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EFFECTS OF MEDICINAL PLANTS AND THEIR EXTRACTS AS DIETARY ADDITIVES ON FISH GROWTH AND FEED EFFICIENCY IN TURKISH AQUACULTURE: A REVIEW

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Abstract
The inadequacy of natural aquaculture stocks to meet the protein needs of the increasing population of today led to an increase in the importance assigned to aquaculture. The fight against infectious diseases that cause financial losses in production is gaining importance everyday while the amount of aquacultural production and stocks increases as well. Antibiotics are used to prevent diseases and promote growth. The official prohibition of the use of antibiotics as growth stimulators by the European Union as of 01 January 2006, made it compulsory to use natural additives in animal nutrition. In this review, studies on the effects of medicinal plants that were used as natural additives in the aquaculture sector in Turkey in the last 10 years on the growth performance of fish were evaluated.

Keywords: Aquaculture sector, Essential oil, Extract, Active substance, Feed additive, Growth performance, Plant origin

Introduction
Aquaculture is claimed to be the fastest growing food production sector in the world (Gasco et al., 2018). The production obtained through aquaculture is gradually increasing both in our country and in the world. The amounts of fish produced through aquaculture in 2019 reached 85.3 million tons in the world and 373,356 thousand tons in Turkey (TUİK, 2020). Due to the increase in stock density in the aquaculture areas, the risk of stress and disease in fish increases

(Ingram et al., 2005). Antibiotics have started to be used as feed additives in animal feeds by adding to water, to feed or by injection in order to prevent disease and stress, increase feed efficiency and ensure growth (Gorbach, 2001; Rico et al., 2013). However, upon concerns over the course of time that using antibiotics without infection, wrong choice of antibiotics, underdosing, simultaneous use of one or more antibiotics might both lead to bacterial resistance and threat human health by leaving residues in animal by-products, the use of antibiotics in feeds as feed additives was completely prohibited in the European Union as of January 1, 2006 (Castanon, 2007; Ringø et al., 2010; Dawood et al., 2022; Yilmaz et al., 2022). Following this prohibition, products that can be alternatives to antibiotics have started to be sought in order to control bacterial diseases by maintaining the health of the gastro-intestinal microflora and to strengthen the immune system of animals, support growth performance and reduce mortality (Talpur et al., 2014). Today, natural growth factors including probiotics (Yılmaz et al., 2022), prebiotics (Yilmaz et al., 2022), organic acids (Yilmaz and Hunt, 2017) and enzymes (Castillo and Gatlin III, 2015) have started to replace antibiotics. In addition, phytoadditives obtained from medicinal plants have potential use in aquaculture and they are used today as an alternative to antibiotics since they are inexpensive, environmentally friendly and have minimal side effects (Dawood et al., 2022; Yilmaz et al., 2022). World Health Organization (WHO) promotes the use of supplementary diets combined with medicinal herbs or plants, which minimize the application of chemicals in fish diet (Dada, 2015). Currently several studies are conducted to investigate the effectiveness of herbal supplements in fish feeds in managing fish diseases and producing healthy fish. This review highlights the importance of adding herbs and herbal products to fish feed for better fish production and better fish health.

