Echinacea: A potential feed and water additive in poultry and swine production

Echinacea: Ein potentieller Futter- und Trinkwasserzusatz in der Geflügel- und Schweinerzeugung

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Introduction

The use of growth promoting antibiotics in animal feeds is prohibited in European Union (EU) since 2006, due to the risks associated with their use and development of resistant strains of bacteria. Now, as a result of this ban and increasing demand of organic animal products, alternative substances are required. These alternatives should be beneficial in maintaining health, improving immunity and performance of farm animals without any residual effects on consumer health and environment. A number of experiments conducted to find alternative substances revealed that no single alternative exists with the effects comparable to antibiotics (NASIR and GRASHORN, 2006). Plant extracts contain numerous substances having pharmacological activities. Especially for essential oils a wide range of effects have been proven, including inhibitory action on pathogens, effects on physiopathologies (e.g. anti-inflammatory, anti-diarrhoea properties) and activity in different body systems e.g. endocrine and immune system (RECOQUILLAY, 2006). Echinacea (E) is a North American indigenous plant (family Asteraceae), which has been traditionally used as a "cure all" for different ailments. In recent years, it has become one of the most popular herbal products in North America and Europe as an immune promoter and immune stimulant (GOEL et al., 2002). Echinacea extracts and preparations have been used traditionally for individuals suffering from sore-throats, coughs, and various respiratory symptoms that could be due to bacterial infections (SHARMA et al., 2008), with the proposed mechanism of action relating to its reported ability to stimulate the immune system (BARRET, 2003). E. purpurea (purple coneflower) is the best known of the dozen or so species of the genus Echinacea and is cultivated widely in North America, Asia, and Europe (especially in Germany) for its beauty as well as for its reported medicinal properties and ability to stimulate immune system (BARRET, 2003). Other important species are E. pallida (pale purple coneflower) and E. angustifolia (narrow-leaved purple coneflower, black Samson Echinacea).

Chemical composition of Echinacea

Chemical composition and biomass of Echinacea varies not only among different varieties, but environmental conditions and agronomical practices also have effect on them. Table 1 represents the biomass partitioning of E. purpurea and micro mineral levels in its leaves. A variety of pharmacologically active substances are present in different plant parts, juices, extracts, and preparations of Echinacea (Table 2). The level of these constituents varies in different plant parts as well as among varieties, and helps in differentiating between preparations made from various plant parts and different species. Major pharmacologically active compounds present in Echinacea and its preparations are alkamides, glycoproteins, polysaccharides, phenolic compounds and cinnamic acids (LIU Y-C et al., 2007; HARBORE and WILLIAMS, 2004).

Alkamides

Alkamides (fatty acid amides) are the major lipophilic, bioactive phytochemicals found abundantly in certain species of Echinacea, especially in high concentrations in the roots of E. purpurea, E. pallida and E. angustifolia (LALONE et al., 2007). Alkamides are characteristic rhizome components of E. angustifolia and the rhizomes and aerial parts of E. purpurea. Alkamides are the major constituents of the ethanol/water extract of Echinacea and are widely used for therapeutic purpose. They are likely to cross the intestinal barrier (MATHIAS et al., 2004) as they are found in the blood stream of patients who ingested Echinacea extracts (DIETZ et al., 2001).

Glycoproteins

Three glycoproteins have been isolated from E. angustifolia and E. purpurea roots (BIUSCHER et al., 1987). Glycoproteins have been implicated in the immunostimulatory activity of Echinacea extracts by inducing cytokine production and by their mitogenic activity (BAUER, 1993; 1994).

Polysaccharides

Two polysaccharides with immunostimulatory properties have been isolated from the aerial parts of E. purpurea. However, from tissue culture of E. purpurea three homogeneous polysaccharides, two neutral fucogalactoylogluccans and an acidic arabinogalactan were isolated (WAGNER et al., 1988). Fucogalactoylogluccans enhanced phagocytosis both in vitro and in vivo, while arabinogalactan spe-
specifically stimulated macrophages to excrete the tumor necrosis factor (TNF) (WAGNER et al., 1988).

**Hydrocarbons**

These are characteristic root constituents of *E. pallida*, where some 11 derivatives, mainly ketoalkenes and ketoalkynes (polyacetylenes) have been identified (HARBORNE and WILLIAMS, 2004). The only hydrocarbon reported from roots of *E. purpurea* is an ester (dodeca-2, 4-dien-1-yl isovalerate) which is also present in roots of *E. angustifolia* (HEINZER et al., 1988). The absence of polyacetylenes from roots of both *E. purpurea* and *E. angustifolia* provides a useful means of differentiating root preparations of *E. pallida* from other two species.

