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NUTRIENTS AND PHYTOCHEMICALS OF WELSH ONION (*ALLIUM FISTULOSUM* L.) AND THEIR IMPORTANCE IN NUTRITION OF POULTRY IN THE FUTURE – A REVIEW

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Abstract

Allium fistulosum L., commonly called spring onion, welsh onion, or Japanese bunch onion, is a clumping, slowly spreading, evergreen perennial type that is mainly grown as a vegetable because of its onion-scented leaves. This species is very similar in taste and smell to the related common onion, Allium cepa, but does not develop bulbs. Welsh onion were detected to contain volatile compounds containing sulphur and polyphenolic compounds which exhibit various biological activities, and which have anti-fungal, anti-oxidative, anti-hypertensive, anti-platelet, regulation of immune function and anti-obesity effects. This plant is much less known in the world than the traditional onion, A. cepa. This review intends to describe and summarize recent advances the nutrients and phytochemicals of welsh onions for using as a poultry alternative feed additive, their beneficial effects, and the mechanisms underlying their involvement for future in poultry nutrition.

***Key words**: nutrients, phytochemicals, poultry, welsh onion.*

INTRODUCTION

Allium is a genus of the Liliaceae family that is easily found in Asia, Europe and America (Gitin et al., 2012). This genus has more than 700 species, including: *A. cepa* L., *A. sativum* L., *A. fistulosum* L., *A. schoenoprasum* L., *A ursinum* L., *A. flavum* L., *A. scorodoprasum* L., *A. vineale* L., *A. atroviolaceum* Boiss., *A. psekemense* B. Fedtsch., *A. kurtzianum*, *A. chinense* and *A. rubellum* and many other species from other countries (Verma et al., 2015; Verma et al., 2008). According to Rose et al. (2005), Allium species are well-known as foodstuffs that are widely used worldwide. Approximately 800 species, including welsh onion (*A. fistulosum*), garlic (*A. sativum*), and onion (*A. cepa*), are known.

Allium fistulosum L., known as Japanese bunching onions, welsh onions or spring onions is one of Allium species known for originating from Romania which has similarities to scallions and smells and tastes similar to *A. cepa* L. Unlike other species, this plant does not form bulbs and has hollow leaves (Immaculate et al., 2020). In Japan and China, this plant is used as a vegetable or as a traditional medicine to improve the function of internal organs and metabolism and treat several diseases such as headaches, diarrhea, stomach pains and colds (Bede and Zaixiang, 2020; Hirayama et al., 2019; Newenhouse, 2011). Welsh onion (*Allium fistulosum* L.) is a major vegetable product widely cultivated from Siberia to tropical Asia as well as in Japan, Korea and China (Hirayama et al., 2019).

According to Waghulde et al. (2021) welsh onion is a perennial species originated from Eastern Asia. Its leaves have nutritional value, and they can be fresh consumed all over the year, still green over the winter. According to Wang et al. (2005) leek is popular in Western Europe and Japanese bunching onion (synonim: Welsh onion) is common in China, Japan, Korea and Taiwan. However, this plant has much less known in the world than the traditional onion, *A. cepa* (Tendaj, 2003). Welsh onion is a clumping, slowly spreading, evergreen perennial type that is mainly grown as a vegetable because of its onion-scented leaves. This species is very similar in taste and smell to the related common onion, *Allium cepa*, but does not develop bulbs. It somewhat has hollow leaves (fistulosum meaning "hollow") and scapes. Welsh onion can reproduce by forming an evergreen clump (Thompson, 1995).

Phytochemical studies reported that Welsh onions contain organosulfur compounds (Zhou et al., 2011) and polyphenolic compounds (Vlase et al., 2013). Welsh onions (*Allium fistulosum* var. maichuon) and shallots (*Allium fistulosum* var. caespitosum) were detected to contain volatile compounds containing sulfur (Kuo et al., 1990). Sulfur-containing compounds from the Allium plant exhibit various biological activities. Several studies have shown Welsh onions have anti-fungal, anti-oxidative, anti-hypertensive, anti-platelet, and anti-obesity effects (Sung et al., 2011; Yamamoto et al., 2005; Sang et al., 2002; Chen et al., 2000).

Welsh onions are mainly used in traditional Chinese medicine because of its natural chemical compounds which are beneficial for human health. Bulbs, pseudo stem juice, leaves, flowers, seeds and roots have medicinal values, as antibacterial, antitumor, antioxidant, antihypertensive, antiobesity, antiplatelet aggregation, and regulation of immune function (Liang et al., 2021; Nohara et al., 2021; Tigu et al., 2021; Hirayama et al., 2019; Sung et al., 2018). The main active compounds include essential oils which mostly contain sulfides, oleic acid, linoleic acid, pectin, allicin, and vitamin C (Nohara et al., 2021; Tigu et al., 2021; Sung et al., 2018; Zhang et al., 2017; Tian et al., 2016). It was reported that the stem, leaf and root extracts of Welsh onions all had an antioxidant effect, and the stem extract showed the strongest antioxidant effect (Wang, 2017). This article aims to review the nutrients and phytochemicals of welsh onion and to determine the possible use as alternative poultry feed additive and feed ingredients, their beneficial effects, and the mechanisms underlying their involvement for future in poultry nutrition.

MATERIALS AND METHODS

A literature review which search from the Google of the potential of Welsh onions as alternative feed additives and feed ingredients for broiler chickens is presented in this paper. This review summarized the existing literature and gathers information to present the current relevance of welsh onions as an effective poultry feed additive, discussing the various compounds present in welsh onions in terms of their bio-functionality. Emphasis is placed on the effects of the Welsh onion diet, growth performance, immunomodulatory properties, gut microbiota and gut morphology, and quality product in poultry. Although the selection of publications to improve upon for optimal application of welsh onions to poultry is still very limited, the review remains based on scientific results.

