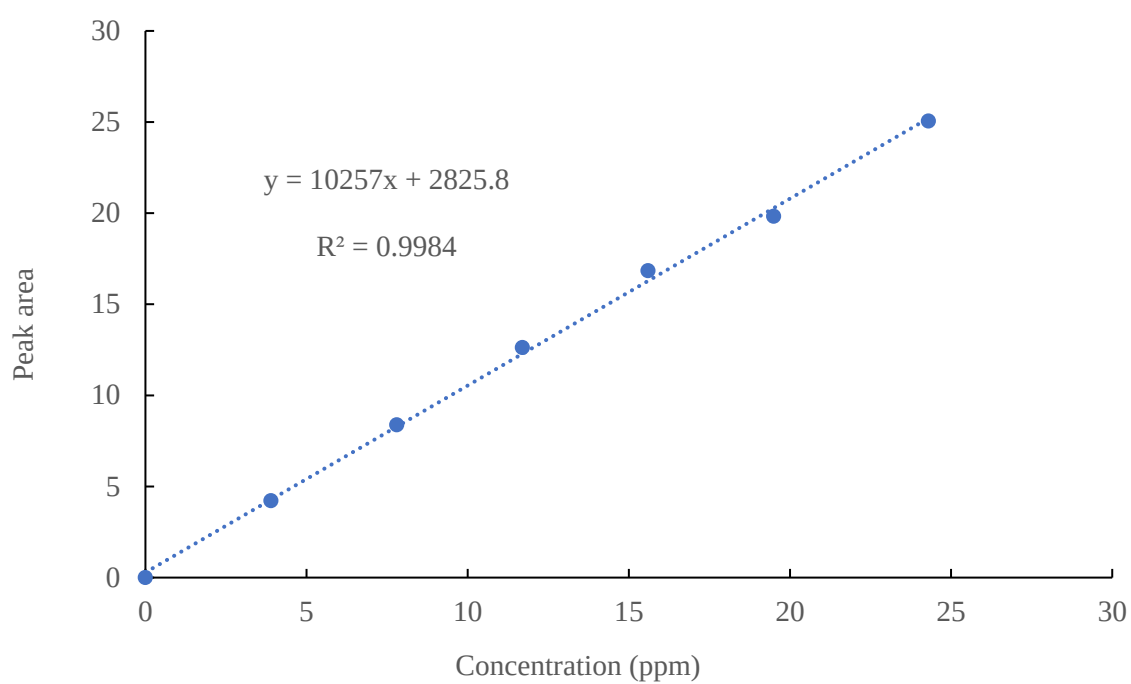


Figure A 17. Working graph for the correct equation of GSH

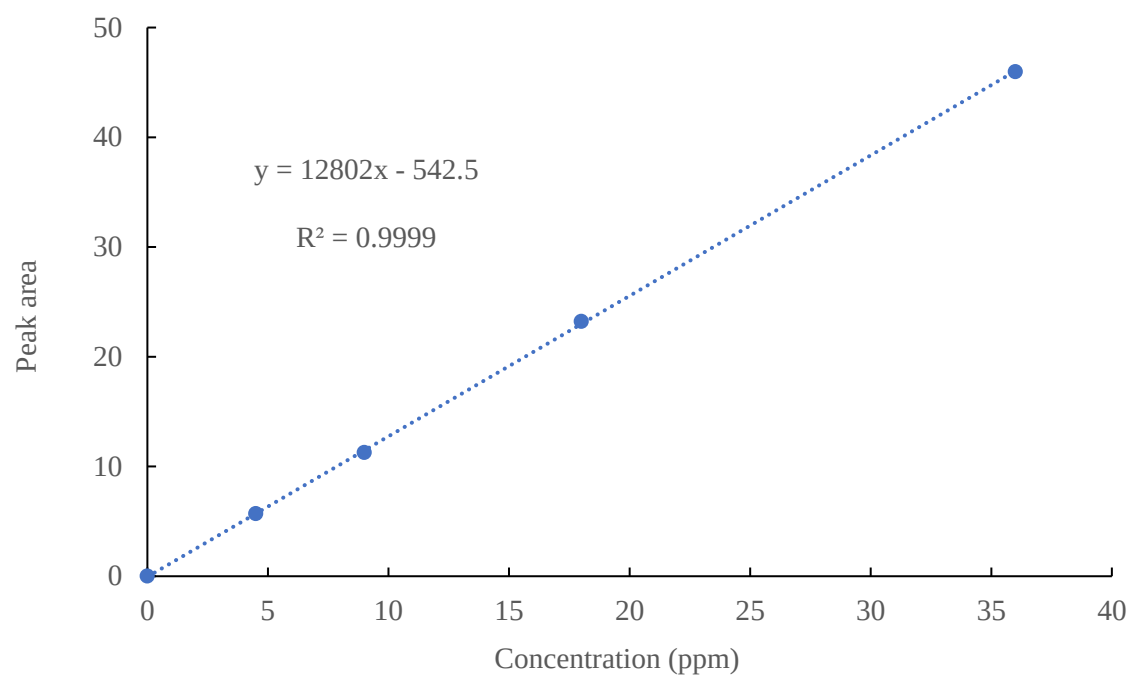


Figure A 18. Working graph for the correct equation of GSSG

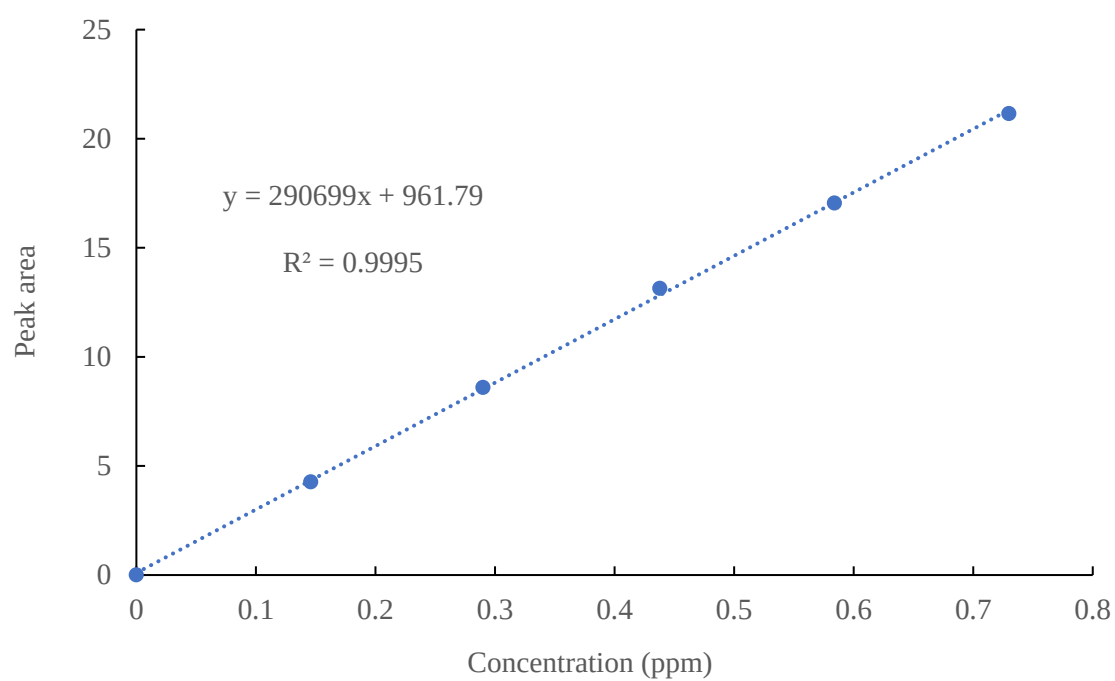


Figure A 19. Working graph for the correct equation of MDA

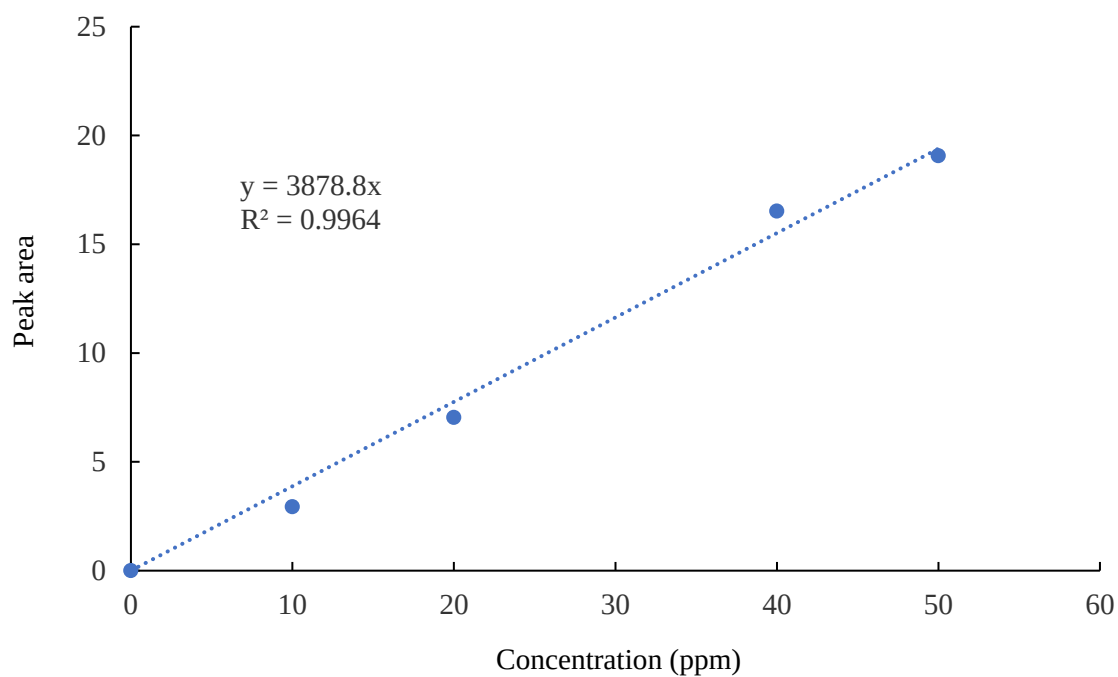


Figure A 20. Working graph for the correct equation of 4-HNE