**Essential Oils**

The roots of *E. purpurea* have been reported to contain up to 0.2% essential oils (BAUER, 1999). The major components were found to be caryophyllene (2.1%), humulene (0.6%), and caryophyllene epoxide (1.3%) (BECKER, 1982). The flowering aerial contain less than 0.1% essential oil. The constituents identified include borneol, bornyl ace-
tate, germacrene D, and caryophyllene and its epoxide, which were present also in aerial parts of *E. pallida* and *E. angustifolia* (Bauer, 1999). The main essential oils in all the plant tissues, irrespective of species, were camphene, β-pinene, and limonene, together with other volatiles such as acetaldehyde, dimethyl sulphide, and hexanal (Harborne and Williams, 2004).

**Phenolic compounds**

Caffeoyl-quinic and caffeoyl tartaric acid esters are characteristic phenolic constituents of *E. purpurea*, *E. angustifolia* and *E. pallida*. Chicoric acid is the major component in all three plant parts of *E. pallida*, while echinacoside is present in an equally high concentration in the roots but only in moderate amounts and trace amounts in flowers and leaves (Harborne and Williams, 2004). Total phenolic contents were highest (23.2 mg/g) in roots of *E. purpurea* as compared to roots of *E. angustifolia* (10.5 mg/g) and *E. pallida* (17.8 mg/g) (Federica et al., 2003). Some researchers have reported that chicoric acid is more abundant in the flowers, with much lower contents in leaves and stem (Bauer et al., 1988). The leaves have been shown to additionally contain chichoric acid methyl ester, 2-caffeoyl-3-feruloyltartaric acid, 2, 3-diferuloyltartaric acid, 2-feruloyltartaric acid and 2-caffeoyl-3-p-coumaroyltartaric acid (Becker and Hsieh, 1985; Soecke et al., 1988). Liu et al. (2007) reported that the contents of caffeic acid derivatives in *E. purpurea* reach its highest in the middle stage of full blossoming and were higher in fresh raw material than in dried raw material. They observed that contents of chicoric acid vary from 0.1% (in dried roots) to 3.3% (in fresh flower buds), caficaric acid vary from 0.1% (in dried roots) to 0.72% (in fresh flower buds), and total phenolic compounds vary from 1.91% (in dried aerial parts) to 6.47% (in fresh flower buds).

**Pharmacological properties of Echinacea**

Echinacea is very popular for its effects on the immune system (Hinz et al., 2007). Results of some experiments studying pharmacological properties of Echinacea are summarized in Table 3. It has demonstrated its properties by stimulation of various immune cells such as macrophages, other monocytes, and natural killer (NK) cells during *in vitro* (Bauer, 1999; Burger et al., 1997; Runinger et al., 2000; Groom et al., 2007; Sullivan et al., 2008) as well as *in vivo* studies (Currier and Miller, 2001, 2002).

Among the many pharmacological effects reported, modulations of macrophages, PMN (polymarphonuclear leukocytes) immune cells and effects on cytokines/chemokines expression in human cells have been demonstrated most convincingly (Woelkert and Bauer, 2007). *E. angustifolia* (root extract) have been reported to enhance immune function by increasing antigen-specific immunoglobulin production (Rehman et al., 1999). Hinz et al. (2007) found that alkamides derived from *E. angustifolia* roots may contribute to the pharmacological action of the herbal extract by inhibiting COX-2 activity at sites of inflammation. Echinacea extracts may be able to modulate inflammation through their inhibitory activity on PGE2 production and alkamides are possible key constituents in the observed anti-inflammatory properties, most likely acting additively or synergistically with other constituents (Lalone et al., 2007). Various extracts of *E. purpurea* showed different activities against human pathogenic bacteria (Sharma et al., 2008). Analysis of polar fractions of *E. purpurea* extracts showed the presence of antiviral activity, with evidence suggesting that polyphenolic compounds other than the known HIV inhibitor, chicoric acid may be involved (Birt et al., 2008).