RESULTS AND DISCUSSIONS

Overview of Bioactive Compounds in Welsh Onion

Welsh onion, synonim green onion (*Allium fistulosum* L.), is an important spice in the world (Wang et al. 2020) with high nutritional value (Gao et al., 2021). Rouphael et al. (2012) reported that spice plants as green onions contain high concentrations of minerals and bioactive ingredients. Welsh onion are indicated to have antioxidant, antifungal, and antihypertensive activity (Singh et al., 2020).

Phytochemical analysis in both *Allium fistulosum* and *Allium ursinum* species indicated the presence of p-coumaric and ferulic acid in phenol carboxylic acid pattern. Isoquercitrin and quercitrin were found only in *A. fistulosum*. Quercetol and kaempferol were identified before and after hydrolysis in *A. fistulosum*, whereas kaempferol was only after hydrolysis in *A. ursinum*. Allicin was identified in all extracts, higher amounts were found in *A. ursinum*. Sitosterol and campesterol were identified in both species, and stigmasterol only in *A. fistulosum* (Vlase et al., 2013).

Udjaili et al. (2015) reported that the phenolic extract of welsh onion root contained total phenolic, flavonoid and tannin as well as the best free radical scavenging activity to ward off DPPH free radicals. The activity test using the

DPPH test showed that the percentage value of the phenolic extract of dry welsh onion was higher than that of the phenolic extract of fresh welsh onion. GC-MS analysis of the ethanol extract welsh onion revealed the presence of 31 compounds, including flavonoids, terpenoids, fatty acids, fatty alcohols and compounds containing sulfur. Therefore, welsh onion may have chemopreventive, anticancer, anti-microbial activity, antioxidant and antidiabetic activity, anti-inflammatory, antibacterial, antifungal, skin conditioning properties due to the presence of secondary metabolites in the ethanolic extract (Monika & Sakthi, 2018).

Tabassum et al. (2016) stated that green onion (syn. scallion and welsh onion) (*Allium fistulosum*) is used as an important spice worldwide. It have high concentrations of allicin, flavonoids, vitamins and other organosulfur compounds (Yin et al., 2003). Phytochemical studies reported that welsh onion contain organosulfur compounds (Zhou et al., 2011) and polyphenolic compounds (Vlase et al., 2013). Allicin, one of the most characteristic organosulfur compounds, is responsible for the pungency and flavor in the monocotyledonous flowering plant Allium (Block et al., 1992). Welsh onion has antioxidant and antibacterial properties and has the potential to benefit the cardiovascular system (Chan et al., 2013), also have antifungal, antihypertensive, antiplatelet, and antiobesity effects (Sung et al., 2011; Yamamoto et al., 2005; Sang et al., 2002; Chen et al. al., 2000).

Welsh onion is a perennial herb widely cultivated throughout the world, especially in China, Japan and Korea. Strong antimicrobial agents such as fistuloside A, B, and C have been isolated from the edible parts of welsh onion. Their antimicrobial activity was evaluated by pathogenic microorganisms or food spoilage based on disc diffusion assays, minimal inhibition concentration (MIC) and determination of minimal fungicide concentration (MFC). Fistuloside A and fistuloside C showed strong antifungal and anti-proteus activity, whereas fistuloside B was only effective against fungi. Fistuloside C showed prominent antifungal activity with 3.1-6.2 ttg/ml MIC and MFC. That fistuloside C has prominent antifungal activity and supports the use of welsh onion to treat microbial infections (Sohn et al., 2006).

Welsh green onions are a powerful antioxidant food comparable to yellow onions, and are a good source of kaempferol. The increase in antioxidant activity and the decrease in flavonoid content (especially kaempferol) during boiling may have some relationship. Consequent studies should be carried out to clarify the reasons for the thermal instability of flavonoids during heating, and the mechanism of thermal enhancement of antioxidant activity in welsh green onions (Aoyama & Yamamoto, 2007).

Welsh onion is also a common Allium plant in Eastern Europe, with antifungal and antimicrobial properties, due to its high concentration of sterols and sulfate compounds (Vlase et al., 2013). Ethanolic extracts 30% of *Allium fistulosum* L. and *Allium sativum* L. were investigated to evaluate their antioxidant and antimicrobial capacity. The highest DPPH scavenging activity in *A. fistulosum* L. leaves was IC50 of 14.61 $g.mL^{-1}$. The highest antioxidant activity using the TEAC test and total phenolic content were observed in stems of *A. fistulosum* L. That the DPPH IC50 value was significantly correlated with the total phenolic content and antioxidant activity using the TEAC assay. The stem extract of *A. fistulosum* L. was more active against *Bacillus subtilis*, with MIC and MBC. That extract Allium spp. can be used as a potential source of natural antioxidants and antimicrobial agents (Chang et al., 2013). Stajner et al. (2002; 1999; 1998) concerning the antioxidant abilities of different Allium species showed that they possess antioxidant abilities in all organs, but especially in the leaves.

Allium fistulosum L. contained GSH (reduced glutathione) 0.497 nmol/mg protein, flavonoids 465.87 mg/g, vitamin C 0.161 mg/g, soluble proteins 7.30 mg/g, carotenoids 2.87 mg/g, and scavenging activity 82.15%. According to the data that the scavenger activity of *Allium fistulosum* L. was high, the generation of OH radicals (the most toxic oxygen species) was reduced by 87.09%. Other results regarding *Allium fistulosum* L. support this assessment due to the high activity of all antioxidant enzymes SOD, CAT, GPX and GP, low concentrations of O2, OH and MDA, and high amounts of GSH, flavonoids, vitamin C and soluble proteins, such as carotenoid content. That *Allium fistulosum* L. was the most promising source of natural, non-toxic antioxidants that can be used in the food, pharmaceutical and cosmetic industries (Stajner et al., 2006). The physicochemical properties of the welsh onion reported by several references showed in Table 1 and phytochemical of welsh onion reported by several authors showed in Table 2.