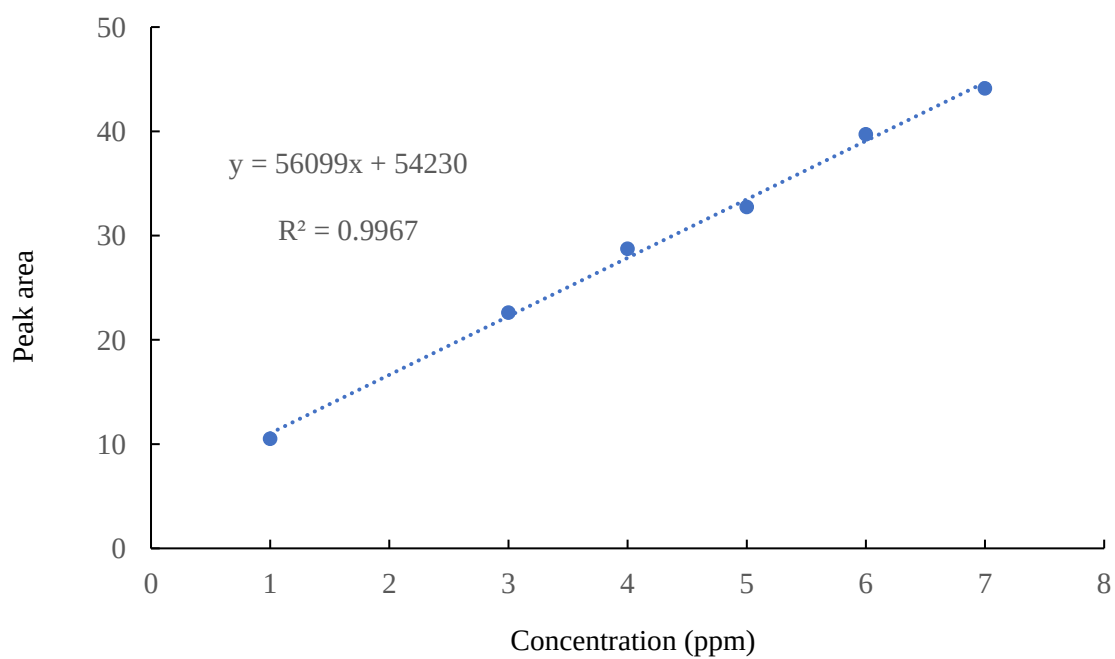


Figure A 21. Working graph for the correct equation of aspartic acid

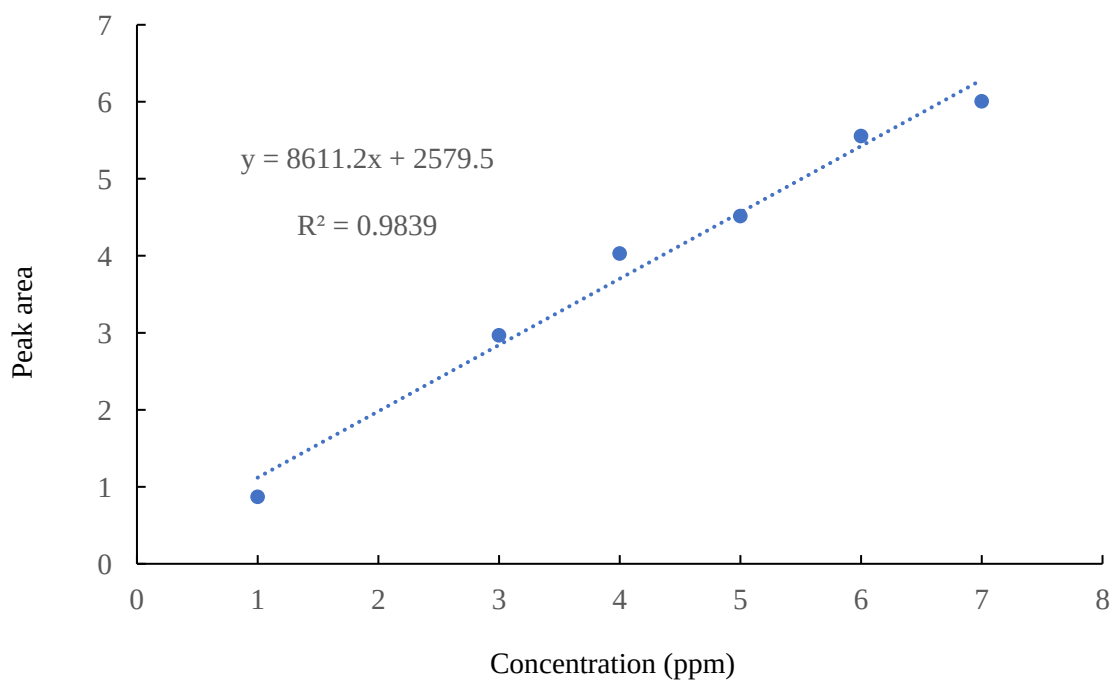


Figure A 22. Working graph for the correct equation of glutamic acid

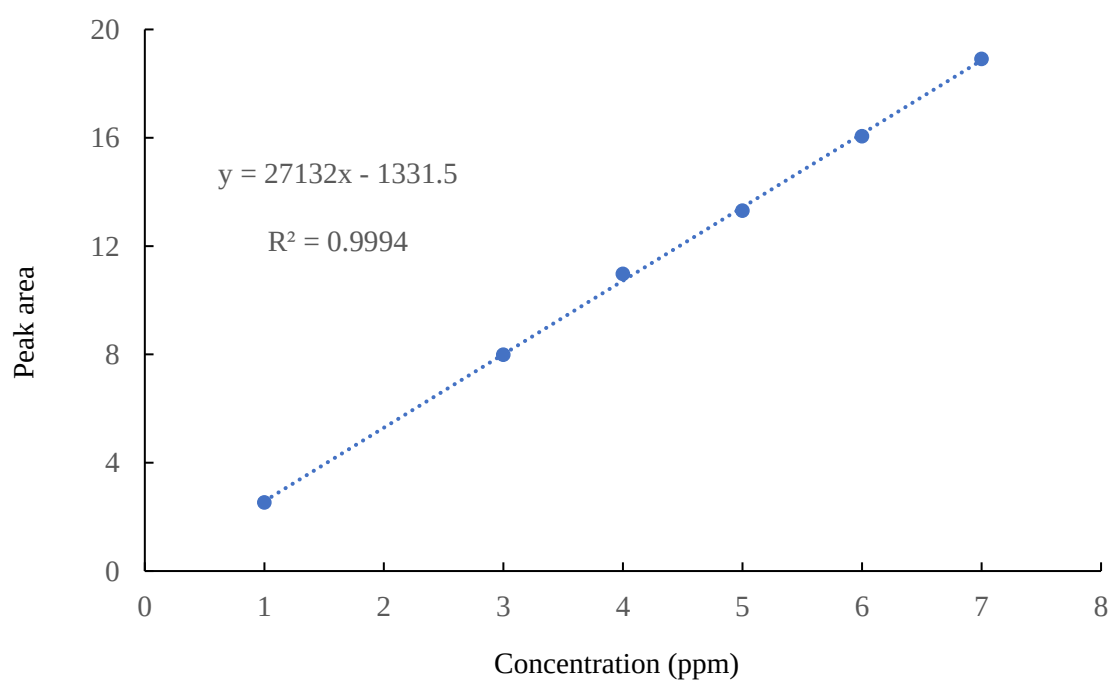


Figure A 23. Working graph for the correct equation of asparagine

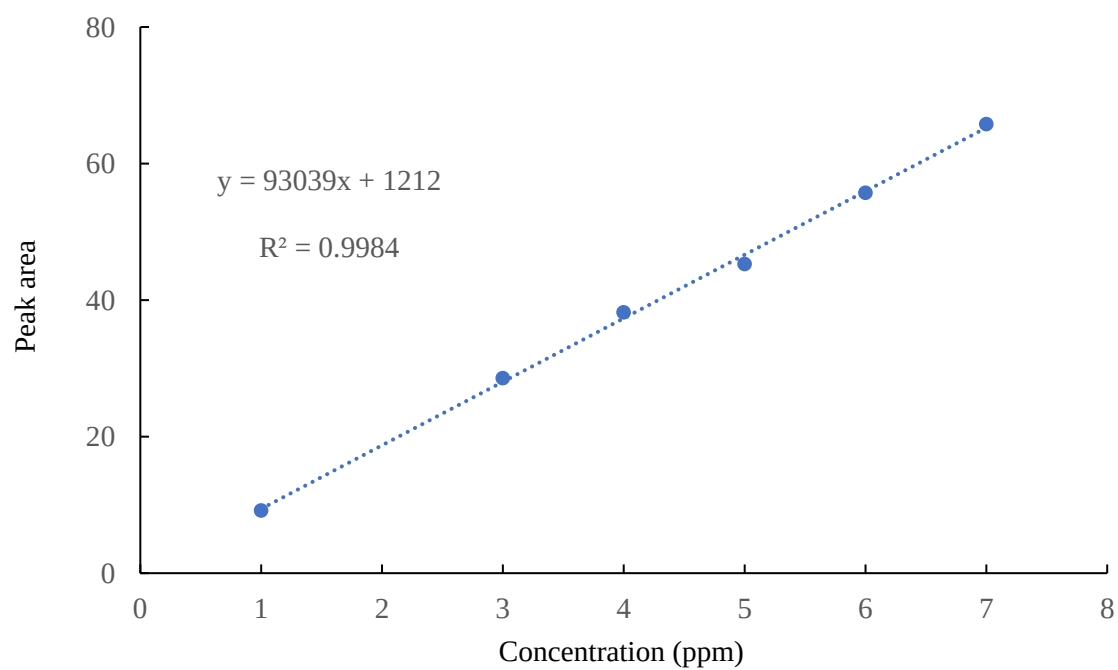


Figure A 24. Working graph for the correct equation of serine

