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EFFECT OF TUMERIC (*Curcuma longa*) ON POULTRY GROWTH AND METABOLISM - A REVIEW

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ABSTRACT

Recently, phytobiotics have gained increasing attention as natural growth-promoting feed additives in broiler production. They have many medicinal properties with no residual side effects and are the best alternatives to antibiotic growth promoters. Turmeric (Curcuma longa) and its compounds, especially curcumin, are one of such perennial herbs which contain some active components which have therapeutic properties such as antibacterial, anticoccidial, antioxidant, hypocholesteremic and hypolipidaemic effects. Tumeric plant provides some compounds that enhance the digestion and absorption of some nutrients in poultry diet. This may be due to the active materials (Curcuminoids and Curcumin) found in Turmeric, causing greater efficiency in the utilisation of feed, resulting in enhanced growth. Multiple biological effects on health promotion and disease prevention have been recognised in Turmeric and its derivatives, especially curcumin. Bibliometric analysis revealed that curcumin has bioactive effects, with the most focused being its anticancer, inflammatory, and antioxidant potentials. Most of curcumin gets metabolised in the liver and intestine; however, a small quantity remains detectable in the organs. Curcumin holds great promise in clinical practice since it behaves as a multifunctional ligand with many pharmacological effects, targeting several cellular pathways. Turmeric is beneficial in minimising inflammatory effects, helps growth performance, boosts immune functions and serves *as an antioxidant in commercial broiler chickens. Dietary Turmeric could be recommended to reduce the acute phase response to diseases and can stimulate growth performance in broiler chickens.*

Keywords: Tumeric, immune, curcumin, growth, antioxidants.

INTRODUCTION

Turmeric (*Curcuma* genus) has a long history of medicinal applications (Dosoky and Setzer, 2018), comprising approximately 120 species. Among the *Curcuma* species, *Curcuma longa L*. (Curcuma; Turmeric) is the most widely recognised; a cultivated plant, grown in warm climates, in many regions of the world (Wu, 2015). However, the taxonomic identity of this genus is complicated because of its extremely short period of flowering and herbarium preparation due to the flashiness of tubers, rhizomes, and inflorescence (Jadhao and Bhuktar, 2018). The Rhizomes are the most commonly used plant part (Lakshmi *et al.,* 2011), and it is composed of a wide variety of compounds, including the bioactive non-volatile curcuminoids (curcumin, dimethoxy-, and bisdemethoxy-curcumin) and the compounds present in volatile oil (mono and sesquiterpenoids) (Lobo *et al*., 2009).

Nutrition has always been known to induce muscle metabolic changes reflected in tissue remodelling, increased protein turnover, and muscle atrophy. From a production point of view, these changes influence production efficiency and meat quality. As a result, they are of tremendous economic importance. However, the genetic and regulatory mechanisms which define these metabolic physiological changes in muscle tissues are complex and poorly understood. Rapidly diagnosing nutritional limitations associated with particular dietary components and management strategies is often difficult. The albeit scanty investigations into molecular interactions of feedstuffs have indicated that gene expression is modified by several nutritional components, including macro elements such as carbohydrates, proteins, fats and cholesterol, vitamins, minerals, as well as phytocompounds, including flavonoids, isothiocyanates and indoles (Kaput and Rodriguez, 2004).

Poultry production has become a profitable and most popular income-generating sector for the uneducated and educated unemployed youth. Most poultry farmers are interested in broiler chicken production due to its quick returns, less space requirement and higher weight gains. The productive potential of poultry has not been fully exploited due to a deficit of feed resources and non-utilisation of available improved technologies for getting high productivity from the poultry at an economical rate. Hence, further enhancing the feeding value of available feed resources is essential to improve the efficiency of feed utilisation and minimise the cost of feed per kilogram live weight gain (Nouzarian *et al*., 2011).