Table 1. The physicochemical properties of the Welsh Onion by Several References

Proximate Composition (%)	Reference	
	Adeyeye (2020)	https://rxharun.com/allium-fistulosum-nutritional-value-health-benefits-recipes/
Moisture	89.55	NR
Ash	0.82	NR
Crude Oil	0.64	NR
Crude Protein	1.82	NR
Crude Fiber	1.65	NR
Carbohydrate	5.54	
Vitamin K (%)	NR	161.17
Vitamin C, (%)	NR	30.00
Vitamin B2, (%)	NR	6.92
Vitamin B6, (%)	NR	5.54
Fe, (%)	NR	15.25
Cu, (%)	NR	7.78
P, (%)	NR	7.00
Mg, (%)	NR	5.48
Mn, (%)	NR	5.96
Total Dietary Fiber, (%)	NR	6.32

NR = not reported

Chemical composition of welsh onion seeds according to Golubkina et al. (2015): oil content 7.1%, protein 23.8%, total phenolic 3.8 mg g^{-1} f.w, Selenium 476 µg kg^{-1} f.w. The advantages of Japanese bunching onion are high nutritive value and unique flavour (Tendaj & Mysiak, 2007). Higashio et al. (2007) reported that Japanese bunching onion is abundant in vitamin C, and contains other valuable compounds such as carotenoids, macronutrients and micronutrients, especially Ca and K, as well as flavonoids, which are potent antioxidants (Aoyama & Yamamoto, 2007; Mysiak & Tendaj, 2006, 2008). The leaf blades contain more vitamin C, carotenoids, vitamins B1, B2, niacin and minerals than the pseudostem. The specific odour of the crop is attributed to volatile allyl sulphides (Warade and Shinde 1998).

Several studies reported that *A. fistulosum* leaf extract contains flavonoids (myricetin, quercetin, rutin, kaempferol, naringenin and hesperetin), polyphenols (benzoic acid, salicylic acid, ferulic acid, caffeine, p-coumaric acid, coumarin, vanillic acid, gallic acid and cinnamic acid) (El-Hadidy et al., 2014). Also contains apigenin (41,5,7-trihydroxy-flavone) (Immaculate et al., 2020), and dichloroacetic acid, 1-buten-3-yne, 1-chloro-, (Z)-,-pinene, D-limonene, thymol (Ajayi et al., 2019). Besides, kujounin A3, kujounin B1, kujounin B2, kujounin B3, allium sulfoxide A2, allium sulfoxide A3, kujounin A1 (Fukaya et al., 2019), onionin A1, and onionin A2 and onionin A3 (Nohara et al., 2014).

Table 2. Phytochemical of Welsh Onion Reported by Several Authors

Phytochemical	Authors		
	Waghulde et al. (2021)	Siregar et al., 2015*	Tigu et al (2021)
Saponin, g/100 g	0.26	NR	NR
Tannin, g/100 g	2.55	√	NR
Cardiac glycosides, g/100 g	1.85	NR	NR
Flavonoids, g/100 g	0.08	√	NR
Alkaloids, g/100 g	0.18	√	NR
Phenolics, g/100 g	NR	√	NR
Steroids, g/100 g	NR	√	NR
Toxicity test, ppm	NR	603.66 (mild)	NR
Quercetin, µg/mL	NR	NR	26
Quercitrin, µg/mL	NR	NR	95
Isoquercitrin, µg/mL	NR	NR	280
Kaempferol, µg/mL	NR	NR	30
Rutin, µg/mL	NR	NR	215
Ferulic ac., µg/mL	NR	NR	230
Alliin, µg/mL	NR	NR	145
Allicin, µg/mL	NR	NR	20

**Phytochemical screening; NR = not reported*

El Hadidy et al. (2014) reported that there were three main compounds isolated from the leaf extract of *A. fistulosum*, namely myricetin, quercetin and rutin. Myricetin was the most abundant compound in Giza 6 and photon varieties, among the three compounds, which was 38.75%. Antioxidant activity test using the DPPH method showed a decreasing in activity after three months of storage based on the percentage of antioxidants. Myricetin was also isolated from *A. fistulosum*. This compound is classified into the flavonoid group, which has six hydroxyl groups at positions 3, 5, 7, 31, 41 and 51 (Yao et al., 2014). The presence of a hydroxyl group at position 51 in ring B greatly affects its antioxidant activity so that it becomes stronger with the IC50 (4 μM) and 463.40 μM in testing using DPPH radical scavenging activity (Ahmadi et al., 2020; Sim et al., 2007; Seyoum et al., 2006).

Kaempferol can be found in fruits and vegetables (Singh & Kumar, 2017; Kruzlicova et al., 2012). This compound is also easily found in some Allium species (Bilyk et al., 1984). Several studies had reported the presence of kaempferol in *A. fistulosum*, *A. ursinum*, *A. schoenoprasum*, *A. sativum* and other species (Amabye, 2015; Shakurfow et al., 2015). Farkas et al. (2004) reported that kaempferol has antioxidant activity in inhibiting heat-induced oxidation in a β-carotene-linoleic acid-model-system (65.3%).

Okungbowa et al. (2017) reported that the leaf extracts of *A. fistulosum*, *B. pinnatum*, *C. citratus* and *H. crinita* possess potent antioxidant activity, phytochemical and nutritional benefits, with *B. pinnatum* having the highest phytochemical and nutritional content. Xu et al. (2005) reported that Welsh onion had 23.6 mg of quercetin per kg of fresh weight (FW), with no other flavonols detected. Miean & Mohamed (2001) reported that Welsh onion leaves had a total flavonol (TF) content of 2720.5 mg/kg of dry weight (DW), with 1497.5 mg/kg of quercetin, 391 mg/kg of luteolin, and 832 mg/kg of kaempferol.

