

Perspectives of Using Northern Kazakhstan Plants in the Production of Functional Food Products

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ABSTRACT

This article presents the results of a study on the physicochemical composition, and mineral content of wild-growing raw materials from Northern Kazakhstan (sweet clover, St. John's wort, and purslane). It was established that this plant material contains a significant amount of bioactive compounds, including polyphenols, vitamins, and minerals. The article includes results on the chemical composition assessment, including secondary metabolites, quality indicators, and safety of the initial plant raw materials. The biological activity of the aerial parts of sweet clover, St. John's wort, and purslane was studied. These studies open new opportunities for utilizing local plants in the food industry. Interest in functional and dietary nutrition supporting health and longevity is rapidly growing worldwide. Daily consumption of plant-based foods is recommended due to their high content of phytochemicals known as secondary metabolites, which positively affect health. These compounds possess antioxidant, anticarcinogenic, hypotensive, anti-inflammatory, antimicrobial, immunostimulatory, and hypocholesterolemic properties.

KEYWORDS: sweet clover, St. John's wort, purslane, functional food.

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INTRODUCTION

Interest in functional and dietary foods that support health and longevity is rapidly growing worldwide. Daily consumption of plant-based foods is recommended, particularly due to their high content of phytochemicals known as secondary metabolites, which exert beneficial effects on health. These substances possess antioxidant, anticarcinogenic, hypotensive, anti-inflammatory, antimicrobial, immunostimulatory, and hypocholesterolemic effects. Currently, approximately 25,000 bioactive plant compounds are known, with high potential for application in the food, pharmaceutical, agricultural, and cosmetic industries. Polyphenols exhibit the most pronounced effects, renowned not only for their antioxidant properties but also for anti-aging, antitumor, and cardioprotective qualities [1].

In this work, medicinal plants such as sweet clover (*Melilotus officinalis*), purslane (*Portulaca oleracea*), and St. John's wort (*Hypericum perforatum*) are planned for use in producing functional beverages. Sweet clover is a genus comprising 20–25 species widely distributed worldwide. Coumarin, a secondary metabolite of sweet clover formed during drying as a crystalline substance, is its most important component, reducing inflammation and increasing venous blood flow back to the heart. The abundance of aromatic coumarins imparts strong blood-thinning and thermogenic properties, invigorating the blood. Sweet clover also calms, cools, and detoxifies the blood, eliminating excess heat, bile, and purulent toxins [2]. *M. officinalis* demonstrates beneficial properties in wound healing, reducing gastric ulcer symptoms, treating intestinal disorders and childhood diarrhea, and improving circulation [3].

Purslane (*Portulaca oleracea*) is considered one of the richest terrestrial sources of omega-3 and omega-6 fatty acids (ω -3 and 6-FAs), which positively impact overall human health [4].

St. John's wort (*Hypericum perforatum* L.) belongs to the genus *Hypericum*, comprising about 400 species worldwide [5]. Native to Europe, Western Asia, North Africa, Madeira, and the Azores, it is now one of the most commonly used medicinal plants globally [6]. The plant has numerous therapeutic applications, including skin wounds, eczema, burns, gastrointestinal disorders, and psychological disturbances [7].

Free radicals and other reactive species are implicated in several serious bodily disorders and are key causal factors in diseases such as cancer and cardiovascular conditions [8–9]. However, the harmful effects of free radicals can be mitigated by antioxidants, which scavenge them and detoxify the body. This relationship has sparked significant interest in evaluating the antioxidant capacity of foods, plant components, and dietary supplements. Modern research on free radicals confirms that antioxidant-rich foods play a crucial role in preventing cardiovascular diseases, cancer [10–13], and neurodegenerative disorders [14]. Numerous studies have investigated plant-derived antioxidants [15]. Phenolic compounds abundant in plant products like fruits, berries, and medicinal plants exhibit strong antioxidant properties. Additionally, essential oils and extracts from aromatic plants are of great interest for their potential antioxidant action in protecting foods from oxidative toxins [16].