In recent years, phytobiotics have gained increasing attention as natural growth-promoting feed additives in broiler chicken production. They have many medicinal properties with minimal residual side effects and are the best alternatives to antibiotic growth promoters (Rahman *et al*., 2014). Beneficial effects of these substances in poultry nutrition are due to their high content of pharmacologically active compounds stimulating appetite and feed intake, improving endogenous digestive secretion and activating immune responses (Nouzarian *et al*., 2011; Toghyani *et al*., 2010). Turmeric (*Curcuma longa*) is one of such perennial herbs which contains some active components which have therapeutic properties, such as antibacterial, anticoccidial, antioxidant, hypocholesterolemic and hypolipidaemic (Qasem *et al*., 2015). It also possesses anti-inflammatory (Holt *et al*., 2005), antiseptic, nematocidal, immunomodulatory and hepatoprotective properties (Rajput *et al*., 2013).

EFFECTS OF TUMERIC ON IMMUNE FUNCTIONS, GROWTH AND ANTIOXIDANT ACTIVITIES

Turmeric plant may provide some compounds that enhance digestion and absorption of some nutrients in poultry diet which may be due to the active materials (Curcuminoids and Curcumin) found in them causing greater efficiency in the utilisation of feed, resulting in enhanced growth, it could control and limit the growth and colonisation of numerous pathogenic and non- pathogenic species of bacteria in the chicken's gut resulting in balanced gut microbial ecosystems that lead to better feed utilisation reflected by improved feed conversion ratio (Ong-ard *et al*., 2010). Applying different levels of Turmeric Powder (TP) has led to a high percentage of breast and thigh weight

(Osawa *et al*., 1995). The increase in breast and thigh weight may be due to the optimum antioxidant activity of turmeric that stimulates protein synthesis by the bird's enzymatic system. It also promotes the digestive system in poultry by improving the utilisation of digestive products (Hernandez *et al*., 2004). It has been demonstrated that TP has a progressive metabolic control on the mechanisms involved in eliminating lipids from the body (Abbas, 2009).

During Arthritis, many immune and joint cells are activated, causing inflammation. Immune cells, including macrophages, lymphocytes, neutrophils, mast cells, natural killer cells, and innate lymphoid cells, as well as synovial tissue cells, like fibroblast-like synoviocytes, chondrocytes, and osteoclasts, secrete different pro-inflammatory factors, including many cytokines and angiogenesis-stimulating molecules (Makuch *et al*., 2021). Arthritis is one of the most widespread chronic inflammatory diseases, affecting about 1% of the total population of poultry with an unknown aetiology. This autoimmune disorder is characterised by burdensome pain, swelling, and, usually, stiffness of symmetrical joints, significantly reducing mobility and overall life comfort. During arthritis progression, persistent inflammation forces systematic changes, causing irreversible cartilage, synovium, and bone degradation, finally deforming the whole joint structure, leading to loss of mobility and muscle atrophy (Kumar *et al*., 2020). It can also cause extraarticular manifestations, forming rheumatic nodules, causing lung and blood vessel diseases or leading to anaemia, peripheral neuropathy, and disorders in many organs (Waugh *et al*., 2013). Turmeric has been reported to have tremendous potential as an alternative treatment for autoimmune diseases due to its impressive number of therapeutic properties (Makuch *et al*., 2021).

Supplementation of Turmeric powder in the basal diet of broiler chickens was reported to improve final body weight due to the increased length of the intestinal villi and decreased pH in the intestine (Makuch *et al*., 2021). Turmeric was reported to have decreased the population of intestinal microbes and selectively increased *Lactobacillus* count (Namagirilakshmi *et al*., 2010). This reduction in the microbial load of broiler chickens was said to be due to turmeric's antibacterial effect on intestinal microbiota (Waugh *et al*., 2013). Turmeric also enhanced the secretion of digestive enzymes, improving nutrient absorption and ultimately resulting in improved growth performance (Kumar *et al*., 2020). Curcumin's antioxidant potential has been attributed to its chemical structure, including carbon-carbon double bonds, β-diketo group, phenyl rings with hydroxyl, and *o*-methoxy groups (Menon and Sudheer, 2007). Many mechanisms can explain the antioxidant activity, such as binding free radicals, hydrogen atom donors, and electron donors to neutralise free radicals. For this reason, laser flash photolysis and pulse radiolysis have been used to elucidate the mechanism of action of curcumin's antioxidant activity (Nardo *et al*., 2008). Curcumin can promote its antioxidant activity by scavenging a variety of Reactive Oxygen species (ROS) such as superoxide radicals, hydrogen peroxide, and Nitric Oxide (NO) radicals and by inhibiting lipid peroxidation (Ak and Gulcin, 2008). This activity is due to the enhancement of many antioxidant enzymes activity such as Superoxide dismutase (SOD), Axial tomography or Catalase (CAT), Glutathione Peroxidase (GPx), and OH-1. By upregulating glutathione transferase and their mRNAs, curcumin can increase the y - I – glutamyl –I – cysteinyl – glycine (GSH) levels. It can also inhibit ROS-generating enzymes, such as Lysyl oxidase (LOX), COX, and xanthine oxidase. It is a chain-breaking antioxidant because of its lipophilic nature, potentially acting as a peroxyl radical scavenger (Priyadarsini *et al.,* 2003). Jayaprakasha *et al.* (2006) also stated that linoleic acid oxidation was much lower in the presence of curcumin, and the antioxidant effect was about 80% when used as a dietary supplement. At the same dose, curcumin was able to double the resveratrol antioxidant activity, due to the double carboxyl and hydroxyl groups (Aftab and Vieira, 2010).