Medicinal, Aromatic Plants

Plants containing bioactive substances or substances with therapeutic properties are called "medicinal plants", and plants rich in essential or ethereal oils are called "aromatic plants" (Baydar, 2021). Medicinal plants, herbs and essential oils have been used for thousands of years as food, spice, dyestuff and medicine (Giannenas et al., 2020). Most medicinal plants do not pose a threat to human health, fish and environment (Stratev et al., 2018). Since medicinal and aromatic plants contain various active compounds including, flavonoids, alkaloids, phenolics, pigments, steroids, terpenoids and essential oils, they can be used instead of antibiotics and other synthetic chemicals in aquaculture (Sivaram et al., 2004; Citarasu, 2010). Medicinal and aromatic plants as well as essential oils and components obtained from these plants reported to be stimulating the digestive system and significantly improving feed consumption, feed utilization and carcass quality by destroying the pathogenic microflora or increasing the concentration of the microbial population in the digestive system, which leads to better digestion and absorption of nutrients (Yadkoori et al., 2015). Most of the plants used both by fish farmers and in scientific studies for potential use in aquaculture correspond to plants widely used in traditional medicine (Reverter et al., 2017). And Reverter et al. (2017) identified over 250 plant species from 75 families and 32 orders, which have been used or reported as potentially interesting in aquaculture. Numerous scientific studies endorse the use of medicinal plants in aquaculture (Syahidah et al., 2015; Kumar et al., 2016; Awad & Awaad, 2017; Shakya et al., 2017; Hernández-Contreras & Hernández, 2020; Kuebutornye & Abarike, 2020; Potiwong et al., 2020; Tadese et al., 2022). Numerous studies both in Turkey and in the world documented the effects of plants as appetite stimulant, growth promoter and digestive enhancer in aquatic species (Table 1). For example, it was found that the addition of *Cumin cyminum* (Yilmaz et al., 2013a) and *Pimenta dioica* (Yilmaz & Ergun, 2014) at different rates to the tilapia diets improve growth. Likewise, trout fed with curcumin in powder form supplemented diets consumed more feed as compared to control and showed improved fish growth (Yonar et al., 2019). In another study, cumin supplementation did not affect the growth and feed efficiency parameters (Yilmaz et al., 2012). One of the aromatic plants, significantly studied as a growth promoter in fish is garlic. Buyukdeveci et al. (2018) reported increased growth performance in rainbow trout (*Oncorhynchus mykiss*) fed diets containing 1, 1.5 and 2% of garlic for 120 days. Similarly, Irkin and Yigit (2016) found that garlic meal could enhance growth and nutrient utilization of European seabass (*Dicentrarchus labrax*) juvenıles. In a different study, garlic supplemented diet increased growth performance in tilapia (Ozguven & Dikel, 2018). Ginger is a spice and medicinal plant which has been used in different forms, doses and durations in fish production. Ginger on fish feed on feed intake, feed conversion ratio, growth rate and weight gain with their possible mechanisms of action abound in literature. For instance, Savaser et al., (2019) supplemented rainbow trout (*Oncorhynchus mykiss*) diets with six different inclusion levels of ginger powder for 60 days, and at the end of the feeding trial was trout challenge with *Yersinia ruckeri*. The results revealed significantly improved growth and immunity. In another study, Onculokur et al. (2014) reported that the use of carob kernel flour (*Ceratonia siliqua*) seed in a diet for koi carp (*Cyprinus carpio*) for 60 days and they found that carob kernel flour seed has potential as an alternative feed ingredient in diets for koi carp (*Cyprinus carpio*) with no adverse effect. Further, it has been proven that the addition of natural carotenoids (astaxanthin, paprika, capsicum) to fish feed for pigmentation purposes improved growth performance (Yilmaz et al., 2013b; Parrino et al., 2019). Likewise, a recent study (Sezgin & Aydin, 2021) reported the pumpkin (*Cucurbita pepo*) seed cake diets had better growth and feed utilization parameters compared to those of the control. . In another relevant study (Dernekbası et al. 2021), peanut meal tested for its dietary effects on growth performance and biochemical composition and fillet color of rainbow trout. They found that 50% peanut meal instead of soybean meal in trout diets could be used in diets of rainbow trout without any negative effects on growth.

