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Influence of Various Irrigation Water Types On the Chemical Composition of Olive Fruit (Koroneiki Var.), As Well as The Physicochemical, Organoleptic Characteristics and Overall Quality Index of Its Virgin Olive Oil

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ABSTRACT

This investigation was carried out to study the influence of different irrigation water types on chemical composition and NPK elements of olive fruits taken from olive trees Kroneiki var as well as the chemical properties of the oil extracted from the olive fruit. The water types used include sweet water (SW), rain water (RW), ground water (GW) and agricultural draining water with sweet water (ADW: SW.1:1). The extracted oils have been tested for their physiochemical properties, fatty acids composition, bioactive components, sensory attributes, overall quality index (OQI) and their contents of some minerals. The results showed that; olives irrigated by RW gave the highest oil percent (19.73 %) and lowest moisture content (48.58%) and crude protein (1.75 %). On the reverse, olives irrigated by ADW+SW gave the lowest oil content (15.01 %) and highest moisture content (62.48%) and total carbohydrates (14.38%). Regarding the quality of the oil extracted from olive fruit, it has been found that the oil extracted from olives irrigated by GW and ADW +SW were of better oxidative stability and lowest oleic acid content. On the other hand, oil extracted from olive fruits irrigated by SW had lower values of (%) acidity, k232 and K270 nm., ΔK, carotenoid and chlorophyll contents and higher content of total phenols and tocopherols. The results had shown also that oil extracted from olive fruits irrigated with RW were of higher acidity and peroxide values, carotenoids and chlorophyll contents compared to other oils extracted from olives irrigated with other irrigation water types. In addition, olives irrigated by RW gave oil having the best sensory evaluation (fruity 7.2) followed by GW (fruity 6.5) then SW (fruity 5.35) and ADW+SW (fruity 4.00). The absence of any negative attributes for all oil samples studied indicated that they all can be classified as extra virgin olive oil .Oil extracted from olive fruits irrigated by SW gave the highest value from OQI 8.55 followed by RW 8.44 then GW 6.37 and ADW+SW 4.74. The results have shown also that the oil which has been extracted from olive fruits irrigated by RW has the maximum values of Pb, Ca, Fe, and Na metals being 1.96, 0.84, 1.66 and 0.81 mg/g olive oil respectively .

Keywords: Olives, Irrigation water types, Fatty acids composition, oxidative stability, Sensory evaluation, Overall quality index and Minerals content, Olive oil.

1. Introduction

Olive (*Olea europaea* L.) is a fruit tree that is native to the Mediterranean region and is grown for oil and canned fruit. Olive oil's growing economic significance worldwide as a result of its positive impact on human health contributes to some of this interest (Jihed Faghim *et al.,* 2021). One of the major and widely used agricultural practices in the arid and semi-arid regions of the Mediterranean

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basin is the cultivation of olive trees (*Olea europaea* L.). This is primarily because of the trees' high nutritional value and remarkable resilience to water scarcity (Connor, 2005; Fernández, 2014).

Olive oil quality is regulated by the International Olive Council and European legislation using specified metrics such as the concentration of free fatty acids (FFA), peroxide value (PV), UV specific extinction coefficients (K232 and K270), and sensory score. According to Boskou *et al.* (1996), the amount of FFA in particular has a significant role in determining the commercial grades of olive oil.

According to Salvador *et al.* (2001), there are multiple elements that influence the chemical and organoleptic properties of olive oil. In terms of Aparicio and Luna (2002), these variables can be divided into four primary categories: agronomic (fertilization and irrigation), cultivation (ripeness and harvesting), technological (fruit storage and extraction process), and environmental (soil and climate). Gomez-Rico *et al.* (2007) state that irrigation is one of these elements that significantly affects the quality of olive oil.

It was clear that the type of water used for irrigation had a significant impact on the storability of olive oil, with rainfed olive trees producing the best olive oil in terms of lower acidity, lower peroxide values, higher total phenol content, and higher sensory scores for the positive sensory attributes with the absence of negative ones. Alsaed *et al.* (2012) observed that water type (treated waste water, will water, and rainfed) had no significant effect on the quantity of both palmitic and stearic acids but significantly affected the quantity of oleic, linoleic, and linolenic acids.