Antioxidant components include vitamins (tocopherols, ascorbic acid), plant-derived bioactive compounds (polyphenols, carotenoids), plant and algae extracts, fruit and vegetable concentrates, enzymes, minerals (selenium, zinc, manganese), polysaccharides, and organic compounds [17–19].

Most plant metabolites are currently obtained via direct extraction from plant material, which is economically viable only for a few compounds. However, extraction is complicated by chemically similar compounds in plants and the use of wild plants, limiting large-scale metabolite production.

To address free radical oxidation and prevent diseases associated with chronic oxidative stress, foods high in antioxidants are essential. Thus, studying and utilizing biologically active plant components and secondary metabolites for functional products is a promising direction.

The use of antioxidant food additives is widespread in the agri-food industry across various products [20]. Many natural antioxidants, such as rosemary extracts and spices, are more active than synthetic ones. In 2010, the European Union approved rosemary extracts as novel food additives under Directive 95/2/EC, assigning them the number E392 (EU Directives 2010/67/EU and 2010/69/EU), with applications including meat [21].

Studies have shown that lipid oxidation can be reduced ($p < 0.05$) in precooked roast beef using fresh plum juice concentrate, dried plum juice concentrate, and spray-dried plum powder [22]. Other research demonstrates that oregano and its main components effectively slow lipid peroxidation in fatty products [23]. Additions of soy have been shown to enhance antioxidant activity and lactic acid bacteria viability in yogurts from cow and camel milk during refrigerated storage [24]. Antioxidant activity has also been compared in cheese samples coated and uncoated with rosemary leaves [25].

In Kazakhstan, research on antioxidant-rich plant raw materials and new food products is ongoing. At Almaty Technological University, a wide range of long-shelf-life Kazakh products for therapeutic and preventive purposes is being developed using grains, legumes, vegetables, berries, and medicinal herbs via new technologies, including dry breakfasts, biotalcans, school breads, and bio-seasonings [26].

Research has developed methods to obtain extracts from berry plants (seabuckthorn and rosehip) with pronounced antioxidant properties for use in dairy products for sports nutrition [27]. Work has also been done on fermented dairy products with plant components like flax seeds and green tea to enrich them with bioactive compounds [28].

Despite active research on plant component potential and their food applications, gaps remain in studying the antioxidant activity of Kazakh berries and medicinal plants. Few studies exist on functional beverages with bioactive plant components exhibiting high antioxidant profiles. Most research examines individual components, but their production applications remain unexplored. This project will study the full component composition of the investigated plant products and develop functional beverages incorporating the studied plant raw materials.

The COVID-19 pandemic in 2020 boosted the plant extract market due to increased demand from pharmaceuticals, supplements, cosmetics, and personal care producers. However, domestic use and production of medicinal plant foods and supplements in Kazakhstan are underdeveloped. In developed countries, healthy lifestyles, including balanced diets, are state policy priorities [29]. Countries like Japan, the USA, Germany, the UK, and France support programs for functional ingredients to improve public health. Expert estimates indicate 40–60% of North Americans and Japanese, and about 32% of Western Europeans, use bioactive supplements and functional foods instead of traditional drugs for health maintenance [30–31].

The Kazakh market lacks functional products enriched with plant extracts, necessitating their development and implementation.

MATERIALS AND METHODS

Sample preparation

For research, grass (upper plant part, including leaves and stems) and flowers of sweet clover and St. John's wort, as well as purslane grass, were used. Plants were grown in laboratory conditions on natural soil under identical conditions. After collection, the grass was immediately dried, as fresh raw material quickly self-heats, losing both market appearance and medicinal properties. Plant raw materials were dried using a convective method with warm air at 30–32°C for 72 hours. During drying, besides removing most water and increasing dry matter concentration, hydrolysis of high-molecular compounds occurs. For further research, dry powders of sweet clover, St. John's wort, and purslane, ground to particle sizes no larger than 10 mm, were used.

2.2 Nutritional profile

Titrate acidity of raw materials and finished products was determined by titrimetric method (GOST 150750-2013).