Welsh onion leaves contain high levels of quercetin, a flavonol compound with potential benefit to human health. Quercetin was reported to have protective effects in reducing the risk of cardiovascular disease and act as anti-cancer and antioxidant agents due to its antiprostanoid and anti-inflammatory responses and decreased rate of DNA degradation (Crystal et al., 2003). Chinese scallions (*Allium fistulosum*) were characterized by their high content of the antioxidant allicin (Wang et al., 2020).

Analysis of the aqueous extract *A. fistulosum* with GC-MS identified D-Limonene, a cyclic monoterpene, as the most abundant bioactive compound in *A. fistulosum* with approximately 99% of the total yield. Also minor bioactive constituents present in the plant include dichloroacetic acid (0.48%), α-pinene (0.36%), 1-Buten-3-yne, 1- chloro-, (Z)- (0.14%) and thymol, TMS derivative (0.07%). D-Limonene has been known to be commonly present in citrus peels, however, it is the first time this compound will be identified by GC-MS analysis as the major bioactive compound in *A. fistulosum* (Ajayi et al., 2019). D-Limonne has been reported to possess anti-oxidant (Yu et al., 2017), anti-inflammatory (Yilmaz & Özbek, 2018; Souza et al., 2003) and anti-carcinogenic (Crowell and Gould,1994) properties.

Overview of Fatty Acids Compounds in Welsh Onion

Linoleic and oleic acids were the most abundant of the total fatty acids in welsh onion and also of the total unsaturated fatty acids with the two totalling 70.44% of all fatty acids. Palmitic and stearic acids were the two most abundant saturated fatty acids, totalling 18.61% of all fatty acids. The total unsaturated fatty acids (77.35%) predominated the total saturated (22.63%), while the percentage poly-unsaturated (56.34%) was far greater than mono-unsaturated (21.04%) (Table 3).

Table 3. The Fatty Acid Profile of the Welsh Onion Reported by Several Authors

Fatty Acid (%)	Authors	
	Adeyeye (2020)	Golubkina et al., 2015
Linoleic, C18:2	52.87	72.34
Oleic, C18:1	17.57	18.30
Palmitic, C16:0	9.80	5.25
Stearic, C18:0	8.81	1.47
Linolenic, C18:3	2.88	0.22
Palmitoleic, C16:1	2.84	0.07
Myristic, C14:0	1.28	0.18
Behenic, C22:0	1.23	0.33
Lauric, C12:0	<1.00	NR
Arachidonic, C20:4	<1.00	NR
Lignoceric, C24:0	<1.00	0.08
Total saturated (SFA)	22.63	7.93
Total unsaturated	77.38	NR
Total mono-unsaturated (MUFA)	21.04	19.01
Total poly-unsaturated (PUFA)	56.34	73.05
Essential fatty acids (EFA)	55.75	NR

NR = not reported

The high level of essential fatty acids in the plant oil is an advantage in food consumption and the good total unsaturated/saturated (P/S) ratio makes the fruit oil nutritionally very useful to be adopted for domestic purposes (Adeyeye, 2020). *Allium fistulosum* plant oil is characterized by a reasonable polyunsaturated/ saturated (P/S) ratio of 3.42. This ratio determines the detrimental effect of dietary fat. A high P/S ratio supports the reduction of serum cholesterol and atherosclerosis and prevention of heart disease (Oomah et al., 2000). The many saturated fatty acids present in plant oils have several important uses. Lauric acid is believed to have antimicrobial properties (Muhammad and Ajiboye, 2010). Palmitic acid is the first fatty acid produced during fatty acid synthesis and from which longer chain fatty acids can be synthesized (Muhammad & Ajiboye, 2010).

Welsh Onion as Poultry Feed Additives

Minh et al. (2017) reported that the growth rate and feed conversion of local chickens increased linearly when fed diet supplemented with chives (= welsh onion) 0 to 2% (DM basis). There was no effect of chive supplementation on hematological and biochemical indices in blood. *E. coli* was shown to be susceptible to chive extract in MIC test. However, supplementation with chives up to 20 g/kg DM diet had no significant effect on fecal *E. coli* counts. That chives can be considered as a prebiotic for natural growth promoter in chickens. Welsh onions is less studied than garlic. Welsh onion have been well known for their medicinal properties, however, there is very little information emphasizing their effect on growth performance of chickens.

Sung et al. (2018) reported the utilization of welsh onion in mice diet that HPLC showed both ethanolic extracts and aqueous extracts of welsh onion contain ferulic acid and quercetin. Oral administration of aqueous extracts and ethanolic extracts of welsh onion to HFD-fed mice decreased body weight, liver, adipose tissue weight and adipocyte size. Serum lipid profiles and adiponectin levels were improved in HFD-fed mice treated with ethanolic extracts of welsh onion but not aqueous extracts of welsh onion. However, both aqueous extracts of welsh onion and ethanolic extracts of welsh onion significantly attenuated HFD-induced changes in serum leptin and insulin-like growth factor 1 levels, liver expression of AMPK, and adipose tissue expression of UCP2. The findings suggested that welsh onion extracts have potential as functional food materials for weight control in obesity.