*E. purpurea* preparations have been reported to activate human macrophages (Mose, 1983) and enhance cytokine production (Bauer, 1999; Burger et al., 1997; Runinger et al., 2000). Solutions made from herb and root *E. purpurea* powders produced definite reproducible macrophage activity, anti-inflammatory and antioxidant properties (Runinger et al., 2000, Zhai et al., 2007). Increased activity of PMN granulocytes has been reported from a number of animal experiments (Miller and Yu, 2004). Mice fed 0.45 mg/day of *E. purpurea* root extract for 1–2 weeks showed significantly higher numbers of NK cells and monocytes, but no granulocytes, lymphocytes or their precursors (Sun et al., 2001). *E. purpurea* extract has been reported to increase both antibody-dependent and innate NK mediated activities against herpes virus infections in *ex vivo* cells from both normal and immune-depressed individuals (See et al., 1997). Increased white cells counts in peripheral blood have been noted following intramuscular injection of *E. purpurea* extracts, but not following oral dosing (Lorenz et al., 1972). *E. purpurea* preparations from roots activate the cellular immunity and stimulate phagocytosis of neutrophils *in vitro*, *in vivo* and after rinsing of mouth cavity (Jurkstiene et al., 2004). Polyasaccharides derived from *E. purpurea* are reported to enhance macrophage activity in mouse, rat and human (Baret, 2003).

Daily dietary administration of *E. purpurea* root extract to normal mice for as little as 1 week resulted in significant elevation of natural-killer (NK) cells; and showed profoundly positive effects in Leukemic mice, when administered daily for 50 days from the onset of Leukaemia (Currier and Miller, 2001). Turner et al. (2005) studied the effect of chemically defined extracts from *E. angustifolia* roots (equivalent of 300 mg root) on rhinovirus infection in 437 volunteers, and found that extracts of *E. angustifolia* root, either alone or in combination, did not have clinically significant effect on infection with a rhinovirus or on the clinical illness that results from it. However, a meta-analysis evaluating the effect of Echinacea on the incidence and duration of common cold showed that Echinacea decreased the odds of developing the cold by 58% and duration of cold by 1.4 days (Siah et al., 2007). Dietary supplementation of *E. purpurea* daily (2 mg/mouse) from puberty (7 week) until just beyond 13 months of age (late middle age in mice) improved survivalability of mice by significantly elevating levels of NK cells in their bone marrow production site, as well as in the major organ to which they traffic and function, i.e. the spleen. Thus, it appears that regular intake of *E. purpurea* (root extract) may indeed be beneficial and prophylactic (Brousseau and Miller, 2005).

Basic research on Echinacea as a medicinal botanical identifies its major activity as a stimulant to the phagocytic potential of polymorphonuclear cells (Wagner et al., 1988), which is a well established measurement of immune function (Athlin et al., 1991). Other immunologically relevant activities of Echinacea plants include inhibition of cyclooxygenase enzyme and 5-lipooxygenase enzyme (two key enzymes involved in the inflammatory response) (Miller-Jackic et al., 1994) and a stimulatory effect on the secretion of various cytokines, including IL-1, IL-6, and TNF-α (Lutig et al., 1989; Rosler et al., 1991, Steinmuller et al., 1993; Sullivan et al., 2008). Echinacoside present in Echinacea exhibited a stronger protection against free radical-induced native collagen degradation than other caffeic acid derivatives, such as chichoric acid, caffeic acid, and chlorogenic acid (Facino et al., 1995).
Taken together, these data suggest that *E. purpurea* may have potential in stimulating the immune system response of humans, laboratory animals as well as livestock under normal and stressful husbandry conditions. Various extracts and purified preparations made from different plant parts of *E. purpurea* can be used to maintain health and improvement of immunity in animals. However, there is little consensus by which species, plant part, or extraction method the "greatest immune-stimulating" properties are achieved. Extracts soluble in water, ethanol and chloroform have all demonstrated phagocyte-stimulating activity (Barret et al., 2003, Bauer, 1999).

Mode and level of administration

Echinacea is either used as dried whole plant; as plant parts; as plant extracts in ethanol, water or chloroform; as plant juices fermented or in alcohol; as dried plant products in powdered form with food/feed or in the form of tea; as plant parts alone or in combination with other plant parts or as a mixture with other species of Echinacea and even other herbal plant species (Miller and Yu, 2004). According to Bone (2004) different Echinacea products and preparations available in the market are:

1. The stabilized juice of *E. purpurea* tops (often sold under the trade name of Echinacin)
2. Fresh or dried whole plants, aerial preparations, root preparations of *E. purpurea, E. angustifolia* or *E. pallida*
3. Mixture of any of above.

Preparations of the above are applied in various dosage forms including liquids (in ethanol-water mixture or other), capsules, and dried extracts (tablets or capsules). Some preparations are administered by intramuscular injection in some countries, especially in Europe (Bone, 2004). Dosage and duration of application also vary from preparation to preparation and depends upon availability of pharmacologically active substances.