The impact of waste water irrigation on the quality of extra virgin olive oil produced from the tunisian cultivar Chemlai was investigated by (Bealbabis *et al.,* 2010). The phenol content of the oils extracted from olive trees that were irrigated with treated wastewater (TWW) was found to have significantly decreased. On the other hand, TWW irrigation decreased oleic acid rates and cumulatively raised palmitic, palmmitoleic, linoleic, and linolenic levels. The overall phenol content was observed to be reduced by irrigation using treated waste water (TWW) by Gharsallacu *et al.* (2006). According to Palese *et al.* (2006) and Bedbabis *et al.* (2009), irrigation with TWW had no influence on the specific UV absorbance K232 and K270, as well as free fatty acid.

Comparatively speaking, oils from waste-water-irrigated olive trees are more susceptible to oxidation. Oils from olive trees that are watered with waste water have a higher polyphenol content and are distinguished by their notable fatty acid composition. According to some recent studies (Gharsallaovi *et al.,* 2011), virgin olive oil from olive trees that are irrigated with rainwater differs from other types in terms of both its chemical composition and sensory qualities (Aparicio and Luna 2002). Usually, rain-fed environments are used to cultivate olive trees. The phenolic chemicals influenced by irrigation, which affect both the oxidative stability and the sensory features, are what draw more attention to irrigated agriculture, though, since the yield response to irrigation is strong even with low water levels (Gomez-Rico et al., 2007).

This investigation aims to study the effect of using different types of water irrigation on the physco-chemical, organoleptic characteristics, fatty acids composition, OQI, heavy metals and bioactive components of olive oil extracted from their fruits which belongs to Kroneikei var. of olive trees.

2.Materials and Methods

2.1 Materials

2.1.1. Olive fruits

Olive fruits have been obtained from olive trees Koroneiki variety, grown in El-Qantara-East, North Sina Governorate and irrigated with different types of water; sweet water (SW), rain water (RW), ground water (GW) and agricultural drainage water with sweet water (ADW +SW 1:1).

2.1.2. Chemicals

All solvents and chemicals were used during this study were in HPLC grade and purchased from Sigma Aldrich, Darmstadt, Germany.

2.2. Methods

2.2.1. Chemical composition of olive fruit

Moisture, oil contents, crude protein, crud fiber and total carbohydrates of fresh and processed olive fruits were determined according to the methods of A.O.A.C (2000). Fiber content was estimated by difference as following equation: %Fiber content = 100- % (oil content + crude protein+ Ash content + total carbohydrates).

2.2.2. Oil extraction from olive fruits samples

Oil extraction from all olive fruits samples were made by hydraulic press using a Carver press and the extracted oils were stored in a dark bottle in the freezer until laboratory investigation.

2.2.3. Physico-Chemical characteristics of olive oil samples

The A.O.A.C. (2016) was used to evaluate the refractive index (RI) at 25 °C, acidity, and peroxide values (% FFA and PV meqO2/Kg oil).

The Commission of the European Union's Regulations EEC/1989/2003 were used to assess the absorbency in the UV at 232 and 270 nm (Diene and Triene) (EEC, 2003). Using a 1% solution of oil in cyclohexane and a path length of 1 cm, the diene and triene extinction coefficients were determined from absorbance at 232 and 270 nm, respectively, using a UV spectrophotometer (JENWAY 6405 UV/Vis. Spectrophotometer, England).

Iodine (I_2/100g oil) and saponification (mg KOH / g oil) values (IV and SV) were calculated from fatty acids content according to Nelson and Susana (1995).