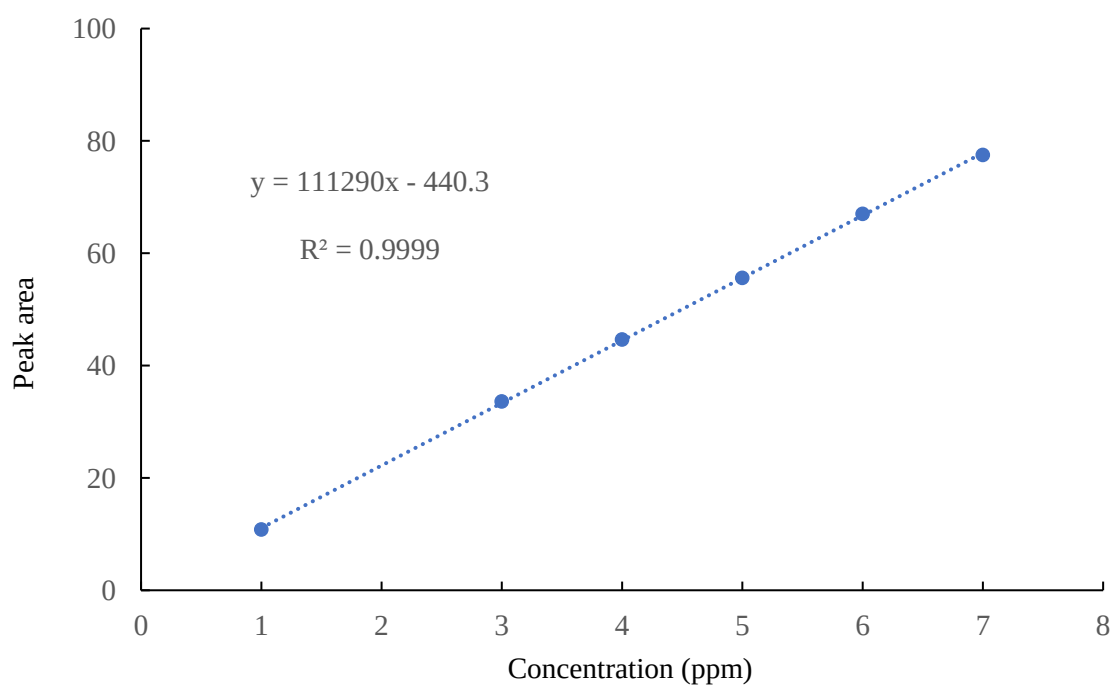


Figure A 25. Working graph for the correct equation of glycine

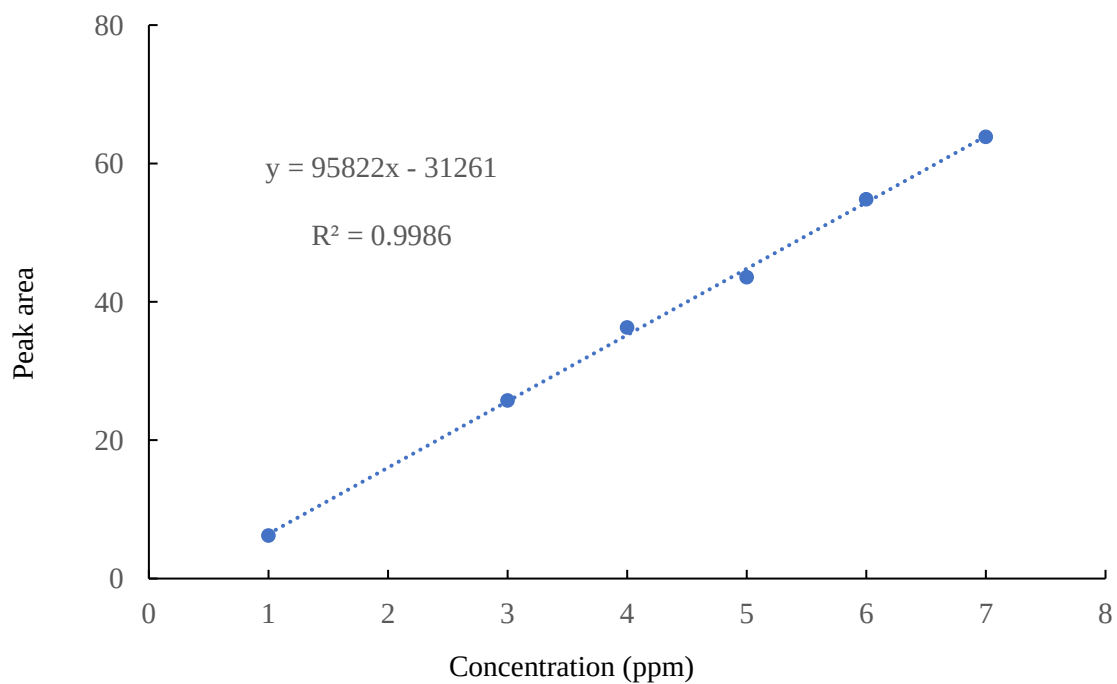


Figure A 26. Working graph for the correct equation of glutamine

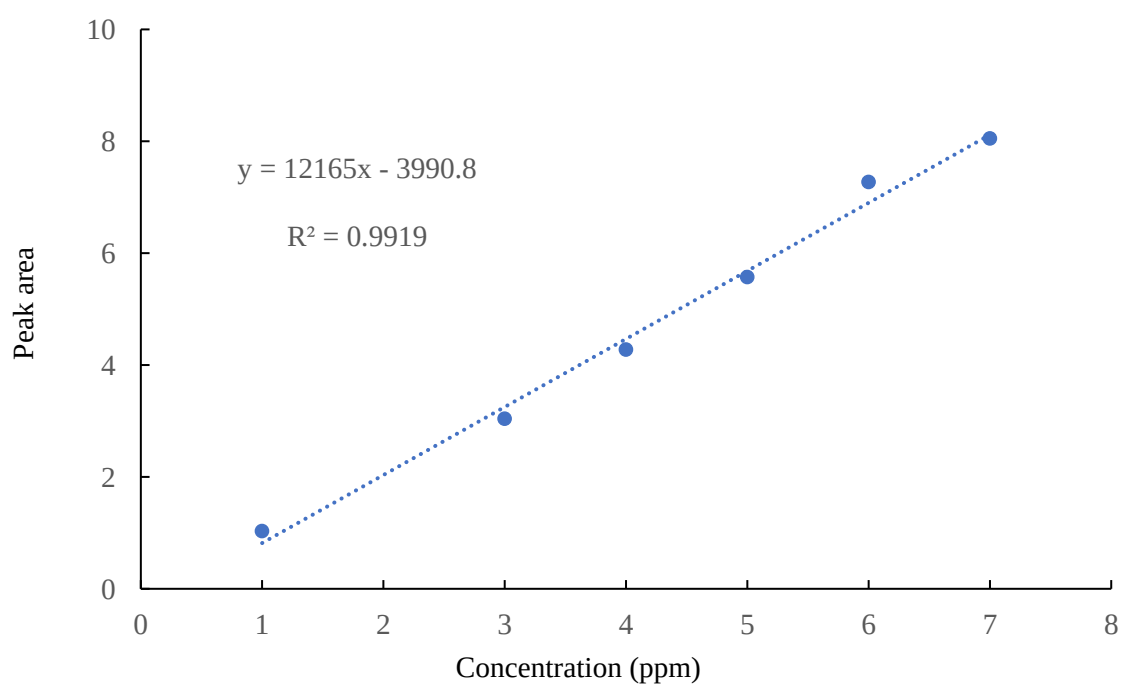


Figure A 27. Working graph for the correct equation of alanine

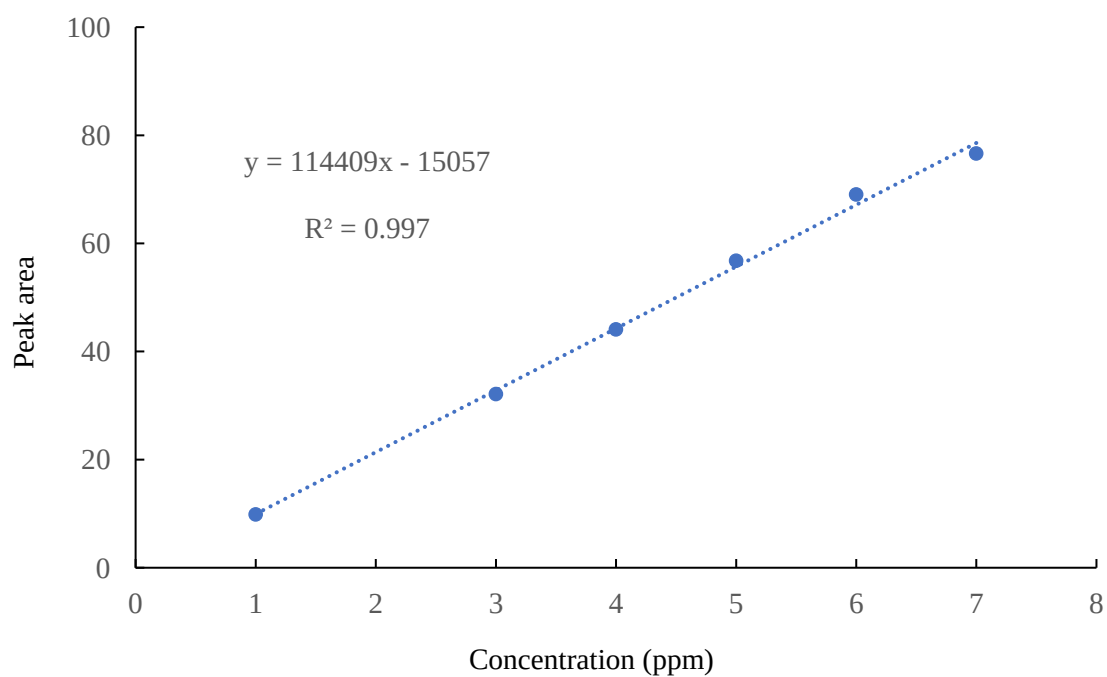


Figure A 28. Working graph for the correct equation of proline