No dose level or duration of Echinacea has been universally standardized. However German Commission E recommends *E. purpurea* aerial parts expressed juice, but not *E. purpurea* root; conversely, it recommends *E. pallida* alcohol root extracts, neither the roots nor aerial portions of *E. angustifolia* are recommended (BGA Commission E, 1989). According to BGA Commission E (1989) Echinacea should be prophylactically used daily for several weeks. However, Jurcic et al. (1989) observed that phagocytosis rate in some countries, especially in Europe (Bone, 2004). The following overview provides some species specific information on the pharmacology, toxicology, and clinical application of Echinacea in various livestock species, including cattle, horse, poultry and swine.

Cattle

Schubert et al. (2002) studied the effect of an *E. purpurea* tincture (containing 70% ethanolic extract of *E. purpurea*), *Thuja occidentalis*, and elemental phosphorus on bovine leukocytes. Bovine mononuclear cells (MNC) and polymorphonuclear (predominantly neutrophils) cells were isolated from cows and cultured for up to 44 hours in the presence and absence of an extract of the product and its individual components. Flow cytometry results showed no significant effect of individual components, which included *Thuja occidentalis, E. purpurea*, and elemental phosphorus, on MNC. However, *E. purpurea* was able to enhance the ability of the PMN to kill target cells via antibody-independent cytotoxicity. Gili et al. (2002) studied the effect of Echinacea supplementation on immune function in transitional calves. Ten weaned calves were assigned to treatments of 0 or 2.5 g/day of Echinacea supplementation in ration for 17 days. The monococytes percentage decreased (P = 0.0253) in treated calves over time and varied between breeds. B cell percentage also decreased (P = 0.0343) with treatment as well as with application time. CD4+ T cell levels significantly increased (P = 0.0253) with Echinacea supplementation and CD2+ T cells and white blood cells percentage tended to be higher in treated calves. Neutrophil contents, packed cell volume, serum protein concentration and body weight were not affected.

Horses

Along with a variety of herbs, Echinacea is also used as immune booster to complement a healthy immune system of horses. According to Williams and Lammreicht (2007), best way to use Echinacea is to supplement at the first signs of illness or infection. If administered too late in the cycle the herb will be less effective. O’Neil et al. (2002) offered a standardized aqueous extract of *E. angustifolia* (prepared from powdered root that was standardized to 4% echinacoside) or an inactive placebo to eight healthy horses for a period of 42 days. Blood samples taken every 7th day were subjected to a complete haematology and biochemistry screen, and a phagocytic function test. Echinacea extract increased the production of lymphocytes and decreased the level of circulating neutrophils in the blood presumably by increasing membrane permeability and migration into tissues. Echinacea administration increased the number of red blood cells and haemoglobin, showing its effect on the oxygen transport mechanism.

Poultry

Research on application of Echinacea preparations in poultry is limited; however it can be used as a guiding line for future studies. Nasir and Grashorn (2007a) studied the effects of application of two different *E. purpurea* juice preparations by drinking water to broilers (Ross 308) on performance and blood parameters for stress, protein and...
lipid metabolism and immune status. *E. purpurea* fermented juice (EFJ) and *E. purpurea* juice on alcohol (EOJ) basis were applied through drinking water at levels of 0.25 ml/kg BW^0.75^ and 0.50 ml/kg BW^0.75^. The dosage of the Echinacea juice for hens was adjusted on the basis of human medical recommendations (0.25 ml/kg BW^0.75^) due to lack of data for poultry. (Metabolic body weight is used for calculation of application level as it represent the weight of those tissues in body that metabolize most of the nutrients that are absorbed in the body; and to adjust the differences among the animals (human and poultry)). Duration of *E. purpurea* juices application was three days followed by treatment free days (8, 9 or 12). The results showed that *E. purpurea* juice supplemented groups performed better as compared to non supplemented groups. There was no significant difference in level of serum total protein, albumin and globulin between 0.25 ml/kg BW^0.75^ and 0.50 ml/kg BW^0.75^ treatments. Levels of ALT, γ-GT, alkyl phosphate, creatine kinase, LDH and serum total cholesterol were non significantly different. Blood picture also showed no significant treatment effect on number of leukocytes, lymphocytes, haemoglobin and haematocrit percentage. In another experiment, comparing the effects of *E. purpurea* fermented juice and *E. purpurea* juice on alcohol basis, applied through drinking water at the rate of 0.25 ml/kg BW^0.75^ and 0.50 ml/kg BW^0.75^ against a negative control, better feed conversion ratio was observed in *E. purpurea* treated groups as compared to control. Serum total protein level was non significantly higher and serum albumin concentration was lower than control group. The application of *E. purpurea* fermented juice at the rate of 0.25 ml/kg BW^0.75^ resulted in non significant improvement of feed conversion ratio and performance (Nasir and Grashorn, 2007b, 2008). Bohmer et al. (2008) studied the effect of intermittent application of *E. purpurea* juices in feed on layer performance and immune status. They found significantly (p < 0.05) increased number of lymphocytes and total leucocytes, but reduced phagocytic activity in groups receiving ethanolic *E. purpurea* juice for 5 days. Treatment of EFJ juice for 2 days (12 days interval) resulted in highest antibody titers as compared to EOJ.