2.2.4. Determination of fatty acids composition of oil samples

2.2.4.1. Preparing of fatty acids methyl esters

According to the instructions in (IOOC, 2009), the fatty acid methyl esters were made. The methyl esters were examined using a GC (Pye-Unicam model 104) fitted with a glass coiled column (1.6 × 4 mm) supported on chromosorb W-AW 100-200 mesh and FID detector. The following gas chromatographic parameters were used for the isothermal analysis: column temperature of 170℃, detector temperature of 300℃, and injector temperature of 250℃; flow rates were 33 ml/min for hydrogen, 30 ml/min for nitrogen, and 330 ml/min for air. In accordance with the procedures of Farag *et al.,* (1984), peak areas were measured using a Spectra Physics Chronjet Integrator.

2.2.5. Oxidative stability of olive oil samples

According to Gutierrez *et al.* (2002), the Rancimat method was used to assess the extracted olive oils' oxidative stability. By measuring the induction time (hours) with an oil sample of 5 g heated to 100°C and an air flow rate of 20 L/h, stability was determined using the Rancimat 679 instrument (Metrohm Herisou, Co., Switzerland).

2.2.6. Sensory evaluation of olive oils samples

The oil samples (15 milliliters each) were shown in covered blue glasses with a diameter of 70 mm and a volume of 30 milliliters, all at a temperature of 28 ± 2°C. The panelists warmed the glass, took off the cover, and smelled and tasted the sample to assess its flavor. This evaluation is calculated as the panelists' median score. The methodology (profile sheet) outlined by IOC (2007) was followed while evaluating the organoleptic properties of virgin olive oil samples.

2.2.7. Determination of overall quality index of olive oil

The overall quality index (OQI) **(**Kiritsakis *et al.,* 1998) was utilized as the following equation for a worldwide quality evaluation of virgin olive oil: QOI is 2.55 + 0.91 SE - 0.78 AV -7.35 K270 - 0.066 PV. Where: PV: Peroxide value (from 1.0-20.0), K270: Absorbance at 270 nm (from 0.08-0.22), AV: Acid value (from 0.1-3.3), and SE: Sensory evaluation (from 3.5-9.0).

2.2.8. Determination of bioactive components of oil samples

I. Total polyphenols:

Using Gutfinger's (1981) method, the total polyphenols (ppm) of extracted live oil were calculated.

II. Total tocopherols:

Total tocopherols were calculated using the method outlined by Wong *et al.* (1988) as α-Tocopherols (ppm).

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III. Pigments contents (carotenoids and chlorophylls):

According to Isabel Minguez-Mosquera *et al.* (1991), the concentrations of carotenoid and chlorophyll were estimated in parts per million.

2.2.9. Determination of NPK elements in defatted olive powder samples

Using an atomic absorption spectrophotometer (Hitachi Z6100, Tokyo, Japan), the minerals nitrogen and potassium (N and K) were examined independently. The phosphomolybdate was used in spectrophotometry to assess the phosphorus content (AOAC, 1990).

2.2.10. Determination of minerals in olive oil

Using an atomic absorption spectrometer with flame atomization (Model 2280 Perkin Elmer, Spain), the mineral components in olive fruits were determined.

3. Results and discussion

The chemical composition of olive fruits. coming from olive trees (Koroneiki var.) irrigated with different types of water; sweet water (SW), rain water (RW), ground water (GW) and agricultural drainage water with sweet water (ADW + SW 1:1) were given in Table (1). As a shown in this table, differences were noticed among these fruits in their contents; moisture, oil, protein and total carbohydrates. Olives irrigated by ADW+SW have the highest values from moisture content and total carbohydrates 62.48 and 14.38 % respectively, and the lowest value from oil content (15.01%) on the other hand, olive irrigated by RW have the lowest values from moisture content and crud protein (48.58 and 1.77%, respectively) and the highest value from oil content 19.73%. Also, from the results, values of oil content, crude protein and total carbohydrates recorded higher amounts (19.22, 3.75 and 13.71%, respectively) in olive fruits irrigated by SW. As well as olive fruits irrigated by GW contains a considerable amount from oil content and crude protein (17.45 and 3.95% respectively).