Plant Extracts

Essential oils, aromatic waters, concretes, absolutes, resinoids, oleoresins, pomades and pomade absolutes are aromatic extracts with high commercial value. From aromatic plants, essential oil and aromatic water are obtained by water and steam distillation while concrete and absolute are obtained by solvent extraction. Oleoresin is produced from resinous products and spices through organic solvent. Pomade is obtained by extraction method from aromatic flowers. All these and similar liquid and semi-solid products are called "Extract" (Baydar, 2021). In the last decades, there is a considerable rise on the use of plant extracts as feed additives in fish nutrition (Hernández-Contreras, & Hernández, 2020). Plant extracts have anti-stress, growth-promoting, appetizing and immune system-stimulating effects in fish due to the active components they contain including alkaloids, terpenoids, tannins, saponins, glycosides, flavonoids, phenolics, steroids and essential oils (Reverter et al. 2014; Hodar et al., 2021). At the same time, these active components have antibacterial, antiparasitic, antifungal and antiviral activity properties that prevent various fish diseases (Hodar et al., 2021). A variety of herbal extracts, plant EOs or their pure compounds have been successfully used as growth performance enhancers including *Tribulus terrestris* extract (Yilmaz et al., 2014; Gultepe et al., 2014), daphne leave extract (Yesilayer et al., 2014), *Avena sativa* water extract (Baba et al., 2016a), *Capparis spinosa* methanolic extract (Bilen et al., 2016a), *Rosmarinus officinalis* extract (Turan & Yigitarslan, 2016), *Ficus carica* and *Allium capa* extract (Yilmaz et al., 2017a), *Artemisia vulgaris* powder and ethanolic extract (Diler et al., 2017a), *Tilia tomentosa* methanolic extract (Almabrok et al., 2018), *Chenopodium album* aqueous methanolic extract (Amhamed et al., 2018), *Lepidium sativum* methanolic extracts (Bilen et al., 2018), *Apium graveolens* extract (Mohamed et al., 2018), *Pelargonium sidoides* extract (Turan, 2018), *Malva sylvestris* methanolic extract (Bilen et al., 2019), grape seed extract (Kesbic & Yigit, 2019), *Melissa officinalis* methanolic extract (Bilen et al., 2020a), *Malva sylvestris* methanolic extract (Bilen et al., 2020b), L-alliin (Yilmaz et al., 2020b) and olive leaf extract (Zemheri-Navruz et al., 2020). Furthermore, some medicinal herbal extracts have been reported to have no effects on growth performance in fish species. For instance, *Viscum album*, *Urtica dioica* and *Zingiber officinale* aqueous extracts (Dugenci et al., 2003), *Brassica rapa* meal, powder after extraction, water extract and methanolic extract (Haliloglu et al., 2012), *Cotinus coggygria* and *Laurus nobilis* extracts (Bilen & Bilen, 2012), *Cotinus coggygria* methanolic extract (Bilen et al., 2013), *Anethum graveolens* methanolic extracts (Bilen et al., 2018), *Cotinus coggygria* methanolic extract (Bilen et al., 2019), R*osmarinus officinalis* and *Aloe barbadensis* extract (Yilmaz et al., 2019a), *Ficus carica* and *Rosmarinus officinalis* extract (Yilmaz & Er, 2019), *Laurocerasus officinalis* extract (Akyüz et al., 2019) were reported to impose no effects on growth performance. In another study, Yilmaz et al. (2020b) reported that oleuropein reduced weight gain and specific growth rate of rainbow trout, when trout were fed with 10 mg/kg oleuropein.