Roth-Maier et al. (2005) studied the effect of dietary supplementation of dried aerial parts of *E. purpurea* as feed additive in the diets of broilers and layers on feed intake, feed conversion efficiency and growth/egg performance. The aerial parts of *E. purpurea* plants were pressed to cobs and stored. These cobs were added to experimental diets of broilers and layers after grinding. Supplementation of 0, 0.6, 1.2, 1.8, 2.4, 3.0, 3.6, 4.2, or 4.8% *E. purpurea* cobs for a continuous period of 5 weeks to broiler diets showed no significant effect on recorded parameters. In another experiment with broilers treated with 0, 2.4% *E. purpurea* cobs or 10 mg/kg feed Flavomycin®, *E. purpurea* supplemented groups showed lower feed intake and body weight gain compared with control and Flavomycin® treated group. Supplementation of 0 or 1.8% *E. purpurea* cobs to layer pullets from 0–21 weeks and 0 or 4.8% *E. purpurea* from 21st week, showed no effect on body weight gain at week 4, 8, and 20, while feed intake of *E. purpurea* group was depressed in week 5–8 by 11%. In the egg production period, no difference between treatment groups was observed. The authors concluded that continuous supplementation of *E. purpurea* cobs is not beneficial for broilers and layers (Roth-Maier et al. 2005). However, Echinacea dietary supplements proved beneficial adjuvants for live anticoccidial vaccines (Allen, 2003). Effects of *E. purpurea* supplementation on weight gain before challenge, and weight gains, lesion scores and plasma levels of carotenoids and NO₂⁻ and NO₃⁻ (which are indicators of macrophage activation and phagocytic activity) following challenge with multiple coccidia species (*Eimeria acervulina*, *Eimeria tenella*, *Eimeria maxima* and *Eimeria necatrix*) were determined. The results showed that, combined live vaccination and feed supplementation with 0.1% or 0.5% dried, ground root preparations of *E. purpurea* during the first two weeks of life provided significant weight gain advantage as compared to live vaccination alone. This advantage persisted through two weeks of *E. purpurea* withdrawal and subsequently challenges infection. *E. purpurea* supplementation also lowered significantly total lesion scores but didn’t significantly modify the effects of vaccination and challenge on plasma carotenoids or NO₂⁻ + NO₃. The author suggested that *E. purpurea* has potential for use as adjuvant for live vaccines when provided as a dietary supplement concurrent with the application of a live vaccine. *E. purpurea* can also be used to provide protective immune-stimulation in the presence of natural populations of coccidian in litter (Allen, 2003). Schranner et al. (1989) studied the effect of the complex drug (Influx) and *E. purpurea* extract in humoral immune response of intact and immunodeficient chickens. The preparations were administered in two oral doses, after which the complete immunoglobulin concentration and the antibody production were determined. The administration of the complex drug to normal Leghorn chicken induced a rise in the serum immunoglobulin concentration, as well as increase in the three classes of antibody. In immunodeficient chickens, the complex drug caused a slight production of IgG. Gardzilewska et al. (2003) studied the effect of plant supplementation feeding on fresh and frozen storage of broiler chicken meat. They supplemented 1% dried *E. purpurea* herb, 0.3% crushed raw garlic in feed. Another group received twice a week raw ginger water extract (5.5 g/cm³) to drink. Chemical composition of breast muscles were analysed freshly and after 4-month storage at −18°C. Supplementation with *E. purpurea* or garlic did not show significant influence on dry matter, crude protein, or raw fat content in the breast muscles. *E. purpurea* supplemented groups showed numerically higher levels of crude protein, better pH value (5.5) and better, darker colour as well as better juiciness. Dried *E. purpurea* herb supplemented (560 mg/kg) in broiler grower diets from 22 to 42 days of age maintained flavour of meat after storage (Koreleiski and Swiatkiewicz, 2007).