Table 1: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the chemical composition of olive fruit

Property (%)	Irrigation water type			
	SW	RW	GW	ADW+SW
Moisture content	51.3	48.58	61.98	62.48
Oil content	19.22	19.73	17.45	15.01
Crude protein	3.75	1.75	3.94	3.88
Total Carbohydrates	13.71	13.03	10.30	14.38

SW: Sweet water, RW: Rain water, GW: Ground water, ADW: Agricultural Drainage water

From the tabulated data in Table (2), there were differences in NPK elements of defatted olive fruits powder (cv Koroneiki) as a result affected type of irrigation water (SW, RW, GW and ADW+SW), it can be observed that RW olive fruits powder have the lowest value from N mineral (0.28%) and the highest values from P and K minerals were 0.17 and 0.66% respectively compared with them in fruits from olive trees irrigated with other, types of water.

Table 2: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the NPK elements content of olive fruit powder (on dry weight)

NPK minerals (%)	Irrigation water type			
	SW	RW	GW	ADW+SW
Nitrogen (N)	0.6	0.28	0.63	0.62
Phosphorus(P)	0.16	0.17	0.14	0.14
Potassium (K)	0.6	0.66	0.44	0.49

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

Physicochemical properties (RI, FAA, PV, K232, K270, ΔK, oxidative stability, IV and SV) of oil extracted from olive fruits obtained from olive trees irrigated with SW, RW, GW and ADW+SW were represented in Table (3).

From the results in this table, there were changes in previous parameters as affected by the different types of irrigation water.

Oils from olives fruits irrigated by ADW + SW had the lowest PV (0.29) meq O_2/Kg oil compared to the other types of irrigation water, but oil from olive fruits irrigated by SW gave the lowest values from FFA, K_{232}, K_{270} and ΔK (0.23%, 1.19 nm.,0.094 nm. and 0.003, respectively) compared with them in olive oil from others irrigation types. Also, from the data in same table oil from RW olive fruits gave the highest values from acidity and peroxide values (0.68% and 7.24 meqO_2/Kg oil, respectively) compared with them in olive oil from other irrigation water types.

Table 3: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the physicochemical characteristics of olive oil

Physicochemical characteristics of oil samples	Irrigation water type			
	SW	**RW**	**GW**	**ADW+SW**
RI at 25 °C	1.4685	1.4681	1.4674	1.4673
Acidity % (% as oleic acid)	0.23	0.68	0.58	0.43
Peroxide value (PV) meqO_2/Kgoil	3.63	7.24	1.92	0.29
K_{232} nm	1.19	1.67	1.79	1.56
K_{270} nm	0.094	0.156	0.188	0.181
ΔK	0.003	0.005	0.006	0.007
Oxidative stability at 100 °C (hr.)	38.04	32.68	51.13	50.98
Iodine value (IV) g of I_2/100g oil	84.46	82.22	80.47	77.65
Saponification value (SV) mg KOH / g oil	201.47	202.36	201.53	201.46

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

Generally values of acidity ranged between 0.23 and 0.68%, PV ranged between 0.29 and 7.24 meqO_2/Kg oil, K_{232} ranged from 1.19 to 1.79 nm , K_{270} ranged from 0.094 to 0.188 nm., and ΔK from 0.003 to 0.007 in oils of olive fruits obtained from olive trees irrigated with SW, RW, GW and ADW + SW, that meaning these values were still less than the permitted upper limit of 0.8 for acidity , 20 meqO_2/Kg oil for peroxide value, 2.5 nm for K_{232}, 0.22 nm, for K_{270} , and 0.01 for ΔK according to IOC (2022) for extra virgin olive oil. These results are agreement with Zaher *et al.* (2017), they found that comparing parameters of quality characteristics of olive oil extracted from olive trees irrigated by effluent (TWW) or irrigated by fresh water shows there no differences in values of these parameters, and they found these parameters are within the acceptable standard limit values. Also from the results, irrigation water type had affected on iodine values (IV) and refractive index (RI) whereas ADW+SW gave olive oil containing lower amounts from IV and RI compared to the other three irrigation water types, but there was no clear affect on saponification values as a result different irrigation water types. The olive fruits irrigated by GW and ADW + SW gave olive oil characterized by the best stability (51.13 and 50.98 hr. respectively), followed by olive oil obtained from olive fruits irrigated by SW and RW (38.04 and 32.68 hr. respectively).The higher oxidative stability of oil extracted from olive fruits obtained from olive trees irrigated by GW and ADW+SW may be related to their high oleic acid content and low peroxide value under study, these results confirm those higher value of oleic acid and lower content of PV where they were found that the irrigation by GW and ADW+SW positively affected in stability of oils.