Essential Oils

It is reported that about 2 thousand species belonging to 60 botanical families in the plant kingdom contain essential oil (Baydar, 2021). Almost every plant synthesizes essential oil, although at an undetectable level. Aromatic plants contain much more essential oil compared to other plants (Sutili et al., 2018; Baydar, 2021). Essential oils have as main components terpenes and other molecules derived from them, such as terpenoids, aldehydes, ketones, acids, phenols, lactones, ethers, and esters (Tongnuanchan & Benjakul, 2014). Aromatic plants and essential oils can replace antibiotic growth promoters by creating positive effects on animals' digestion, gut microbiome, health and growth (Sutili et al., 2017). Growth promoter efficacy depends on factors such as dietary form, nutrient density and composition, essential oil composition and quality, dosage, age of animals, growth performance level. (Socaci et al., 2020).The essential oils extracted from plants have been found to show several positive influences on feeding of livestock's, especially in aquaculture (Acar et al., 2015; Aydin % Barbas, 2020; Dawood et al., 2022). Some reports have shown that orange peel (Acar et al., 2015), thyme and sage oil (Sonmez et al., 2015), *Origanum vulgare* oil (Cihangir & Diler, 2016), *Origanum vulgare* L. essential oil (Diler et al., 2017c), juniper berry oil (Kesbic, 2019a), cinnamon oil (Kesbic et al., 2019b), *Hypericum perforatum* oil (Acar et al., 2018b), *Vitis vinifera* seed oil (Arslan et al., 2018), *Lavandula stoechas* oil (Yilmaz, 2019a), bergamot peel oil (Acar et al., 2019; Kesbic et al., 2020a) and *Monterey cypress* leaf essential oil (Kesbic et al., 2020b) could promote growth of fish. Furthermore, some medicinal herbal extracts have been reported to have no effects on growth and feed efficiency parameters of fish. For instance, citrus limon peel, rosemary oil, clove oil, *Hypericum perforatum* oil, pomace oil, *Rosa canina, L.* oil were reported to impose no effects on growth performance (Baba et al., 2016b; Sahin et al., 2017; Cilingir et al., 2017; Yilmaz et al., 2020a; Alnaiem & Aydin, 2021).

Plant Fruit and Syrups

Fruit and plant syrups are also used as feed additives because they are rich in phenolic ingredients. It has been found that the addition of blackberry syrup and black mulberry syrup in different proportions to tilapia feed improves growth performance (Yilmaz, 2019b; Yilmaz, 2020c). In another study, it was found that supplementation of carob (*Ceratonia siliqua*) syrup to *O. mossambicus* feeds did not affect the growth performance of the fish (Yilmaz et al., 2018).

Addition of organic acid to fish feed is a subject that has been studied in aquaculture in recent years. Yilmaz et al. (2019c) found that trans-cinnamic acid did not have any negative effects on the growth performance, feed consumption, nutrient composition, digestive enzymes, visceral indices, intestinal and stomach pH values, serum enzymes and fats, and antioxidant capacity of the fishes.

Table 1. The role of feed ingredients supplemented to fish feed in Turkey

Additives	Fish species	Mean initial body weight	Concentration and supplement duration	Optimum levels	Results	References
Extract						
Brassica rapa (water and methanol extract)	*O. mykiss*	0.67 g	4 Wks	N/A	FW, FCR, PER ↑, WG, SGR ↔,	Haliloglu et al. (2012)
Cotinus coggygria (extract)	*C. carpio*	4.14 g	0.5, 1, 1.5 g kg^{-1} of feed, 4 wks	N/A	FW, WG, SGR, FCR ↔	Bilen et al. (2013)
Paprika, capsicum (extract)	*O. mossambicus*	~5 g	40, 60 mg/kg, 45 days	N/A	FW, WG, SGR ↑, FCR ↓	Yilmaz et al. (2013b)
Daphne leave (extract)	*O. mykiss*	107.71 g	250, 500 mg/kg, 60 days	250 mg/kg	WG, SGR ↑, FCR ↓, FW, CF ↔	Yesilayer et al. (2014)
Tribulus terrestris (extract)	*O. mossambicus*	0.0120 g	200, 400, 600, 800 mg/kg, 45 days	600 mg/kg	FW, WG, SGR ↑, FCR ↓	Yilmaz et al. (2014)
	O. niloticus	2.61 g	200, 400, 600 mg/kg, 88 days	400 mg/kg	WG, SGR ↑, FCR ↓, FW ↔,	Gultepe et al. (2014)
Avena sativa (water extract)	*C. carpio*	9.91 g	5, 10, 20 g/kg, 60 days	10 g/kg	WG, SGR ↑, FCR ↓	Baba et al. (2016a)
Capparis spinosa (methanolic extract)	*O. mykiss*	12.04 g	0.1, 0.5 g/kg, 30 days	N/A	FW, FI, WG, SGR, PER ↑, FCR ↔	Bilen et al. (2016a)
Rosmarinus officinalis (extract)	*C. gariepinus*	10.59 g	0.25, 0.5%, 60 days	N/A	WG, PER ↑, FCR ↓, SGR ↔,	Turan and Yigitarslan (2016)
Artemisia vulgaris (powder and ethanolic extract)	*O. mykiss*	21 g	Powder: 0.1, 0.5, 1, 2% Extract: 250, 1000 mg/kg, 90 days	N/A	FW, WG, SGR ↑, FCR ↓	Diler et al. (2017a)
Ficus carica, Allium capa (extract)	*C. carpio*	2.48 g	1, 3, 5 g/kg, 90 days	N/A	WG, SGR ↑, FCR ↓ FW, CF ↔,	Yilmaz et al. (2017a)
Tilia tomentosa (methanolic extract)	*C. carpio*	4.35 g	0.01, 0.05, 0.1%, 45 days	N/A	FW, WG, SGR ↑ 00.1% and 0.1% groups FCR ↓ 0.05% and	Almabrok et al. (2018)