A study was conducted to examine the effects of Chongbaek (= welsh onion) aquaeos extract (*Allium fistulosum*) and Chongbaek 30% ethanol extract on bone growth using an animal model (rat) lacking calcium and vitamin D. Serum analysis showed that Chongbaek extract promoted bone growth based on the osteogenic markers ALP, calcium, osteocalcin, and type 1 collagen and increase bone mineral content, bone mineral density, and growth plate length. Overall, the results suggest that Chongbaek aquaeos extract and Chongbaek ethanol extract can be used to facilitate bone growth and increase bone mineral density in children and adolescents by lengthening the growth plate without any adverse side effects, such as metabolic disturbances or release of trigger hormones obesity (Ryuk et al., 2021).

Welsh onion is an important ingredient of cuisine. It has nutrients such as carbohydrates, proteins, lipids, minerals (magnesium, calcium, potassium and iron), vitamins (A, C, E, K) and a lot of fiber that facilitate digestion and avoid different problems like colon diseases and constipation (Sakakibara, et al., 2003).

Recently, plant-derived feed additives have gained considerable interest as sustainable substitutes in poultry diets (Habibi and Ghahtan, 2019; Sugiharto, 2016). Plant-derived additives that are effective in poultry are expected to stimulate feed consumption, increase secretion of digestive enzymes, activate the immune system, modulate gut microbiota, and have antibacterial, coccidiostatic, antiviral, antioxidant and/or anti-inflammatory activities (Habibi & Ghahtan, 2019; Sugiharto, 2016; Toghyani et al., 2011).

Research on the use of welsh onion in diet of animal model that have a significant effect on growth performance and health is expected if applied to poultry will have a significant effect on performance and health of poultry.

CONCLUSIONS

From the review, linoleic and oleic acid were the most abundant of the total fatty acids in welsh onion (*A. fistulosum* L.), palmitic and stearic acids were the two most abundant saturated fatty acids. Welsh onion also rich in nutrients and secondary metabolites. This plant showed powerful of bioactivities such as antioxidant, antibacterial, antifungal, anti-inflammatory and others, and have a great role in the health field and the growth performance. So, it is possible use as alternative poultry feed additive and feed ingredients for future in poultry nutrition.

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REFERENCES

Adeyeye, A. (2020). Physico-chemical characteristics and fatty acid profile of *Allium fistulosu*m vegetable plant. *International Journal of Advanced Chemistry*, *8*(2), 239-243.

Ahmadi, S.M., Farhoosh, R., Sharif, A., & Rezaie, M. (2020). Structure-antioxidant activity relationships of luteolin and catechin. *Journal Food Science*, *85*, 298–305.

Amabye, T.G. (2015). *In Vitro* antimicrobial efficacy of fractions from onion (*Allium cepa*) leaves extract from Wukro, Ethiopia. *American Journal of Life Science, 3*(5), 365-368.

Aoyama, S., & Yamamoto, Y. (2007). Antioxidant activity and flavonoid content of welsh onion (*Allium fistulosum*) and the effect of thermal treatment. *Food Science Technology Research*, *13* (1), 67-72.

Ajayi, G.O., Akinsanya, M.A., Agbabiaka, A.T., Oyebanjo, K.S., Hungbo, T.D., & Olagunju, J.A. (2019). D-Limonene: A major bioactive constituent in *Allium fistulosum* identified by GC-MS analysis. *Journal Phytopharmacology*, *8*, 257–259.

Bede, D. & Zaixiang, L. (2020). Dietary polysaccharides from Allium Species: A critical review in dietary polysaccharides from allium species: extraction, characterization, bioactivity, and potential utilization. *Acta Science Agriculture*, *4*, 1–15.

Bilyk, A., Cooper, P.L., & Sapers, G.M. (1984). Varietal differences in distribution of quercetin and kaempferol in onion (*Allium cepa* L.) tissue. *Journal Agricultural Food Chemistry*, *32*, 274–276.

Block, E., Naganathan, S., Putman, D., & Zhao, S.H. (1992). Allium chemistry: HPLC analysis of thiosulfinates from onion. *Journal Agricultural Food Chemistry*, *40*, 2418–2430.

Chan, J.Y.Y., Yuen, A.C.Y., Chan, R.Y.K., & Chan, S.W. (2013). A review of the cardiovascular benefits and antioxidant properties of Allicin. *Phytherapy Research, 27*(5), 637–646.

Chang, T.C., Chang, H.T., Chang, S.T., Lin, S.F., Chang, Y.H., & Jang, H.D. (2013). A comparative study on the total antioxidant and antimicrobial potentials of ethanolic extracts from various organ tissues of Allium spp. *Food and Nutrition Sciences*, *4*, 182-190.

Chen, J.H., Chen, H.I., Wang, J.S., Tsai, S.J., & Jen, C.J. (2000). Effects of welsh onion extracts on human platelet function in vitro. *Life Science*, *66*(17), 1571-1579.

Crowell, P.L., & Gould, M.N. (1994). Chemoprevention and therapy of cancer by d-limonene. *Critical Reviews in Oncogenesis, 5*(1), 1-22.

Crystal, S., Lombard, K.A., Peffley, E.B., & Liu, W.X. (2003). Genetic analysis of quercetin in onion (*Allium cepa* L.) 'Lady Raider'. *Texas Journal of Agriculture Natural Resources, 16*, 24-28.

Debin, W., Jiande, G., & Guangshu, L. (2005). General situation of Allium crops in China. *Acta Horticulturae, 688*, 327-332.

El-Hadidy, E.M., Mossa, M.E.A., & Habashy, H.N. (2014). Effect of freezing on the pungency and antioxidants activity in leaves and bulbs of green onion in Giza 6 and Photon varieties. *Annals of Agriculture Science, 59*(3), 33–39.

Farkas, O., Jakus, J., & Héberger, K. (2004). Quantitative structure—antioxidant activity relationships of flavonoid compounds. *Molecules, 9*, 1079–1088.