Table (4) shows the fatty acids composition of oils extracted from olive fruits obtained from olive trees after irrigation with SW, GW, RW and ADW+SW. From the data in this table, it can be seen that, oil from olive fruits irrigated by SW had the lowest values from C16:0, C16:1, C17:0, C17:1, C18:0 and C18:1 acids and the highest values from C18:2 and C18:3 acid compared to oils from olive fruits irrigated with RW, GW and ADW+SW. No changes clear in C20:0 and C20:1 acids of oil extracted from olive fruits of all treatments. Value of C22:0 acid recorded a decrease in oil olive fruits RW and

GW compared to SW fruits, but it disappeared in oil from olive fruits irrigated with ADW+SW olive fruits.

With regarding the data in this table C18:1 acid was found in high percentages (71.28%), but C18:2 acid was found in low concentration (6.29%) in oil coming from olive trees irrigated by ADW+SW compared to others water types, Also the higher values for C18:1 and lower value lenoleic acid (C18:2) were found in olive oil extracted from olive fruits harvested from olive trees irrigated with GW compared to oil from SW, these results are agreement with data reported by Gomez-Alonso *et al.* (2007). Also, results revealed that, C18:3 acid was found to be 0.8, 0.79, 0.63 and 0.74% in oils coming from olive trees irrigated by SW, RW, GW and ADW+SW respectively.

Generally, the variability of fatty acids composition (C16:0, C18:0, C18:1, C18:2 and C18:3) of oils coming from olive trees irrigated with different types of water; SW, RW, GW and ADW+SW under investigation are within the permitted level as mentioned by IOC (2006).

Table 4: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the fatty acid composition of olive oil

Irrigation water type	Fatty acids composition										
	C16:0	**C16:1**	**C17:0**	**C17:1**	**C18:0**	**C18:1**	**C18:2**	**C18:3**	**C20:0**	**C20:1**	**C22:0**
SW	14.56	1.13	0.03	0.07	2.03	67.21	11.30	0.80	0.43	0.29	0.12
RW	14.46	1.48	0.13	0.21	2.51	68.84	10.22	0.79	0.40	0.24	0.05
GW	16.31	1.52	0.13	0.20	3.09	70.0.	7.45	0.63	0.47	0.24	0.08
ADW+SW	16.75	1.39	0.05	0.13	2.41	71.38	6.29	0.74	0.41	0.08	----

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

Data in Table (5) revealed that the median for the positive attributes; fruity , bitter and pungent of oils obtained from olive trees irrigated by SW, RW, GW and ADW+SW, it is clear from the obtained data in this table, that the olive trees irrigated by RW gave olive oil characterized by a higher positive sensory attributes ; fruity (7.2) followed by oil from GW olives gave the fruity 6.5 then oil from SW olives gave the fruity 5.35 and oil from ADW + SW olives gave the fruity 4.75 with the absence of any negative attributes for all samples , such score for all olive oil samples classify they as extra virgin olive oil (EVOO) according to IOC (2007). The variation in sensory attributes may be due to the differences in irrigation water composition (Alsaed *et al.,* 2012). Also, irrigation water type had an influence on the OQI (overall quality index) of olive oil, whereas SW gave the highest value from the OQI (8.55) and RW gave nearly the same value (8.44), followed by GW (6.37), then ADW+SW (4.74).