EFFECTS OF TUMERIC ON BROILER CHICKENS' GROWTH PERFORMANCE

Turmeric (*Curcuma longa*) is a widely used spice, especially in broiler chickens' diet (Akbarian *et al*., 2012). The active ingredients found in Turmeric (*Curcuma longa*), such as demethoxycurcumin, bisdemethoxycurcumin, tetrahydrocurcuminoids and especially Curcumin, are the crucial indispensable bioactive components liable for the biological action of Curcuma longa (Nouzarian *et al*, 2011). Traditionally, it has been used to treat various diseases/disorders such as liver obstruction, inflammation, stomach disorders, fresh wounds, insect stings and viral infections in broiler chickens to enhance growth performance (Nouzarian *et al*, 2011). Curcumin also has anti-inflammatory and antioxidant properties and have been used in gastrointestinal and respiratory disorders, as well as, improving the functioning of alimentary canal in the absorption of nutrients and consequently lead to an increase in feed consumption for birds in broiler chicken’s treatments and to enhance growth performance (Karami *et al*., 2011).

At a considerable inclusion level, turmeric promotes better growth in broiler chickens, particularly in body weight gain and improved feed conversion ratio (Kafi *et al*., 2017). It can reduce fat deposition in broiler chickens, which may result in leaner meat, a desirable trait in the poultry industry (Baqer *et al*., 2023). Turmeric enhances the immune system of broiler chickens, making them more resistant to diseases (Kafi *et al*., 2017). This is likely due to the immunomodulatory properties of curcumin, the active ingredient in turmeric. The antioxidative properties of turmeric contribute to better health and growth in broiler chickens by reducing oxidative stress, which can otherwise impair growth and immune function (Godara and Singh, 2019). It helps to improve the digestion of other nutrients by stimulating the secretion of digestive enzymes, which enhances the digestion of the food intake, which in turn helps to improve the overall growth of broiler chickens (Baqer *et al*., 2023).

BIOACTIVE COMPOUNDS IN TUMERIC AND USES

Curcuma longa contains different curcuminoids, although curcumin was found to be the most active one; it was first isolated in 1815 (Vogel and Pelletier, 1815), and the purified crystalline compound was described in 1870 (Daube, 1870). Although curcumin generally refers to 1,7-bis (4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione, the compound is also known as "curcumin I". It is a diferuloylmethane with a crystalline yellow-orange colour, molecular weight of 368.39 g/mol, melting temperature of 183°C, and with the chemical formula C21H20O6. Chemically, it exhibits keto-enol tautomerism. It has a predominant keto form in neutral and acidic solutions. In contrast, the predominant form is in the solid state, and in an alkaline solution, it is more stable in its enol form (Anand *et al.,* 2007). There are two additional compounds also known as curcumin, which are curcumin II [demethoxycurcumin, 1-(4-hydroxy-3-methoxyphenyl)-7-(4-hydroxyphenyl)-1,6-heptadiene-3,5-dione] and curcumin III [bisdemethoxycurcumin, 1,7-bis(4-hydroxyphenyl)-1,6 -heptadiene-3,5- dione] (Buckingham, 2018).