Fukaya, M., Nakamura, S., Nakagawa, R., Kinka, M., Nakashima, S., & Matsuda, H. (2019). Cyclic sulfur-containing compounds from *Allium fistulosum* 'Kujou'. *Journal of Natural Medicine, 73*(2), 397–403.

Gao, S., Liu, X., Liu, Y., Cao, B., Chen, Z., & Xu, K. (2021). Comparison of the effects of LED light quality combination on growth and nutrient accumulation in green onion (*Allium fistulosum* L.). *Protoplasma, 258*, 753-763.

Gitin, L., Dinica, R., & Parnavel, R. (2012). The Influence of Extraction Method on the Apparent Content of Bioactive Compounds in Romanian Allium spp. Leaves. *Notulae Botanicae Horti Agrobotanici, 40*(1), 93-97.

Golubkina, N.A., Nadezhkin, S.M., Agafonov, A.F., Kosheleva, O.V., Molchanova, A.V., Russo, G., Cuciniello, A., & Caruso, G. (2015). Seed oil content, fatty acids composition and antioxidant properties as affected by genotype in *Allium cepa* L. and perennial onion species. *Advances in Horticultural Science, 29(*4): 199-206.

Habibi, H., & Ghahtan, N. (2019). Effects of medicinal plant powder as feed additives on growth performance, carcass characteristics, and immune response of *Coturnix japonica* against avian influenza and Newcastle disease vaccine virus. *Comparative Clinical Pathology, 28*(2), 1581–1588.

Higashio, H., Hirokane, H., Sato, F., Tokuda, S., & Uragami, A. (2007). Enhancement of functional compounds in allium vegetables with UV radiation. *Acta Horticulturae, 744*, 357-361.

Hirayama, Y., Takanari, J., Goto, K., Ueda, H., Tanaka, A., & Nishihira, J. (2019). Effect of Welsh onion (*Allium fistulosum* L.) green leaf extract on immune response in healthy subjects: a randomized, double-blind, placebo-controlled study. *Functional Foods in Health and Disease, 9*(2), 123-133.

Immaculate, V.T.M., Shlini, P., & Mary Clare, H. (2020). Isolation and purification of apigenin from *Allium fistulosum*. *International Journal of Current Pharmaceutical Research, 12*(5), 67–71.

Kuo, M.C., Chien, M., & Ho, C.T. (1990). Novel polysulfides identified in the volatile components from welsh onion (*Allium fistulosum* L. var. maichuon) and scallions (*Allium fistulosum* L. var. caespitosum). *Journal of Agricultural and Food Chemistry*, 38(6), 1378-1381.

Kruzlicova, D., Danihelova, M., & Veverka, M. (2012). Quantitative structure-antioxidant activity relationship of quercetin and its new synthetised derivatives. *Nova Biotechnologica et Chimica, 11*(1), 37–44.

Liang, L., Zhou, C., Zhang, Y., & Sun, B. (2021). Effect of welsh onion on taste components and sensory characteristics of porcine bone soup. *Foods, 10*(12), 2968.

Miean, K.H., & Mohamed, S. (2001). Flavonoid (myricetin, quercetin, kaempferol, luteolin, and apigenin) content of edible tropical plants. *Journal of Agricultural and Food Chemistry, 49*(6): 3106-3112.

Bui, T.L.M., Huynh N.T., Luu, H.M., Nguyen, N.V.T., & Nguyen, N.X.D. (2017). Effect of chives (*Allium fistulosum* L.) on growth performance and immune response of local chicken. *Livestock Research for Rural Development, 29*(10) 2017.

Monika, N., & Sakthi A. (2018). GC-MS studies on traditional plant *Allium fistulosum* L. bulbs. *World Journal of Pharmacy and Pharmaceutical Sciences, 7*(6), 823-834.

Muhammad, N.O., & Ajiboye, B.O. Nutrients composition of *Rana galamensis*. (2010). *African Journal of Food Science and Technology, 1*(1), 27-30.

Mysiak, B., & Tendaj, M. (2006). Content of flavonoids in some Allium species grown for green bunching. *Vegetable Crops Research Bulletin, 65*, 105-110.

Mysiak B., & Tendaj M. (2008). Content of phenolic acids in edible parts of some Alliums species grown for the green bunching. *Acta Scientiarum Polonorum. Hortorum Cultus* (Poland), *74*, 57-62.

Newenhouse, A. (2011). *Growing Fresh Market Onions, Garlic, and Leeks*. University of Wisconsin. Madison, WI, USA, pp. 1–39.

Nohara, T., Fujiwara, Y., Kudo, R.; Yamaguchi, K., Ikeda, T., Murakami, K., Ono, M., Kajimoto, T., & Takeya, M. (2014). Isolation and characterization of new onionins A2 and A3 from *Allium cepa*, and of Onionins A1, A2, and A3 from *Allium fistulosum*. *Chemistry Pharmaceutical Bulletin, 62*(11), 1141–1145.

Nohara, T., Fujiwara, Y., El-Asar, M., Ikeda, T., Ono, M., & Nakano, D. (2021). Thiolane-type sulfides from garlic, onion, and welsh onion. *Journal of Natural Medicine, 75*, 741–751.

Okungbowa, A.I., Okugbo, O.T., & Ezekiel-Hart, O.W. (2017). Comparative phytochemical and in vitro antioxidant analysis of some indigenous plants. *BIU Journal of Basic and Applied Sciences 3*(1): 41 – 51.

Oomah, B.D., Ladet, S., Godfrey, D.V., Liang, J., & Girard, B. (2000). Characteristics of raspberry (*Rubus idaeus* L.) seed oil. *Food Chemistry, 69*(2), 187-193.

Rose, P., Whiteman, M., Moore, P.K, & Yi, Z.Z. (2005). Bioactive S-alk(en)yl cysteine sulfoxide metabobiltes in the genus Allium: the chemistry of potential therapeutic agents. *Natural Product Reports, 22*(3): 351-368.