					0.1% groups	
Chenopodium album (methanolic extract)	*C. carpio*	2.4 g	0.01, 0.05, 0.1 g/kg, 45 days	N/A	FW, WG, SGR ↑, FCR ↔	Amhamed et al. (2018)
Anethum graveolens, Lepidium sativum (methanolic extract)	*C. carpio*	3.46 g	1, 2 g/kg, 45 days	N/A	FW, SGR, WG ↑, FCR ↔ in 2 g/kg *L.sativum* group SGR ↓, FCR ↑ in 1 g/kg *A. graveolens* group	Bilen et al. (2018)
Apium graveolens (extract)	*C. carpino*	6.5 g	0.1, 0.5, 1%, 45 days	0.1%	FW, WG, FCR, SGR ↑	Mohamed et al. (2018)
Pelargonium sidoides (extract)	*C. gariepinus*	1.09 g	5 and 10 ml/100 g^{-1}, 90 days	N/A	WG, PER ↑, SGR ↔, FCR ↓	Turan (2018)
Laurocerasus officinalis (extract)	*O. mykiss*	30.52 g	5 g/kg, 28 days	N/A	FW, WG, SGR, FCR ↔	Akyuz et al. (2019)
Malva sylvestris, Cotinus coggygria (extracts)	*S. aurata* and *D. labrax*	19.92 g and 18.66 g	500, 1000 mg/kg, 60 days	N/A	FW, FI, WG ↑, SGR, FCR ↔ in *M. sylevestris* groups, FW, FI, WG, FCR, SGR ↔ in *C. coggygria* groups	Bilen et al. (2019)
Grape seed (extract)	*O. mykiss*	7.35 g	0.5, 1, 2 g/kg, 90 days	1 g/kg	FCR ↓, RGR, SGR PER ↑	Kesbic and Yigit (2019)
Rosmarinus officinalis, Ficus carica (extract)	*O. mykiss*	12.47 g	0.5, 1, 2 g/kg, 60 days	N/A	WG, SGR, FCR ↔	Yilmaz and Er (2019)
Rosmarinus officinalis, Aloe barbadensis (extract)	*O. niloticus*	7.516 g	0.1 0.25, 0.5%, 90 days	N/A	FW, WG, SGR, FCR, CF ↔	Yilmaz et al. (2019a)
Melissa officinalis (extract)	*O. mykiss*	23.03 g	0.1, 0.5, 1 g/kg, 75 days	0.5 g/kg,	FW, WG, SGR ↑, FCR ↔	Bilen et al. (2020a)
Malva sylvestris (methanolic extract)	*O. mykiss*	54.97 g	0.1, 0.5 g/kg, 30 days	0.1 g/kg	FW ↑, WG ↑, SGR ↑, FI ↑, FCR ↔, PER ↔	Bilen et al. (2020b)