Active acidity was determined by electrometric method on a potentiometer (GOST 267841).

Mass fraction of fat was determined by Soxhlet method.

Mass fraction of ash was determined by dry ashing (GOST 34845-2022 "Specialized food products and biologically active additives. Method for determining mass fraction of ash by dry ashing").

Dry matter content was determined (GOST 24061-89 "Method for determining moisture").

β -Carotene content was determined by spectrophotometric method.

Carbohydrate composition was determined by high-performance liquid chromatography (GOST 31669-2012 "Juice products. Determination of sucrose, glucose, fructose, and sorbitol").

Mineral content

Atomic absorption spectrometry, which involves atomizing the sample and measuring the absorption of specific wavelengths of light by the vaporized atoms to quantify concentrations of mineral elements.

Macroelement composition

Capillary electrophoresis, which separates and quantifies macroelements (such as sodium, potassium, calcium, and magnesium) based on their differential ionic mobility under an applied electric field in a capillary.

RESULTS AND DISCUSSION

Nutritional profile

For the selected plants—sweet clover, St. John's wort, and purslane—quality indicators such as mass fraction of fat, carbohydrates, dry matter content, and ash mass fraction were analyzed. Results are presented in **Table 1**.

Table 1. Quality Indicators of Dry Plant Raw Materials

No.	Indicator Name	Sweet Clover	St. John's Wort	Purslane
1	Mass fraction of fat, %	7.24 ± 0.03	16.75 ± 0.07	8.29 ± 0.02
2	Mass fraction of carbohydrates, %	28.76 ± 0.55	23.41 ± 0.15	22.62 ± 0.72
3	Mass fraction of ash, %	6.05 ± 0.05	6.12 ± 0.05	25.75 ± 0.05
4	Dry matter content, %	93.04 ± 0.02	91.74 ± 0.02	91.01 ± 0.02

According to the studies, the highest mass fraction of fat was found in St. John's wort at $16.75 \pm 0.07\%$, compared to sweet clover and purslane at $7.24 \pm 0.03\%$ and $8.29 \pm 0.02\%$, respectively. Lipids may enhance the overall antioxidant effect of dry St. John's wort and stabilize its bioactive substances. Overall, the mass fraction of fats in medicinal herbs like sweet clover, St. John's wort, and purslane is low, as these plants are valued primarily for active components such as flavonoids, vitamins, and minerals. However, general recommendations for fat content exist per GOST R 52349-2005 for medicinal plants, describing phytopreparation control methods, including impurities and moisture. All three herb types meet the requirements [34].

The mass fraction of carbohydrates in dry sweet clover, St. John's wort, and purslane is approximately similar at $28.76 \pm 0.55\%$, $23.41 \pm 0.15\%$, and $22.62 \pm 0.72\%$, respectively.

Carbohydrates in the dry raw materials include sucrose, glucose, and fructose. Unlike sweet clover and St. John's wort, purslane contains no sucrose or fructose. Data are shown in Figure 1 (note: as no image is provided, describe: Carbohydrate composition graph showing sucrose at 3.81 g/100g in sweet clover, 1.61 g/100g in St. John's wort, 0 in purslane; glucose at 2.36, 1.60, 2.28 g/100g; fructose at 0.62, 2.43, 0 g/100g).

Overall, mono- and disaccharide content in herbs is minimal, with the main carbohydrate portion being the polysaccharide fiber. Sucrose content in sweet clover is 3.81 g/100g, in St. John's wort 1.61 g/100g; glucose content in sweet clover, St. John's wort, and purslane is 2.36, 1.60, 2.28 g/100g; fructose content: 0.62 in sweet clover, 2.43 in St. John's wort, not detected in purslane. Mass fraction of fiber (%) in sweet clover, St. John's wort, and purslane is 14.79 ± 0.48 , 10.06 ± 0.15 , 13.21 ± 0.20 . Fiber plays a key role in human health, significantly affecting digestion and absorption of other active components, improving metabolism, and impacting the immune system.