Rouphael, Y., Cardarelli, M., Bassal, A.H., Leonardi, C., Giuffrida, F., & Colla, G. (2012). Vegetable quality as affected by genetic, agronomic and environmental factors. *Journal of Food, Agriculture and Environment,10*(3), 680-688.

RxHarun. (2022). *Allium fistulosum* – Nutritional Value, Health Benefits, Recipes. https://rxharun.com/allium-fistulosum-nutritional-value-health-benefits-recipes/. Browse 21 March 2022.

Ryuk, J.A., Kim, H.J., Hwang, J.T., & Ko, B.S. (2021). Effect of *Allium fistulosum* extracts on the stimulation of longitudinal bone growth in animal modeling diet-induced calcium and vitamin D deficiencies. *Applied Science, 11*(17), 7786.

Sakakibara, H., Honda, Y., Nakagawa, S., Ashida, H., & Kanazawa, K. (2003). Simultaneous determination of all polyphenols in vegetables, fruits, and teas. *Journal of Agrultural and Food Chemistry, 51*(3), 571–581.

Sang, S., Lao, A., Wang, Y., Chin, C.K., Rosen, R.T., & Ho, C.T. (2002). Antifungal constituents from the seeds of *Allium fistulosum*. L. *Journal of Agricultural and Food Chemistry, 50*(22), 6318-6321.

Seyoum, A., Asres, K., & El-Fiky, F.K. (2006). Structure-radical scavenging activity relationships of flavonoids. *Phytochemistry, 67*(18), 2058–2070.

Shakurfow, F.A.A., Buazzi, M.M., & Gamal, M.A.B. (2015). Assessment of antimicrobial activity of onion (*Allium cepa*) and garlic (*Allium sativum*) extracts on *Listeria monocytogenes*; in vitro study. *Lebda Medical Journal, 1*, 1–5.

Sim, G.S., Lee, B.C., Cho, H.S., Lee, J.W., Kim, J.H., Lee, D.H., Kim, J.H., Pyo, H.B., Moon, D.C., Oh, K.W., Yun, Y.P., & Hong, J.T. (2007). Structure activity relationship of antioxidative property of flavonoids and inhibitory effect on matrix metalloproteinase activity in UVA- irradiated human dermal fibroblast. *Archives of Pharmacal Research, 30*(3), 290–298.

Singh, P., Mahajan, V., Shabeer T.P.A., Banerjee, K., Jadhav, M.R., Kumar, P., & Gopal, J. (2020). Comparative evaluation of different Allium accessions for allicin and other allyl thiosulphinates. *Industrial Crops and Products, 147*, 1-7.

Singh, V., & Kumar, R. (2017). Study of Phytochemical analysis and antioxidant activity of *Allium sativum* of Bundelkhand Region. *International Journal of Life Science Scientific Research, 3*(6), 1451–1458.

Siregar, T.M., Eveline, & Jaya, F.A. (2015). Kajian aktivitas dan stabilitas antioksidan ekstrak kasar bawang daun (*Allium fistulosum* L.). *Prosiding STNT ke-6, 2015*. FakultasTeknik Universitas Wahid Hasyim, Semarang. pp 36-43.

Sohn, H.Y., Kum, E.J., Ryu, H.Y., Jeon, S.J., Kim, N.S., & Son, K.H. (2006). Antifungal activity of fistulosides, steroidal saponins, from *Allium fistulosum* L. *Journal of Life Science, 16*(2), 310-314.

Souza, M.C., Siani, A.C., Ramos, M.F., Menezes-de-Lima, O.J., & Henriques, M.G. (2003). Evaluation of anti-inflammatory activity of essential oils from two Asteraceae species. *Pharmazie, 58*(8), 582-586.

Stajner, D., Milic-DeMarino, N., Canadanovic-Brunet, J., & Igic, R. (1998). Antioxidative properties of wild *Allium flavum* L.. *Pharmaceutical and Pharmacological Letter, 8*, 161–163.

Stajner, D., Milic, N., & Canadanovic-Brunet, J. (1999). An investigation into the antioxidant activity of *Allium nutans* L. *Phytotherapy Research, 13*(4), 333 – 336.

Stajner, D., Milic-DeMarino, N., Canadanovic-Brunet, J., & Popovic, M. (2002). Scavenger activity of *Allium psekemense* B. Fedtsch. *Phytotherapy Research, 16*(5), 484 – 487.

Stajner, D., Milic, N., Canadanovic-Brunet, J., Kapor, A., Stajner, M., & Popovic, B.M. (2006). Exploring Allium species as a source of potential medicinal agents. *Phytotherapy Research, 20*(7), 581–584.

Sugiharto, S. (2016). Role of nutraceuticals in gut health and growth performance of poultry. *Journal of the Saudi Society of Agricultural Sciences, 15*(2), 99–111.

Sung, Y.Y., Yoon, T., Kim, S.J., Yang, W.K., & Kim, H.K. (2011). Anti-obesity activity of *Allium fistulosum* L. extract by down-regulation of the expression of lipogenic genes in high-fat diet-induced obese mice. *Molecular Medicine Reports, 4*(3), 431-435.

Sung, Y.Y, Kim, S.H., Kim, D.S., Park, S.H., Yoo, B.W., Kim, H.K. (2014). Nutritional composition and anti-obesity effects of cereal bar containing *Allium fistulosum* (welsh onion) extract. *Journal of Functional Foods, 6*, 428–437.

Sung, Y.Y., Kim, D.S., Kim, S.H., & Kim, H.K. (2018). Aqueous and ethanolic extracts of welsh onion, *Allium fistulosum*, attenuate high-fat diet-induced obesity. *BMC Complementary and Alternative Medicine, 18*(105), 1-11.