The results of the studies in poultry showed that efficacy of *E. purpurea* depends upon its preparation (level of active substances) and on its mode of administration. Dried *E. purpurea* cobs supplementation in feed showed no significant effect on performance as well as immune status of broilers and layers (Roth-Maier et al. 2005), but dietary supplements of *E. purpurea* seem to be useful adjuvants for live anticoccidial vaccines (Allen, 2003) and improved performance when *E. purpurea* juices are administered through drinking water (Nasir and Grashorn, 2007a, 2007b, 2008) and maintained meat quality during storage (Koreleiski and Swiatkiewicz, 2007). There is lack of research on using other application methods and *E. purpurea* preparations in poultry. Supplementation of *E. purpurea* extracts (ethanol or water) or liquid preparations (juices) can be more beneficial as compared to dried products, as they contain higher amounts of active substances which can be absorbed easily.

**Swine**

Preparations made from *E. purpurea* have been reported to improve swine health, performance, and meat quality.
Supplementation of *E. purpurea* water extract (500 mg/kg of feed) in pig diets improved body weight gain and feed conversion, reduced cholesterol contents of meat and improved its lightness (Hanczakowska, 2007). Intermittent application (2 or 5 days) of *E. purpurea* juice followed by 12 or 9 days of interval improved health of pigs by increasing number of lymphocytes and leucocytes and increased phagocytosis rate of granulocytes (Bohmer et al., 2008). The higher dose of extract (1000 mg/kg feed) improved water holding capacity of meat and raised its pH at 45 min after slaughter (Hanczakowska, 2007). Kuhn et al. (2005) studied the effect of supplementation of *E. purpurea* ethanolic extract (0.125 ml/kg body weight) in liquid feed during the whole pregnant and suckling period of sows in six intervals (5 days treatment, followed by 2 weeks of break, respectively). The *E. purpurea* treatment of sows resulted in immunostimulatory effects both in sows and piglets with highest change in peripartal period. In one day old piglets, the concentrations of IgG, IgA, and CRP were significantly increased in *E. purpurea* group (P = 0.004, P < 0.001. P = 0.05, respectively). Up to 70 days of age, the rate of treatment of *E. purpurea* cobs with 10 ml/kg body weight resulted in immunostimulatory effects both in sows and *E. purpurea* treated sows was decreased in tendency (P = 0.08). The growth performance and carcass quality of offspring was not affected by *E. purpurea* treatment of sows.