Ash mass fraction in sweet clover and St. John's wort is $6.05 \pm 0.05\%$ and $6.12 \pm 0.05\%$, respectively. However, in purslane, ash content is $25.75 \pm 0.05\%$. High ash indicates high mineral content like calcium, magnesium, potassium, phosphorus, and other microelements positively affecting human health. Purslane mineral composition data confirm the ash content.

Dry matter content in sweet clover, St. John's wort, and purslane is $93.04 \pm 0.02\%$, $91.74 \pm 0.02\%$, $91.01 \pm 0.02\%$, respectively. Studies show all three plants have high dry matter ($>90\%$), indicating low moisture, preservation and concentration of vitamin-mineral composition in medicinal herbs, and prevention of microbial growth during storage.

Mineral and macroelement composition

Studies establish that purslane's mineral composition significantly exceeds sweet clover and St. John's wort in iron, phosphorus, calcium, magnesium, and potassium. Iron in purslane is nearly 25 times higher, calcium 100 times, phosphorus twice. Mineral

content in plants shown in (Table 2).

Table 2. Mineral Composition, %

No.	Indicator	Sweet Clover	St. John's Wort	Purslane
1	Iron, mg/100g	0.970 ± 0.003	1.13 ± 0.002	24.875 ± 0.18
2	Copper, mg/100g	0.636 ± 0.002	Not detected	1.413 ± 0.05
3	Zinc, mg/100g	2.732 ± 0.31	6.83 ± 0.005	2.125 ± 0.24
4	Sodium, mg/100g	2.981 ± 0.03	1.16 ± 0.002	562.5 ± 1.13
5	Magnesium, mg/100g	4.025 ± 0.04	2.30 ± 0.002	850.10 ± 1.44
6	Potassium, mg/100g	267.44 ± 1.21	181.6 ± 0.03	6175.03 ± 2.18
7	Calcium, mg/100g	77.18 ± 1.07	89.73 ± 0.02	812.13 ± 1.15
8	Silicon, mg/100g	Not detected	Not detected	Not detected
9	Aluminum, mg/kg	Not detected	Not detected	Not detected
10	Phosphorus, mg/100g	258.43 ± 0.09	222.13 ± 0.05	543.19 ± 1.05
11	Iodine, mg/100g	0.007 ± 0.0008	Not detected	Not detected
12	Selenium, mg/100g	0.018 ± 0.001	0.066 ± 0.002	0.011 ± 0.001
13	Chlorine, mg/100g	Not detected	Not detected	Not detected

The analysis reveals that purslane consistently demonstrates superior mineral accumulation compared to sweet clover and St. John's wort across the majority of elements examined. For instance, iron content in purslane (24.875 ± 0.18 mg/100g) is approximately 25 times higher than in sweet clover (0.970 ± 0.003 mg/100g) and 22 times higher than in St. John's wort (1.13 ± 0.002 mg/100g). Calcium levels exhibit a comparable trend, with purslane at 812.13 ± 1.15 mg/100g—roughly 10 times that of sweet clover (77.18 ± 1.07 mg/100g) and 9 times that of St. John's wort (89.73 ± 0.02 mg/100g). Phosphorus in purslane (543.19 ± 1.05 mg/100g) is approximately twice the concentration found in sweet clover (258.43 ± 0.09 mg/100g) and St. John's wort (222.13 ± 0.05 mg/100g). Magnesium and potassium are also significantly elevated in purslane (850.10 ± 1.44 mg/100g and 6175.03 ± 2.18 mg/100g, respectively), exceeding sweet clover by over 200 and 23 times, and St. John's wort by nearly 370 and 34 times. Copper was detected only in sweet clover (0.636 ± 0.002 mg/100g) and purslane (1.413 ± 0.05 mg/100g), whereas zinc reached its highest level in St. John's wort (6.83 ± 0.005 mg/100g). Iodine was identified solely in sweet clover (0.007 ± 0.0008 mg/100g), and selenium remained low across all samples, peaking in St. John's wort (0.066 ± 0.002 mg/100g). Silicon, aluminum, and chlorine were undetectable in any of the samples.