It is universally known as the "wonder drug of life" (Gera *et al.,* 2017). In ancient times in the Far East, curcumin was used to treat inflammatory conditions of various organs, for liver and digestive tract problems, and wound healing. In the 1970s, the first research on curcumin's health benefits was carried out, showing that curcumin has multiple therapeutic potentialities (Gera *et al.,* 2017; Salehi *et al.,* 2019). The hydrophobic nature of curcumin after oral administration triggers a poor absorption rate by the gastrointestinal tract. On the other hand, curcumin offers promising potential for therapeutic development. It is categorised as a Generally Recognised As Safe (GRAS) material, with a stable metabolism and low toxicity (Gera *et al.,* 2017). Also worthy of note is the colouring attributes of curcumin for industrial applications (Joshi *et al.,* 2009; Buckingham, 2018). Curcumin is an orange–yellow dye, practically insoluble in water, authorised by the European Union (EU) as a food additive. Other names, such as CI 75300, Natural Yellow 3 or diferuloylmethane, and the E code E100 are also used. Curcumin stability in aqueous solution is pH-dependent, with an optimum cut-off point of 1–6. Its colour turns to red in the charged state (pH<1 or pH>7) (Goel *et al.,* 2008), and sunlight exposure accelerates curcumin degradation (Priyadarsini, 2009).

Curcumin is usually applied at a 5-500 mg/kg dose, depending on the food category. It is mainly used in dairy products, beverages, cereals, mustard, food concentrates, pickles, sausages, confectionery, ice cream, and meat, fish, eggs, and bakery products (Lakshmi, 2014; Solymosi *et al.,* 2015). Mixed with annatto (orange-red condiment and food colouring derived from the achiote tree seeds), it is also added to seasonal sauces, mayonnaise sauces, and butter (Satyanarayana *et al.,* 2010). Curcumin is a good and cheap alternative to saffron, although it cannot substitute the saffron taste, despite being named "Indian saffron" in Europe (Scartezzini and Speroni, 2000). As an additive, curcumin is stable during thermal treatment and in dry foods. It is relatively inert to reactions with other ingredients, although it may form salts with phytates and citrates, and it is inert in reactions with phosphates, chlorides, and bicarbonates (Stankovic, 2004).

An important issue regarding storage is the likelihood of microbial contamination that provokes foodstuffs' deterioration and poisoning by food-borne pathogens (Ebrahimabadi *et al.,* 2010), even though it has been proven that curcumin exhibits some antimicrobial effects (Naz *et al.,* 2010). Guo *et al.* (2021) proved that chicken meal treated with curcumin-rich Turmeric extract oil (1% or 2%) was safe and free from microbiological contamination over 90-day storage. Abdeldaiem (2014) showed that curcumin increased soybean oil's oxidative stability and reduced total bacterial moulds and yeast count in chicken breast fillet samples. Thus, curcumin suppressed lipid peroxidation and seemed helpful as a natural preservative (Abdeldaiem, 2014).

EFFECTS OF TUMERIC IN HEALTH PROMOTION AND DISEASE PREVENTION

Turmeric and its derivatives, especially curcumin, have been recognised for multiple biological effects on health promotion and disease prevention. Indeed, a bibliometric analysis performed by Yeung *et al.* (2019) revealed that the United States, China, India, Japan, and South Korea are the main contributors to the scientific advances found on curcumin bioactive effects, with the most focused being their anticancer, anti-inflammatory, and antioxidant potential (Dai *et al.* (2018). Antioxidant potential of curcumin has been attributed to its chemical structure, including carbon-carbon double bonds, β-diketo group and phenyl rings with hydroxyl and *o*-methoxy groups (Menon and Sudheer, 2007). Activities such as binding free radicals, hydrogen atom donors, and electron donors help to neutralise free radicals using laser flash photolysis and pulse radiolysis (Nardo *et al.,* 2008). According to the multifactorial and heterogeneous nature of different disorders, including inflammatory, metabolic, neoplastic, neurodegenerative, and central nervous system related disorders, compounds with no side effects, that are non-toxic to livestock, and have multiple properties, such as curcumin, are excellent candidates for treating these pathologies (Kunnumakkara *et al*., 2017). This strategy offers a better chance of effective prophylaxis or treatment and supports curcumin's ongoing research and development as a preventive and disease-modifying agent (Epstein *et al*., 2010).