Maass et al. (2005) conducted a number of experiments using dried cobs of *E. purpurea* herb as feed additive in diets of sows, piglets, and grower/finisher pigs on growth performance, blood picture, plasma enzymes including proliferation of lymphocytes, antibody status, and protein and immune globulin content of colostrum. The control groups were supplemented with alfalfa meal. The *E. purpurea* cobs consisted of aerial parts of *E. purpurea* plant, which were carefully dried and pressed. The sows received 0, 1.2, or 3.6% *E. purpurea* cobs in the diets continuously from day 85 to day 110 of gestation and 0, 0.5, or 1.5% *E. purpurea* cobs up to day 28 of lactation. In this experiment, no significant differences were found for growth performance, weight loss, blood picture, plasma enzymes, and colostrum composition. In second experiment, 1.8% *E. purpurea* cobs, or 20 mg/kg feed Flavomycin® supplementation did not show any significant effect on performance and immune status. In third experiment, 48 grower/finisher pigs were used during a 9-wk experimental period with two supplementation phases (wk 1–3 and wk 6–9). The heat sterilised *E. purpurea* pressed juice obtained from aerial parts of the plant was used. The experimental groups received 0, 0.15% cobs or 4–6 ml pressed juice per day respectively. The juice was given on top of feed at both feeding times. *E. purpurea* supplemented groups showed significantly (P < 0.03) better feed conversion ratio than animals of the unsupplemented groups. In all these trials, the haematological parameters were not affected, but the rate of phagocytosis was enhanced. The authors concluded that dietary administration of *E. purpurea* in form of cobs as feed additive might have a stimulating effect on the immune system, especially in the situations with the increased stress for the immune system. Moreover, feed conversion can be improved with addition of *E. purpurea* to diets. Hermann et al. (2003) conducted an experiment to study the effect of dietary *E. purpurea* on viremia and performance in porcine reproductive and respiratory syndrome virus (PRRSV)-infected nursery pigs. The certified organic *E. purpurea* ground root powder was mixed in basal diets at 2% and 4% and compared with a negative control and a diet containing carbadox (0.055 g/kg of diet; as fed basis) on PRRSV challenged pigs. Seven days after starting the diets all pigs were intranasally inoculated with PRRSV isolate (ATCC VR-2332) at a concentration of 10⁴ tissue culture infectious doses 50/ml. Among PRRSV challenged pigs, dietary *E. purpurea* did not affect (P > 0.10) the rate or level of ELISA-detectable antibody response from day 7 to 42 or the level and duration of PRRSV in serum. For PRRSV- unchallenged animals receiving diets supplemented with *E. purpurea* at 2 or 4%, no differences (P > 0.10) were observed in average daily gain, average daily feed intake or gain: feed ratio. Holden and McKean (2002) conducted a series of experiments to compare the health and performance of weaning pigs fed varying levels of Echinacea with those receiving a subtherapeutical level of a common antibiotic (Mecadox). At the tested levels (0.01, 0.25, 0.5, 2.0 and 3.0%) in feed, no statistical advantage in weight gain or feed conversion was observed when compared with the diet containing 45 ppm of Mecadox or with negative control containing no antimicrobial or botanical inclusion. Echinacea treated pigs exhibited a light, but not objectionable off-flavour of their meat when compared to control. They observed that in weeks 0 to 3 and 0 to 4 the higher levels of Echinacea (0.5% and 2.0%) were significantly more efficient than the control, but the results from the Flavomycin® treated groups did not show any negative effects or signs of toxicity. There was no negative effect of *E. purpurea* juice supplementation on performance as well as liver functions in broilers (Nasir and Grasshorn, 2007a, 2007b). Amounts of lead and cadmium are very less in different preparation of *E. purpurea* (Zitkevicius et al., 2003). Męgns et al. (1991, 2000) performed acute, sub-acute and genotoxicity studies on mice and rats and found *E. purpurea* to be “virtually non-toxic to rats and mice”. Single oral (15 g/kg body wt) or intravenous doses (5 g/kg body wt) of the expressed juice of *E. purpurea* proved virtually non-toxic to rats and mice. After four weeks of oral administration in doses amounting to many times the human therapeutic dose, a reversibility of the changes in liver enzymes and haematology were observed. Laboratory tests and necropsy findings gave no evidence of any toxic effects in rats. Tests for mutagenicity carried out in micro-organisms and mammalian cells in vitro and in vivo gave negative results. In an in vitro carcinogenicity study *E. purpurea* did not produce malignant transformation in hamster embryo cells. Studies looking for chromosome aberration and sister chromatid exchange in bacteria and cultured animal cells have also found no evidence of mutagenicity (Męgns et al., 1991). Maximum feasible oral and intravenous doses of ethanol-stabilized fresh pressed juice of *E. purpurea* similarly failed to cause measurable damage in mice or rats (Męgns et al., 2000). Application of *E. purpurea* root extract (2 mg/mouse/day) continuously from puberty (7 week) to 13 months did not show any signs of toxicity, rather it improved NK cells (Broussseau and Miller 2005). The squeezed sap of the *E. purpurea* plant is well tolerated in long term (up to 12 weeks) use, with no significant side effects when the sap was administered orally (Parham, 1996). This conclusion was supported by Hobbs (1994) and Klügler (2003), who found no published reports indicating that Echinacea had toxic side effects. 

**Toxicity of Echinacea**

The toxicity of *Echinacea* sp. appears to be very low. The results of experiments using different preparations and products of *Echinacea* sp. on various livestock species did not show any negative effects or signs of toxicity. There was no negative effect of *E. purpurea* juice supplementation on performance as well as liver functions in broilers (Nasir and Grasshorn, 2007a, 2007b). Amounts of lead and cadmium are very less in different preparation of *E. purpurea* (Zitkevicius et al., 2003). Męgns et al. (1991, 2000) performed acute, sub-acute and genotoxicity studies on mice and rats and found *E. purpurea* to be “virtually non-toxic to rats and mice”. Single oral (15 g/kg body wt) or intravenous doses (5 g/kg body wt) of the expressed juice of *E. purpurea* proved virtually non-toxic to rats and mice. After four weeks of oral administration in doses amounting to many times the human therapeutic dose, a reversibility of the changes in liver enzymes and haematology were observed. Laboratory tests and necropsy findings gave no evidence of any toxic effects in rats. Tests for mutagenicity carried out in micro-organisms and mammalian cells in vitro and in vivo gave negative results. In an in vitro carcinogenicity study *E. purpurea* did not produce malignant transformation in hamster embryo cells. Studies looking for chromosome aberration and sister chromatid exchange in bacteria and cultured animal cells have also found no evidence of mutagenicity (Męgns et al., 1991). Maximum feasible oral and intravenous doses of ethanol-stabilized fresh pressed juice of *E. purpurea* similarly failed to cause measurable damage in mice or rats (Męgns et al., 2000). Application of *E. purpurea* root extract (2 mg/mouse/day) continuously from puberty (7 week) to 13 months did not show any signs of toxicity, rather it improved NK cells (Broussseau and Miller 2005). The squeezed sap of the *E. purpurea* plant is well tolerated in long term (up to 12 weeks) use, with no significant side effects when the sap was administered orally (Parham, 1996). This conclusion was supported by Hobbs (1994) and Klügler (2003), who found no published reports indicating that Echinacea had toxic side effects. 