Olive leaf (extract)	*C. carpio*	15.90 g	0.1, 0.25, 0.5, 1%, 60 days	0.25%	RGR, SGR ↑, FCR ↓	Zemheri-Navruz et al. (2020)
Prunus domestica (extract)	*O. mykiss*	27.61 g	0,1, 0,5, 1%, 21 days	N/A	FW, WG, FCR, SGR ↔	Terzi et al. (2021)
Powder						
Cotinus coggygria, Laurus nobilis (powder)	*O. mykiss*	66.13 g	1, 1.5%, 8 Wks	N/A	FW, WG, FI, SGR, FCR, PER ↔	Bilen and Bilen (2012)
Brassica rapa (powder)	*O. mykiss*	0.67 g	15%, 4 Wks	N/A	FW ↑, PER, FCR, WG, SGR ↔	Haliloglu et al. (2012)
Cuminum cyminum (seed meal)	*O. mossambicus*	0.56 g	0.5, 1, 1.5, 2%, 75 days	N/A	FW, WG, SGR, FI, FCR ↔	Yilmaz et al. (2012)
	O. mossambicus	0.012 g	0.5, 1, 1.5, 2%, 45 days	1.5%	FW, WG, SGR ↑, FCR ↓, CF ↔	Yilmaz et al. (2013a)
Albizia julibrissin (seed meal)	*C. carpio*	6.5 g	10, 20, 30, 40%, 60 days	20%	SGR ↓, CF ↑, FW, WG , FI , FCR ↔	Kirecci et al. (2014)
Ceratonia siliqua (seed meal)	*C. carpio*	12 g	10, 20, 30, 40%, 60 days	20%	FW, WG, FI , SGR ↓, PER ↔, FCR ↑	Onculokur et al. (2014)
Pimenta dioica (seed meal)	*O. mossambicus*	0.012 g	5, 10, 15, 20 g/kg, 50 days	15 g/kg	FW, WG, SGR, CF ↑, FCR ↓	Yilmaz and Ergün (2014)
Allium sativum (meal)	*D. labrax*	10.60 g	2, 4, 6%, 60 days	N/A	FW ↑, SGR ↑ in 4% garlic meal group, FCR, PER ↔	Irkin and Yigit (2016)
Allium sativum (powder)	*O. mykiss*	6.83 - 8.19 g	1, 1.5, 2%, 120 days	N/A	FW, WG, SGR ↑, FCR ↔	Buyukdeveci et al. (2018)
	Hybrid tilapia	2.57 g	0.5 and 1%, 90 days	N/A	FW, WG, FI, PER ↑, FCR ↓, SGR ↔	Ozguven and Dikel (2018)
Zingiber officinale (powder)	*O. mykiss*	108.7 g	0.5, 1, 2.5, 5, 10, 20 g/kg	2.5 g/kg	WG ↑, FCR ↓	Savaser et al. (2019)
Curcumin (powder)	*O. mykiss*	31.29 g	1, 2, 4%, 8 weeks	N/A	FW, WG, SGR ↑, FCR ↓	Yonar et al. (2019)
Cucurbita pepo (Pumpkin seed cake)	*C. carpio*	16.24 g	33, 66, 100%, 63 days	66%	FW, WG, SGR ↑, FCR ↓, FI, CF ↔	Sezgin and Aydin (2021)