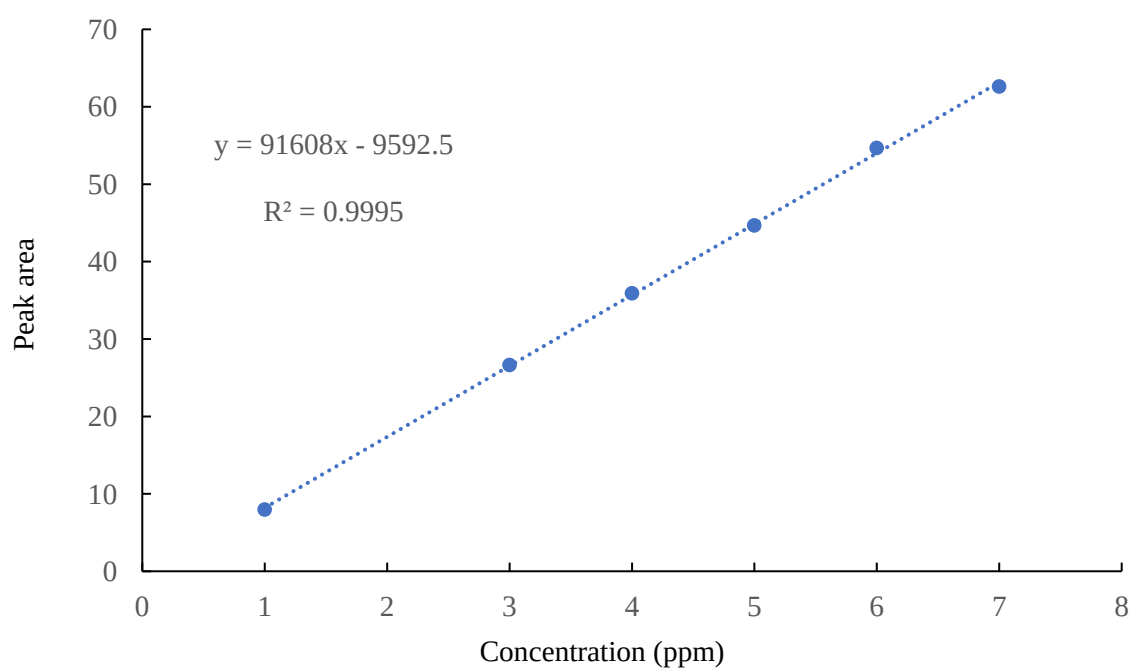


Figure A 29. Working graph for the correct equation of tyrosine

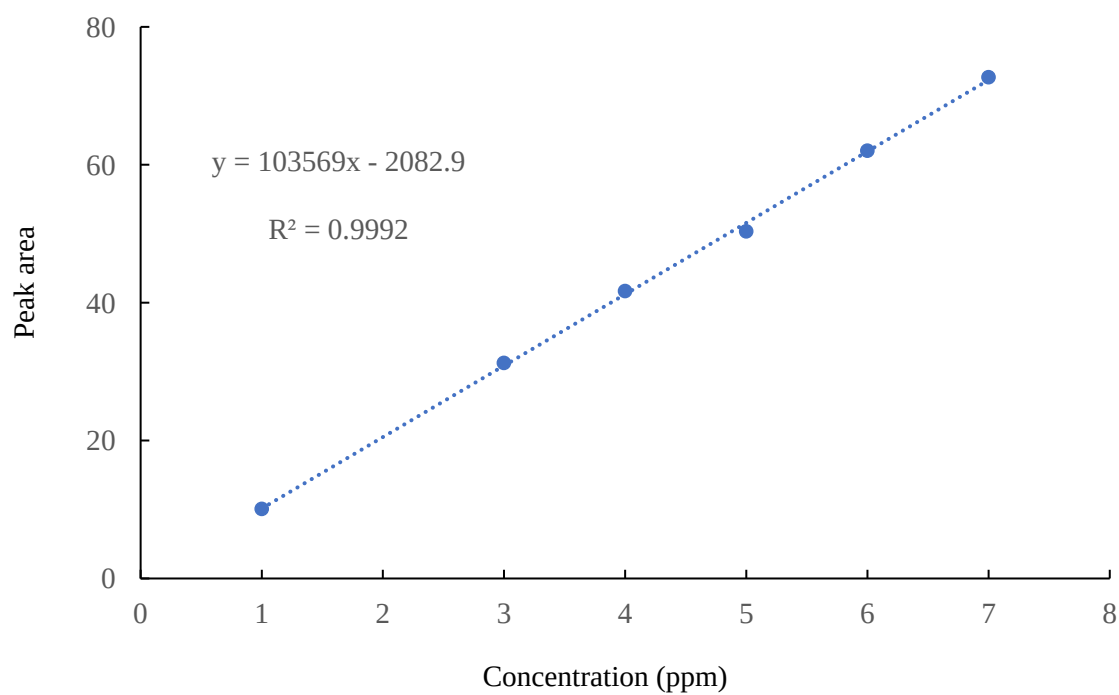


Figure A 30. Working graph for the correct equation of arginine*

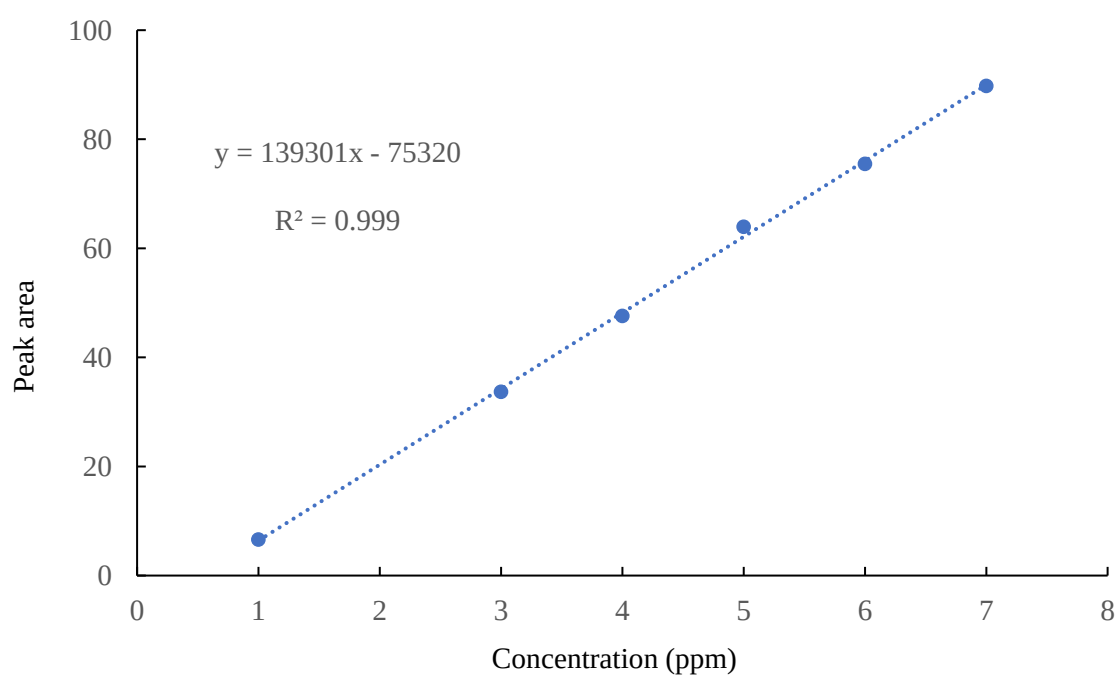


Figure A 31. Working graph for the correct equation of cysteine

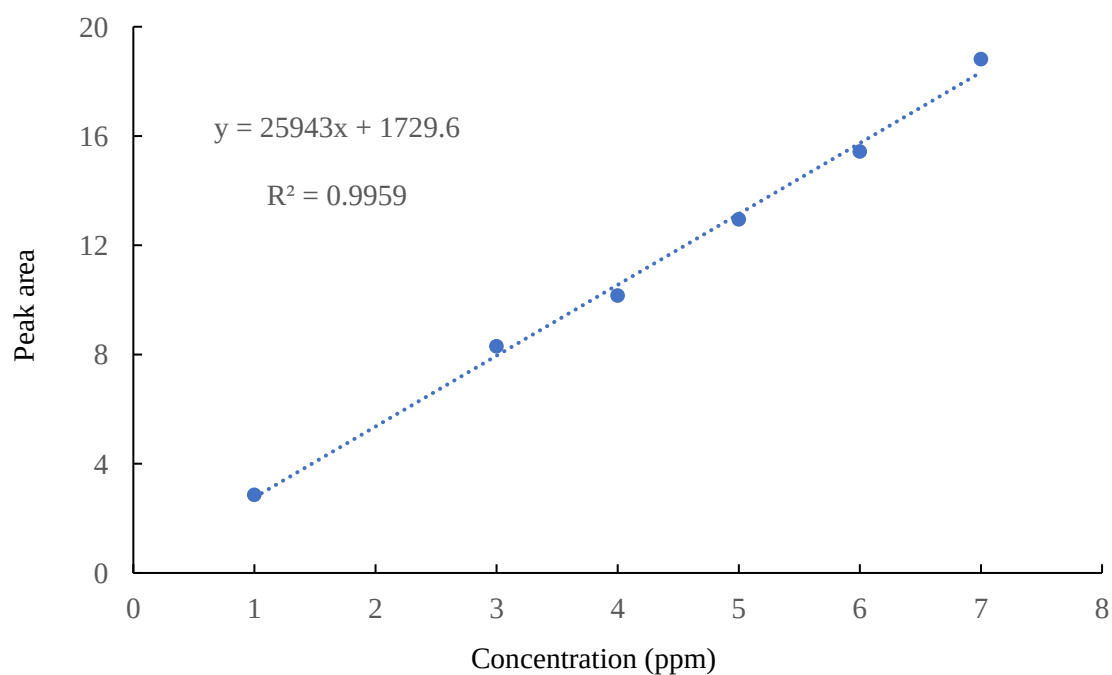


Figure A 32. Working graph for the correct equation of histidine*