Turmeric could control and limit the growth and colonisation of numerous pathogenic and non-pathogenic species of bacteria in the chicken's gut, resulting in a balanced gut microbial ecosystem that leads to better feed utilisation and improved feed conversion (Dai *et al*., 2018). Studies have shown that curcumin has great potential for treating numerous inflammatory diseases (Edwards *et al.,* 2017; Dai *et al.,* 2018). It was shown that curcumin can: i) Inhibit pro-inflammatory transcription factors (NF-κB and AP-1); ii) Reduce the pro-inflammatory cytokines TNFα, IL-1b, IL-2, IL-6, IL-8, MIP-1a, MCP-1, CRP, and PGE2; iii) Down-regulate enzymes such as 5-lipoxygenase and Cyclooxygenase (COX) -2 and -5; and iv) Inhibit the Mitogen-Activated Protein Kinases (MAPK) and pathways involved in Nitric Oxide Synthase (NOS) enzymes synthesis (He *et al.,* 2015). On the other hand, a close relationship between antioxidant molecules and their anti-inflammatory potential is becoming increasingly evident, given that oxidative stress triggers chronic inflammation. In this way, curcumin is also able to modulate the NF-κB expression. Activating the NF-κB pathway leads to pro-inflammatory cytokine production, such as interleukin (IL-1, IL-2, IL-6, IL-8) and TNFα, which activate pro-inflammatory signalling pathways. In addition, curcumin could decrease oxidative stress and inflammation through the Nrf2 pathway. The Cyclooxygenase (COX) pathway converts arachidonic acid into prostaglandins and thromboxanes, involving two COX isoenzymes (COX-1 and COX-2). Particularly, COX-2 is induced by various cytokines and tumour promoters, thus closely linked to inflammation and carcinogenesis, with many studies demonstrating that curcumin can inhibit the induction of COX-2 gene expression (He *et al.,* 2015; Dai *et al*., 2018).

Curcumin also has an anticancer effect. It has been shown to prevent carcinogenesis by affecting angiogenesis and cancer cell growth. It also suppresses cancer cell metastasis and induces cancer cell apoptosis. The different molecular targets through which curcumin acts are downregulating or upregulating (Dai *et al.,* 2018). Cancer cells can produce new blood vessels by stimulating proangiogenic factors. Curcumin has been shown to have anti-angiogenic activity by inhibiting angiogenic factor stimulators, such as Vascular Endothelial Growth Factor (VEGF) and basic fibroblast growth factor. It was revealed to be able to downregulate the VEGF expression through NF-κB and AP-1 regulation, attenuating IL-8 expression (*He et al.,* 2015). Dai *et al.* (2018) showed that curcumin can inhibit angiogenesis through Vascular Endothelial Growth Factor Regulators (VEGFRs) and the modulation of PI3K/Akt signalling pathway. Moreover, it was revealed that curcumin can downregulate metalloproteinase (MMP)2 and MMP-9, and upregulate the tissue inhibitor MMP-1, which ensures extracellular matrix stability and coherence (He *et al.,* 2015).

INFLUENCE OF TUMERIC ON NUTRIENT ABSORPTION AND DIGESTION

Uptake and distribution of curcumin, a bioactive compound in turmeric, in body tissues is essential for its biological activity. Most curcumin gets metabolised in the liver and intestine; however, a small quantity remains detectable in the organs. Bioavailability and absorption of curcumin in different organs of mice were found to be persistently accumulated in the liver and spleen, while lung uptake decreased with time. Brain uptake of curcumin was at 2 minutes' post-injection, and its radioactivity was rapidly washed out from the brain at 30 minutes (Ryu *et al*., 2006). Oral administration of 400 mg curcumin to rats was reported by Ravindranath and Chandrasekhara (1981), and about 60% of the dose was absorbed. The authors, however, noted that tiny quantities in the liver and kidney (<20 μg/tissue) were observed from 15 minutes up to 24 hours after administration. Pan *et al*. (2000) observed that the distribution of curcumin in the intestines, spleen, liver, and kidneys, were 177.04, 26.06, 26.90, and 7.51 μg/g, respectively after one hour Intraperitoneal (I.P) administration of curcumin (0.1 g/kg) to mice; only traces (0.41 μg/g) was observed in the brain at 1 hour (Pan *et al*., 2000). Dietary curcumin (2%) yields low levels in the plasma, between 0 and 12 nM, when given to the mice. In contrast, tissue concentrations of curcumin in liver and colon mucosa were 0.1-0.9 nmol/g and 0.2-1.8 μmol/g, respectively. In comparison with dietary administration, when curcumin was given intragastrically, it resulted in more curcumin in the plasma but much less in the colon mucosa, indicating that the mode of administration plays a role in the distribution of curcumin (Sharma *et al*., 2001). In contrast, Garcea *et al*. (2004) reported poor availability of curcumin in the peripheral or portal circulation following oral administration, while curcumin was not found in liver tissue, trace levels of products of its metabolic reduction were detected.