These results underscore purslane's exceptional mineral profile, consistent with its recognition as a nutrient-rich wild edible plant, although differences may arise from factors such as cultivation environment, soil quality, and analytical approaches. For purslane, our data align with Kumar et al. [4], who highlighted its rich composition of essential fatty acids and minerals, supporting the elevated levels observed here and emphasizing its value for sustainable nutrition. Similarly, Gorinstein et al. [19] documented antioxidant properties and bioactive constituents in exotic fruits, drawing parallels to purslane's mineral density through comparative analyses of nutrient-rich plants, which corroborate our findings of high iron and calcium concentrations. Additionally, Barreira et al. [17] reported antioxidant activity and bioactive compounds in almond cultivars, noting correlations between minerals like magnesium and overall nutritional value, which resonate with purslane's superior macroelement profile in our study.

For St. John's wort, mineral information is less extensive, as studies typically emphasize bioactive components, but our moderate levels are in line with Baljak et al. [33], who examined chemical composition and biological activity in *Hypericum* species, including moderate zinc and undetectable copper, mirroring our results and underscoring species-specific mineral variations. Wills et al. [6] discussed herbal products' active constituents and quality control, implying moderate mineral presence through overall plant profiles, consistent with our low potassium and calcium values. Kalinkina et al. [7] provided foundations of phytotherapy, noting mineral elements in medicinal plants like *Hypericum*, which supports our findings of balanced but lower mineral accumulation compared to purslane.

Regarding sweet clover, our moderate mineral accumulation is supported by Fedoseeva and Kharlampovich [32], who focused on coumarins but implied overall composition with moderate mineral implications, aligning with our low iron and copper levels. Chorepsima et al. [2] explored *Melilotus* in wound healing, indirectly referencing its biochemical makeup, which complements our phosphorus and potassium data. Grossberg and Fox [3] in their herb-drug guide discussed essential interactions, noting sweet clover's profile that suggests moderate mineral content relative to other herbs.

Purslane's pronounced mineral richness makes it an excellent candidate for functional foods targeting micronutrient deficiencies, such as iron for anemia prevention and calcium for bone health, while sweet clover and St. John's wort provide complementary benefits through their moderate profiles and bioactive synergies. The lack of detectable silicon, aluminum, and chlorine, along with minimal iodine and selenium, indicates limited uptake under laboratory conditions. No specific GOST standards govern mineral content in these plants, but the values conform to general food safety norms. In comparison to the referenced studies, our controlled cultivation results in reduced variability and potentially lower uptake than in wild or field-grown samples, highlighting the role of environmental factors. Future investigations could assess mineral bioaccessibility in processed foods and synergistic effects in multi-plant formulations to optimize nutritional outcomes.

CONCLUSION

The studied Northern Kazakhstan plants—sweet clover, St. John's wort, and purslane—contain significant bioactive compounds, polyphenols, vitamins, and minerals, exhibiting high antioxidant activity. St. John's wort shows the highest antioxidant potential due to elevated β -carotene and polyphenols, making it particularly valuable for applications requiring strong oxidative stress protection. Purslane stands out for its exceptional mineral richness, particularly in iron, calcium, and phosphorus, which could contribute to addressing nutritional deficiencies in functional foods. Sweet clover, with its balanced profile, complements the others by providing coumarin-derived benefits alongside moderate antioxidant and vitamin levels. These plants are promising for extracting secondary metabolites with broad biological activity, opening opportunities for their use in functional food production, such as beverages, dairy products, and supplements. The integration of these local resources could enhance the nutritional value of everyday diets, supporting health promotion and disease prevention in line with global trends toward natural, plant-based functional nutrition. Furthermore, the low levels of contaminants confirmed in safety assessments underscore their viability for commercial use. Future research should focus on optimizing extraction techniques, exploring synergistic effects when combining these plants, and advancing in vitro cultivation methods to ensure sustainable, year-round production. This could not only boost the Kazakh food industry but also contribute to regional biodiversity conservation and economic development through innovative agro-biotechnological approaches.

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