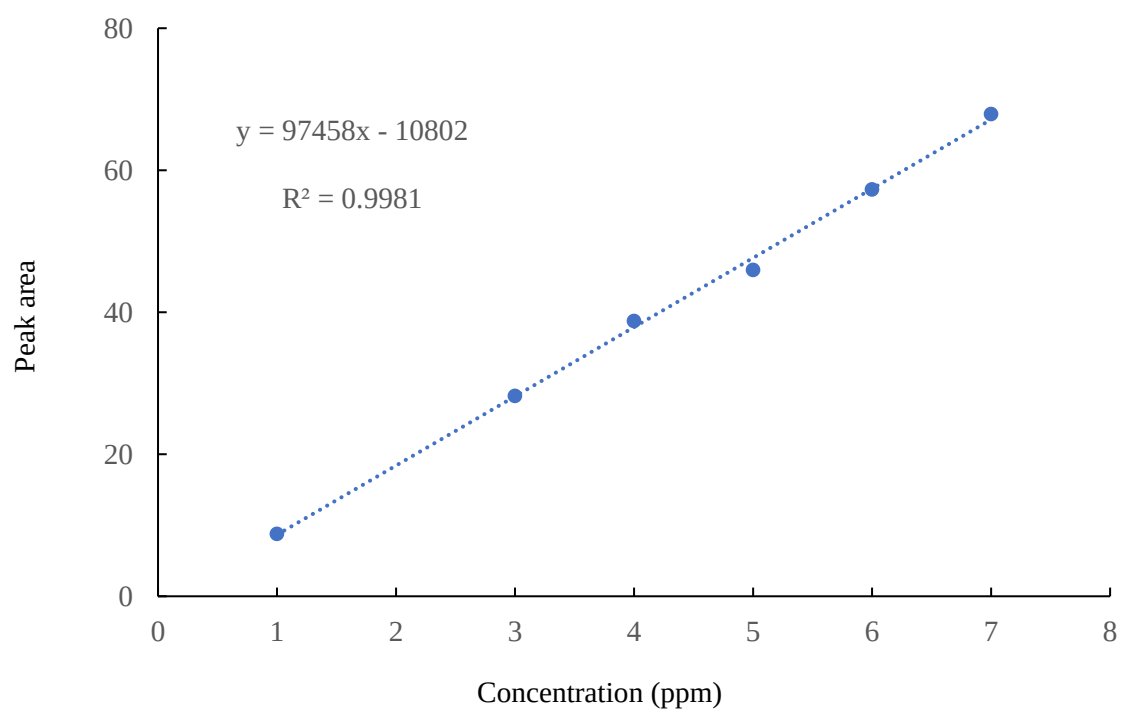


Figure A 33. Working graph for the correct equation of threonine*

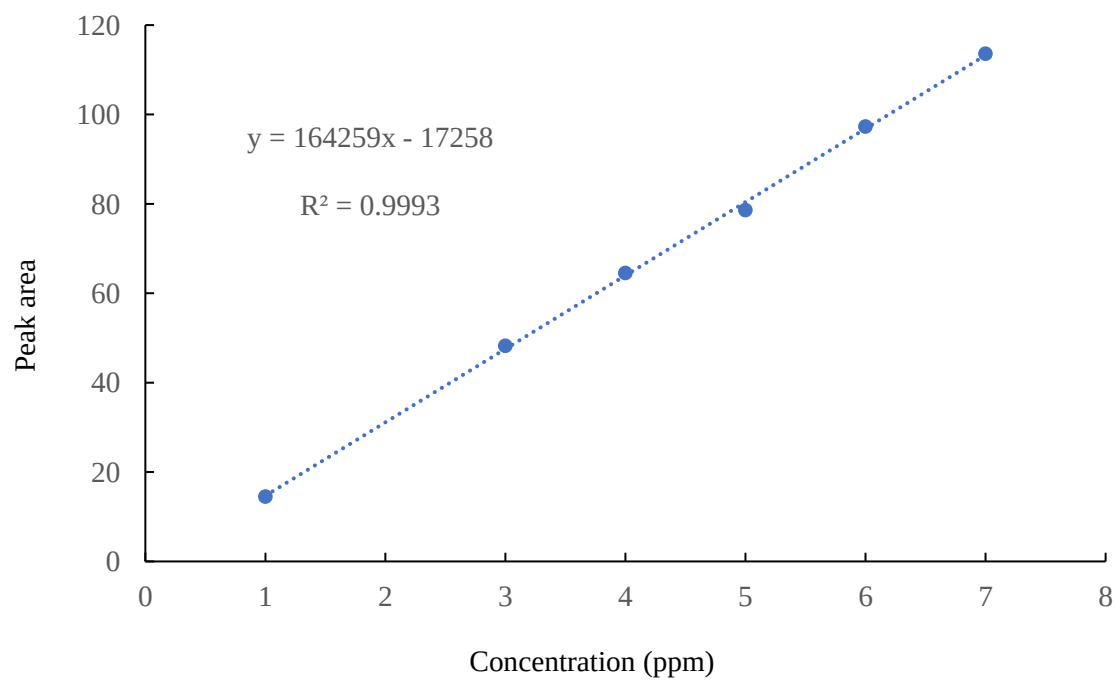


Figure A 34. Working graph for the correct equation of valine*

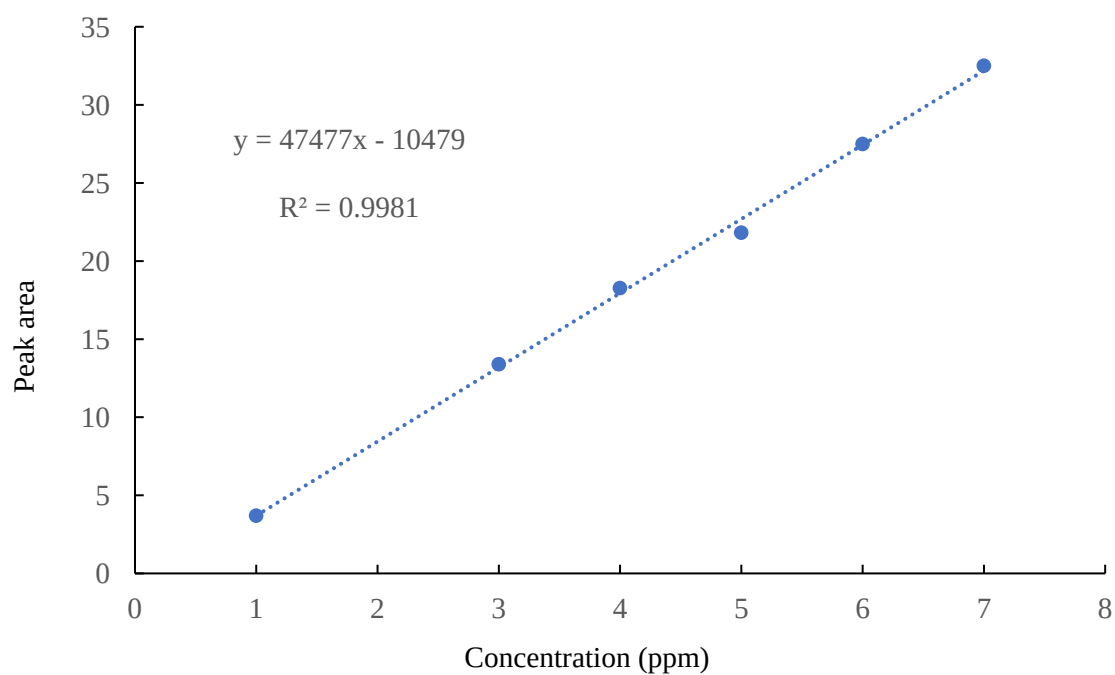


Figure A 35. Working graph for the correct equation of methionine*

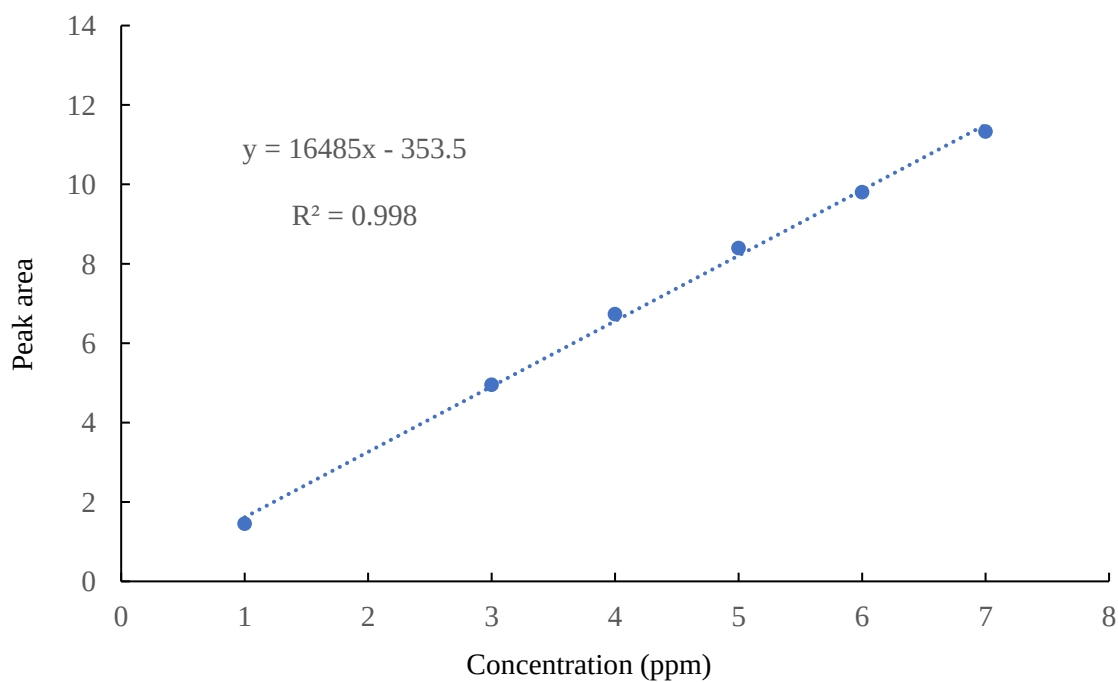


Figure A 36. Working graph for the correct equation of leucine*