Arch.Geflügelk. 4/2009
effects. E. purpurea contains saturated pyrrolizidine alkaloids (isotussilagine and tussilage) at a level of 0.006%, which are also thought to be non toxic (PEARSON, 2000; NEWALL et al., 1996).

CHOW et al. (2006) conducted an experiment in which pregnant mice were fed daily E. purpurea from pregnancy onset until gestational days 10, 11, 12, 13, and 14. A specific commercially prepared extract of E. purpurea in powdered form was homogenized into finally ground standard chow such that individual mice consumed 0.45 mg/day (dose per body weight). This chow was added to standard diet and offered at the beginning of the active period (6:00 pm). Controlled mice consumed identically prepared chow without E. purpurea. The results showed that the significant, pregnancy induced elevation in splenic lymphocytes and nucleated erythroid cells was all but eliminated in those females which consumed E. purpurea daily throughout their pregnancy. Moreover, consuming E. purpurea during pregnancy reduced the number of viable foetuses. High concentrations of E. purpurea have been shown to inhibit enzyme activity in human sperm, reduce oocyte penetration by sperm and can cause denaturation of sperm DNA (Ov-DZEEK et al., 1999a; 1999b). The results of the experiments conducted using different preparations of E. purpurea suggest that there is no toxic or harmful effect on performance and health of laboratory animals as well as different livestock species. However, care should be taken, while feeding E. purpurea to animals kept for breeding purpose.

Conclusions

The ban imposed on subtherapeutic use of antibiotics in animal feeds in EU, public pressure for banning antibiotics in other countries and increasing demand of organic animal products has created a whole new incentive and urgency to quantifying the usefulness of phytogenic products in animal nutrition. The outcome of experiments with phytogenic products may be used as guiding line and rationale for the application of these substances in livestock production. Echinacea is one of the few herbs that are extensively researched in laboratory animals as well as it is under continuous study in human trials for its potential clinical use. It contains a variety of active substances like alkamides, glycoproteins, polysaccharides, phenolic compounds, cinnamic acids, essential oils and flavonoids, which are effective in treatment of various ailments and improving immunity and health. The toxicity of Echinacea is reported to be very low. Present research on the use of Echinacea in livestock is limited, but it can be used as a guiding line and rationale for its use in livestock. In this review, the extent of present knowledge and need for future studies are discussed in the light of effectiveness of active substances of E. purpurea in improving health, performance and immunity of various livestock species.

Summary

Feed additives with performance and health stimulating effects are widely used in animal production. For a long time antibiotics have been the dominating substances in animal nutrition with distinct growth promoting effects. After the ban imposed on the subtherapeutic use of antibiotics in animal feeds in European Union (EU) and the increasing demand of organic animal products, alternative substances are required, which can maintain health and improve performance of livestock without any residual effects. E. purpurea is one of the most promising phytogenic additives due to its immuno-stimulatory and potentiatory properties. Echinacea has been widely investigated in laboratory animals, as well as it is under continuous study in human trials for its potential clinical use. It contains a variety of active substances like alkamides, glycoproteins, polysaccharides, phenolic compounds, cinnamic acids, essential oils and flavonoids, which are effective in treatment of various ailments and improving immunity and health. The toxicity of Echinacea is reported to be very low. Present research on the use of Echinacea in livestock is limited, but it can be used as a guiding line and rationale for its use in livestock. In this review, the extent of present knowledge and need for future studies are discussed in the light of effectiveness of active substances of E. purpurea in improving health, performance and immunity of various livestock species.

Key words

Echinacea purpurea, swine, poultry, phytogenic compounds, immunostimulator

Zusammenfassung

Echinacea: Ein potentieller Futter- und Trinkwasserzusatz in der Geflügel- und Schweinerzeugung


Arch.Geflügelk. 4/2009
Verbesserung der Gesundheit, der Leistung und der Immunität bei verschiedenen Nutztiertarten diskutiert.

**Stichworte**

Echinacea purpurea, Schwein, Geflügel, phytoogene Inhaltsstoffe, Immunstimulation

**Acknowledgements**

Author Zahid Nasir was granted scholarship from Higher Education commission (HEC) of Pakistan and German Academic Exchange Service (Deutscher Akademischer Austausch Dienst – DAAD) for his Ph D and research work at Hohenheim University, Stuttgart, Germany. We appreciate their financial support. Thanks goes to Berghof-Kräuter GmbH, Heilbronn, Germany for providing Echinacea purpurea juices.

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