ROLE OF TUMERIC IN BIOAVAILABILITY OF NUTRIENTS

Natural products are not chemically stable and are susceptible to oxidative degradation, affecting the integrity of molecules and leading to the development of free radicals. Employing natural products in formulations is challenging due to unfavourable features, including low solubility, inadequate bioavailability, and weak stability in environmental stresses (Shoji *et al*., 2004). Consequently, to maintain the peculiar profile of these compounds, specific delivery methods offer the possibility of using natural compounds to treat poultry disorders. Curcumin, a compound from turmeric, holds great promise in clinical practice since it behaves as a multifunctional ligand with many pharmacological effects, targeting several cellular pathways (Zhou *et al*., 2011).

The efficacy of any compound is determined by the bioavailability of its free concentration, not only in blood but also surrounding the therapeutic target (Smith *et al*., 2010). Intraperitoneal administration of unformulated curcumin inhibited the pro-fibrotic effects and reduced the idiopathic pulmonary fibrosis progression, while oral administration was revealed to be ineffective (Smith *et al*., 2010). This highlights the need to select a proper administration route for the same curcumin formulation to attain the therapeutic target and achieve adequate efficacy. Studies in rats have shown a dose-dependent limitation to the bioavailability of unformulated curcumin for the same route of administration, where increasing the administered dose has not increased tissue concentrations (Perkins *et al.,* 2002; Kunnumakkara *et al*., 2017). The distribution of unformulated curcumin was also variable among the different tissues. The highest amounts of unformulated curcumin were identified in rats' gut, stomach, liver, and spleen (Kunnumakkara *et al*., 2017). In the gastrointestinal tract of mice, the highest amount of unformulated curcumin was identified in the small intestines. Still, the kidney, heart, lungs, and muscles showed moderate amounts of unformulated curcumin in descending order, while trace curcumin amounts were identified in the brain (Perkin *et al*., 2002).

CONCLUSION

Turmeric (*Curcuma* genus) has a long history of medicinal applications (Dosoky and Setzer, 2018), comprising approximately 120 species. Among the *Curcuma* species, *Curcuma longa L.* (Curcuma; Turmeric) is the most widely recognised and cultivated in a warm climate, and in many regions of the world (Wu, 2015). Turmeric could control and limit the growth and colonisation of numerous pathogenic and non-pathogenic species of bacteria in the chicken's gut, resulting in balanced gut microbial ecosystems that lead to better feed utilisation, reflected by improved feed conversion ratio.

Turmeric plants may provide some compounds that enhance the digestion and absorption of some nutrients in poultry diets due to the active materials (Curcuminoids and Curcumin) found in turmeric, causing greater efficiency in the utilisation of feed and resulting in enhanced growth. Multiple biological effects on health promotion and disease prevention have been recognised in turmeric and its derivatives, especially curcumin. Indeed, a bibliometric analysis performed revealed that curcumin has bioactive effects, primarily focused on its anticancer, inflammatory, and antioxidant potentials. Most curcumin gets metabolised through the liver and the intestine; however, a small quantity remains detectable in the organs. Curcumin holds great promise in clinical practice since it behaves as a multifunctional ligand with many pharmacological effects, targeting several cellular pathways. Turmeric can minimise inflammatory effects, help growth performance, boost immune functions, and be an antioxidant in commercial broiler chickens. Dietary turmeric could be recommended to reduce the acute phase response to diseases and stimulate growth performance in broiler chickens.

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