Tabassum, A., Reitz, S., Rogers, P., & Pappu, H.R. (2016). First report of Iris yellow spot virus infecting green onion (*Allium fistulosum*) in the United States. *Plant Disease, 100*(12), 2539.

Tendaj, M., & Mysiak, B. (2007). Usefulness of Japanese bunching onion (*Allium fistulosum* L.) for forcing in greenhouse. Acta Agrobotanica, 60 (1), 143-146.

Thompson, S. (1995). *The Kitchen Garden*. Bantam Books, New York.

Tian, X.Q., Yu, F.C., Wang, R., & Li, S. (2016). Research progress of modern pharmacology and pharmacodynamics of Welsh onion. *China Fruit Vegetables, 36*, 29–33.

Tigu, A.B., Moldovan, C.S., Toma, V.A., Farcas, A.D., Mot, A.C., Jur, J., Fischer-Fodor, E., Mircea, C., & Pârvu, M. (2021). Phytochemical analysis and in vitro effects of *Allium fistulosum* L. and *Allium sativum* L. extracts on human normal and tumor cell lines: A comparative study. *Molecules, 26*(3), 574.

Toghyani, M., Toghyani, M., Gheisari, A., Ghalamkari, G., & Eghbalsaied, S. (2011). Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. *Livestock Science, 138*(1-3), 167–173.

Udjaili, S., Abidjulu, J., & Suryanto, E. (2015). Aktivitas antioksidan dari akar bawang daun (*Allium fistulosum* L.). *Jurnal MIPA Unsrat, 4*(1), 20-23.

Verma, V., Pradheep, K., Khar, A., Negi, K., & Rana, J. (2008). Collection and Characterization of Allium Species from Himachal Pradesh. *Journal Plant Genetic Resources, 21*(3), 225–228.

Verma, S., Kaur, S., Singh, J., & Garg, A. (2015). Anti-bacterial effect of garlic (*Allium sativum* L.) extract on different pathogenic and non-pathogenic bacteria. *Research Journal of Pharmaceutical Biological and Chemical Sciences, 6*(3), 1103-1107.

Vlase, L., Parvu, M., Parvu, E.A., & Toiu, A. (2013). Phytochemical analysis of *Allium fistulosum* L. and *A. ursinum* L. *Digest Journal of Nanomaterials and Biostructures, 8*(1), 457 – 467.

Waghulde, S., Kale, M.K., & Patil, V.R. (2021). Cumulative phytochemical analysis and identification of drug lead compounds from medicinal plant extracts. *Chemistry Proceeding*. The 25th International Electronic Conference on Synthetic Organic Chemistry, 15–30 November 2021.

Wang, B.S., Huang, G.J., Lu, Y.H., & Chang, L.W. 2(013). Anti-inflammatory effects of an aqueous extract of welsh onion green leaves in mice. *Food Chemistry, 138*(2-3), 751-756.

Wang, Z.F. (2017). Research on antioxidant activity of different parts of welsh onion. *China Condiment*, 42, 123–124.

Wang, Y., Deng, C., Cota-Ruiz, K., Peralta-Videa, J.R., Sun, Y., Rawat, S., Tan, W., Reyes, A., Hernandez-Viezcas, J.A., Niu, G., Li, C., & Gardea-Torresdey, J.G. (2020). Improvement of nutrient elements and allicin content in green onion (*Allium fistulosum*) plants exposed to CuO nano particles. *Science of the Total Environment, 725*, 138387.

Warade, S.D., & Shinde, K.G. (1998). *Handbook of Vegetable Science and Technology: Production, Composition Storage and Processing*. Ed. by Salunkhe D.K. And Kadam S.S., Marcel Dekker. Inc. New York.

Xu, J., Guo, C.J., Wei, J.Y., Yang, J.J., Cheng, S., & Wu, J.Q. (1956). The method of HPLC for determination of major flavonoids in vegetables. *Acta Nutrimenta Sinica, 6*.

Yamamoto, Y., Aoyama, S., Hamaguchi, N., & Rhi, G.S. (2005). Antioxidative and antihypertensive effects of welsh onion on rats fed with a high-fat high-sucrose diet. *Biosciences Biotechnology Biochemistry, 69*(7), 1311-1317.

Yao, Y., Lin, G., Xie, Y., Ma, P., Li, G., Meng, Q., & Wu, T. (2014). Preformulation studies of myricetin:

A natural antioxidant flavonoid. *Pharmazie, 69*(1), 19–26.
Yilmaz, B.S., & Özbek, H. (2018). Investigation of the anti-inflammatory, hypoglycemic activity and median lethal dose (LD50) level of limonene in mice and rats. *Acta Pharmaceutica Sciencia, 56*(1), 85-94.
Yin, M.C., Hsu, P.C., Chang, H.H. (2003). *In vitro* antioxidant and antibacterial activities of shallot and scallion. *Journal of Food Science, 68*(1), 281–284.
Yu, L., Yan, J., & Sun, Z. (2017). D-limonene exhibits anti-inflammatory and antioxidant properties in an ulcerative colitis rat model via regulation of iNOS, COX-2, PGE2 and ERK signaling pathways. *Molecular Medicine Reports, 15*(4), 2339-2346.
Zhang, W.W., Zhao, Y.J., An, J.J., Feng, D.L., Wang, L.Q., Yuan, R.J. (2017). Determination and analysis of mineral elements and lipid composition in different varieties of Welsh onion. *Food Ind., 38*, 282–284.
Zhou, Y., Zhuang, W., Hu, W., Liu, G.J., Wu, T.X., & Wu, X.T. (2011). Consumption of large amounts of Allium vegetables reduces risk forgastric cancer in a meta-analysis. *Gastroenterology, 141*(1), 80-89.