Nigella sativa (Black cumin seed)	*C. carpio var. specularis*	16.2	25, 50%, 63 days	N/A	WG, SGR, FI, CF ↓, FCR↔	Aydin (2021)
Peanut meal	*O. mykiss*	108.70	50, 100%, 8 weeks	N/A	FW, WG, SGR ↑, FCR ↓	Dernekbası et al. (2021)
Active substances						
Carvacrol	*O. mykiss*	10.79 g	1, 3, 5 g/kg, 60 days	N/A	FW, WG, FCR, SGR ↔	Yilmaz et al. (2015)
Carvacrol and Thymol	*P.hypophthalmus*	1.33 g	1, 3, 5 g/kg, 90 days	N/A	FW, WG, SGR ↑, FCR ↔	Yilmaz et al. (2017b)
Trans-cinnamic acid	*O. mykiss*	21.63 g	0.025, 0.050, 0.075, 0.150%, 60 days	N/A	FW, RGR, FCR, SGR ↔	Yilmaz et al. (2019c)
L-alliin	*O. mykiss*	12.6 g	10 mg/kg, 60 days	N/A	FW, SGR, WG ↑, FCR ↓, FI ↔	Yilmaz et al. (2020b)
Oleuropein	*O. mykiss*	12.6 g	10 mg/kg, 60 days	N/A	FW ↑, WG, SGR ↓, FCR, FI ↔	
Essential oils						
Sweet orange peel	*O. mossambicus*	0.91 g	1, 3, 5 g kg^{-1}, 90 days	1 g kg^{-1}	WG, SGR ↑, FCR ↓	Acar et al. (2015)
Mint, thyme and sage oil	*O. mykiss*	13.3 g	0.5, 1.0, 1.5 %, 60 days	N/A	FW, SGR ↑, FCR ↓ in thyme and sage oil groups, FW, SGR ↓, FCR ↑ in mint oil	Sonmez et al. (2015)
Citrus limon peels essential oil	*O. mossambicus*	12.87 g	0.5, 0.75, 1%, 60 days	N/A	WG, SGR, FCR ↔	Baba et al. (2016b)
Origanum vulgare L. essential oil	*O. mykiss*	Fry: 0.4 g, Juvenil: 27.50 g	0.125, 1.5, 3 mg/kg, 90 days	N/A	FW, WG ↑, SGR, FCR ↔	Cihangir and Diler (2016)
	O. mykiss	26 g	0.125, 1.5, 2.5, 3 ml/kg, 90 days	N/A	FW, WG, SGR, CF ↑, FCR ↓, in 1.5, 2.5 and 3 ml/kg groups	Diler et al. (2017c)
Origanum onites essential oil	*O. mykiss*	26.05 g	0.125, 1.5, 2.5, 3 mL/kg, 90 days	N/A	FW, SGR ↑, FCR ↓, CF ↔	Diler et al. (2017b)
Hypericum perforatum oil	*O. mykiss*	20 g	1, 2, 3 mL/kg, 90 days	N/A	WG, SGR, CF, FCR ↔	Cilingir et al. (2017)
	C. carpio	3.07 g	5, 10 g/kg, 60 days	5 g/kg	FW, WG, SGR ↑, FCR ↓	Acar (2018b)