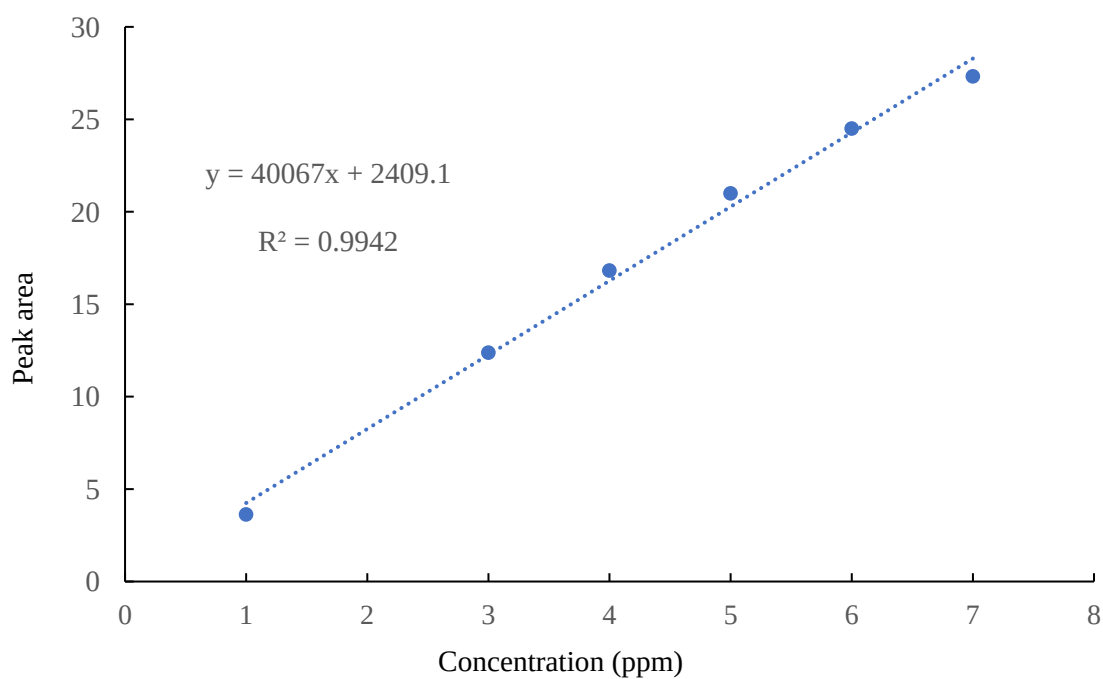


Figure A 37. Working graph for the correct equation of isoleucine*

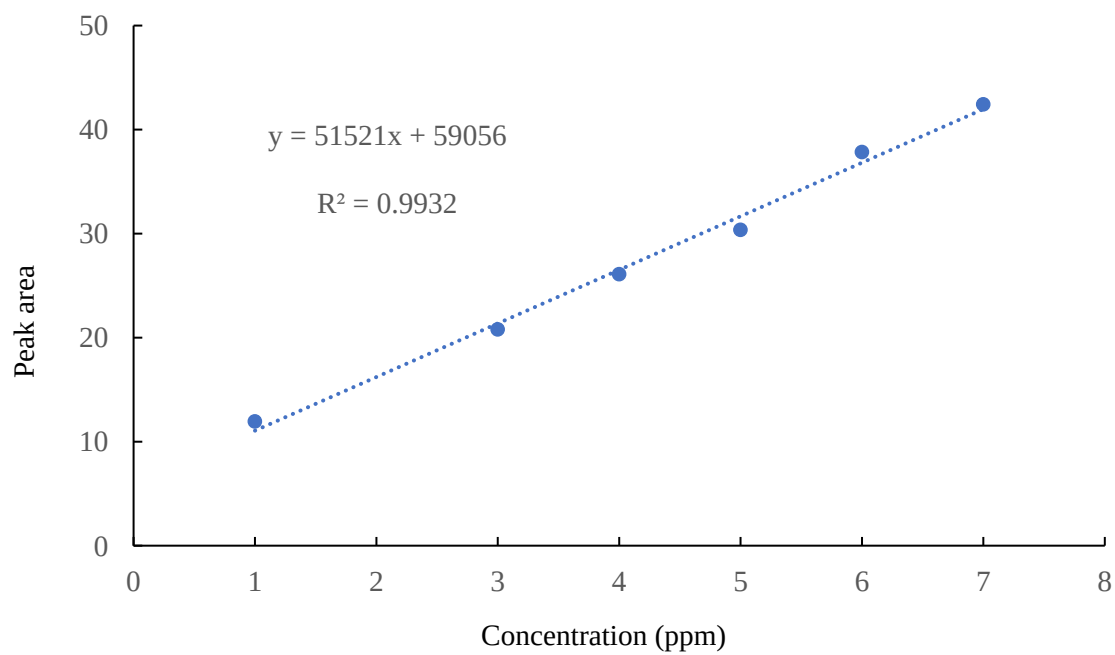


Figure A 38. Working graph for the correct equation of phenylalanine*

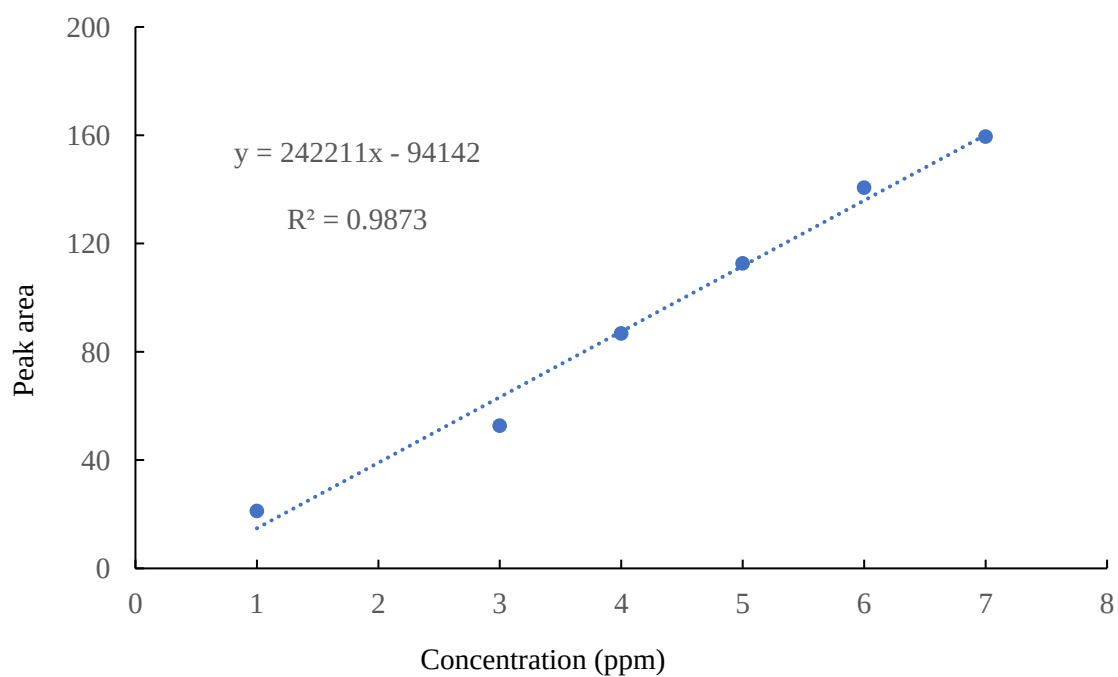


Figure A 39. Working graph for the correct equation of tryptophan*

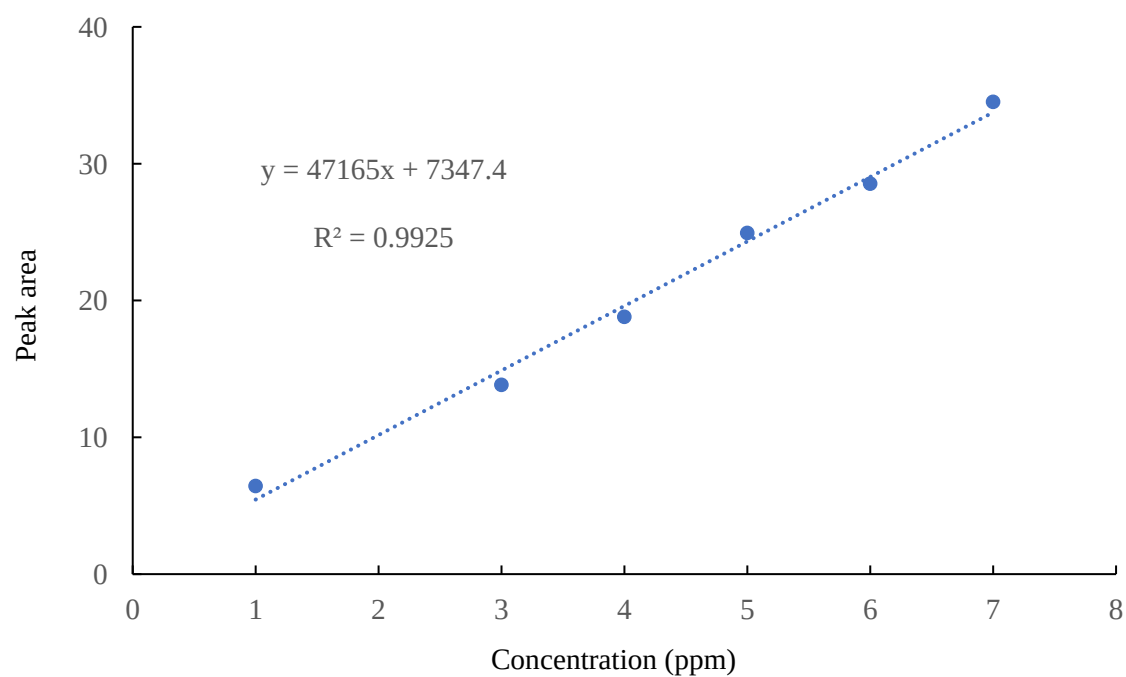


Figure A 40. Working graph for the correct equation of lysine*

CURRICULUM VITAE

Haval Mohammed ALI

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ACADEMIC ACTIVITIES

Paper:

1. H. M. Ali, F. Karataş., D. Özer, and S. Saydam, “Amino Acids Profile of *Loranthus europaeus* from Different Countries,” *Iğdır Üniversitesi Fen Bilim. Enstitüsü Derg.*, vol. 13, no. 4, pp. 2743–2750, 2023, doi: 10.21597/jist.1246133.
2. H. M. Ali, F. Karataş, D. Özer, and S. Saydam, “Element and Water-Soluble Vitamins Profile of *Rhus coriaria* L. (Sumac) Grown in Different Regions,” *Biol. Trace Elem. Res.*, no. 0123456789, 2023, doi: 10.1007/s12011-023-03890-y.

3. H. M. Ali, D. Özer, F. Karataş, and S. Saydam, “Amino Acid Profile of *Rhus coriaria* L . (Sumac) Grown in Different Regions Farklı Bölgelerde Yetiştirilen *Rhus coriaria* L .’ nin (Sumak) Amino Asit Profili,” *J. Agric. Nat.*, vol. 7, no. 2, pp. 423–429, 2024.