Rosmarinus officinalis oil	*O. mykiss*	30 g	0.5, 1, 1.5%, 60 days	N/A	FW, PGR, SGR ↔	Sahin et al. (2017)
	O. mykiss	10,14 g	0.025, 0.1, 0.05%, 60 days	N/A	FW, WG, SGR ↓, FCR ↑, FI ↔	Kıvrak and Didinen (2017)
Camellia sinensis oil	*O. mykiss*	76.25 g	0.25, 0.5, 1%, 42 days	N/A	FW, FI ↓, FCR, WG ↔	Altınterim et al. (2018)
Vitis vinifera seed oil	*O. mykiss*	30 g	250, 500, 1000 mg/kg, 60 days	N/A	FW, SGR ↑, FCR ↔ in 1.000 mg/kg group	Arslan et al. (2018)
Citrus bergamia peel oil	*D. labrax*	5.10 g	0.5, 1, 2%, 60 days	1%	SGR, RGR ↑, FCR ↓	Acar et al. (2019)
	O.niloticus	2.57 g	0.5, 1, 2%, 8 weeks	0.5%	FW, RGR, SGR ↑, FCR ↓	Kesbic et al. (2020a)
Juniper berry oil	*C. carpio*	3.07 g	5, 10 mL/kg, 60 days	N/A	FW, RGR, SGR ↑, FCR ↓, DFI ↔	Kesbic (2019a)
Cinnamomum verum oil	*O. mykiss*	10.68 g	1, 2, 4, 10 mL/kg, 60 days	4 mL/kg	FW, SGR ↑, FCR ↓	Kesbic (2019b)
Capsicum sp. oil	*O. mykiss*	~7 g	1, 2, 4, 6‰, 60 days	2‰	FW, RGR, SGR, DFI ↑, FCR ↔	Parrino et al. (2019)
Lavandula stoechas oil	*C. carpio*	10.88 g	5, 10 g/kg, 60 days	5 g/kg	FW, WG ↑, FCR ↓, SGR ↑	Yilmaz (2019a)
Pomace oil	*O. mykiss*	12.10 g	4, 8, 12%, 60 days	N/A	FW, WG, SGR FCR ↔	Yilmaz et al. (2020a)
Monterey cypress Leaf essential oil	*C.carpio*	7.86 g	0.5, 0.75, 1%, 60 days	N/A	FW, RGR, SGR ↑, FCR ↓, DFI ↔	Kesbic et al. (2020b)
Rosa canina, L. oil	*O. mykiss*	1.7 g	2,4,6 mL/kg	6 mL/kg	FW, WG, RGR, SGR, FCR ↔	Alnaiem and Aydin (2021)
Fruits and Plants Syrups						
Carob syrup	*O. mossambicus*	30.70 g	0.625, 1.25, 2.5, 5%, 60 days	N/A	FW, WG, FCR, SGR ↔	Yilmaz et al. (2018)
Blackberry syrup	*O. niloticus*	26.75 g	7.5, 15, 30 g/kg, 90 days	15 g/kg	FW, RGR, SGR ↑, FCR ↓	Yilmaz (2019b)
Black mulberry syrup	*O. niloticus*	9.74 g	0.75, 1.5, 2.0, 3.0%, 60 days	2%	FW, WG, SGR ↑, FCR ↓	Yilmaz et al. (2020c)
Fruit pigments						
Anthocyanin	*O. niloticus*	8.24 g	20, 40, 80, 160 mg/kg, 60 days	N/A	FW, RGR, SGR, FCR ↔	Yilmaz (2019d)

CF: Condition factor, DFI: Daily feed intake, FCR: Feed conversion ratio, FI: Feed intake; FW: Final weight; WG: Live weight gain; PER: Protein efficiency ratio; PGR: Proportional growth rate; RGR, relative growth rate; SGR: Specific growth rate; WG: Weight gain; N/A: Not available

Conclusion

In recent years, the tendency to return to nature in animal production in the world and in our country and the tendency towards the production and consumption of organic products have led to the preference of herbal products in the aquaculture sector as well. Herbal products are also preferred due to their easy availability and because they are cheap, harmless for the environment and biologically recyclable in addition to having minimal side effects and broad spectrum effect against pathogens. Furthermore, addition of natural and reliable medicinal and aromatic plants, their extracts and essential oils to fish feed to stimulate growth is a subject that has been studied in aquaculture in recent years since the use of all kinds of growth-stimulating synthetic substances, especially antibiotics, is prohibited.

In this review, the effects of different phytogenic products (plant extracts, essential oils and active substances) and their doses added to feed on the growth parameters of fish were reported. This review aims to encourage feed companies to benefit from medicinal and aromatic plants that do not pose a threat to fish health, human health and environment and whose effectiveness has been proven by intensive scientific studies.

Informed consent

Not available.

Conflicts of interest

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

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Contribution of authors

Ebru YILMAZ: Conceptualization, Software, Data curation, Writing – original draft
Uğur TAN: Data curation, Formal analysis, Writing – original draft, Investigation

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