Table 5: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the sensory characteristics and overall quality index of olive oil

Irrigation water type	Positive attributes			Category	OQI
	Fruity	**Bitter**	**Pungent**		
SW	5.35	1.2	0.75	EVOO	8.55
RW	7.20	2.50	3.25	EVOO	8.44
GW	6.50	3.50	2.75	EVOO	6.37
ADW+SW	4.75	5.0	4.25	EVOO	4.74

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

Table 6 shows the bioactive components (total phenols, total tocopherols, chlorophyll and carotenoid contents) of oil from fruits obtained from olive trees irrigated with SW, RW, GW and ADW+SW. Olive trees irrigated with GW and ADW+SW effect negatively the total phenols, total tocopherols and carotenoids content but they effect positively the chlorophyll contents. Also, olive trees irrigated with RW effect negatively the content of total phenols and total tocopherols, but it caused increase in chlorophyll and carotenoids contents in oil extracted from their fruits compared with oil from SW fruits. The reduce in total phenols of oil from fruits obtained from olive trees irrigated with GW and ADW+SW may be related to these trees had the highest fruits moisture content (61.98 and 62.48% respectively) under study which it caused to decrease to total phenols, whereas the decrease of total phenol content in olive oil is related to their high solubility in aqueous phase (Bedbabis *et al.,* 2010). Furthermore the high decrease of total phenols in oil from RW compared to other water types, this might be a result of (K) mineral supply by RW that caused increase of (K) element concentration in fruits as a shown in Table (2) which has been reported to determine an earlier change of fruit color from green to black (Chartzoulakis *et al.,* 2004).

Table 6: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the bioactive compounds of oil fruit

Bioactive compounds (ppm)	Irrigation water type			
	SW	**RW**	**GW**	**ADW+SW**
Total phenol content (TPC)	385.70	140.29	195.37	199.48
Total tocopherols	82.92	72.58	66.51	75.42
Carotenoids contents	0.55	0.81	0.50	0.44
Chlorophyll contents	0.55	2.42	2.19	1.67

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

The results for elements (Pb, Ca, Mg, Fe, Na and Cu metals) concentration of samples of olive oil obtained from the fruits of olive trees (Koroneiki var.) which irrigated by SW, RW, GW and ADW+SW are shown in Table (7). Estimation the amount of previous mentioned elements can be used for the characterization of olive oil quality, which clear difference for each olive oil sample concentration as a result their type of irrigation water. Table (7) shows the maximum values for Pb, Ca, Fe, and Na metals in the measured concentration are 1.96, 0.84, 1.66 and 0.81mg/g, oil respectively for olive fruits oil which their trees were irrigated by RW. As a shown in this table the highest concentration of Mg metal in olive fruits oil was 0.83 mg/gm oil, which their trees irrigated by ADW+SW. Cu metal is very toxic, because if it is taken at high concentration, it can cause many problems for human health such as damage brain (Odeh *et al.,* 2015).

Cu element was determined 0.01 mg/g oil for olive oil samples which their trees irrigated with RW, GW and ADW+SW, but it was found to be zero in oil from SW olive fruits.

Table 7: Effect of using different irrigation water types for irrigating olive trees (Koroneiki var.) on the element's concentration of olive oil

Elements mg/g oil	Irrigation water type			
	SW	**RW**	**GW**	**TDW+SW**
Pb	1.33	1.96	0.71	1.22
Ca	0.82	0.84	0.15	0.58
Mg	0.33	0.3	0.15	0.83
Fe	0.91	1.66	0.34	0.06
Na	0.34	0.81	0.63	0.17
Cu	Zero	0.01	0.01	0.01

SW: Sweet water, **RW:** Rain water, **GW:** Ground water, **ADW:** Agricultural drainage water

4. Recommendation

Due to the limited sources of fresh water and the problem of shortage in Egypt, therefore through this study. we can recommend the use of a mixture of agriculture drainage water with sweet water to irrigate olive tree, as there is no negative impact on the physic-chemical and organoleptic characteristics of the oil extracted from olive fruits obtained from olive trees irrigated with this type of irrigation water, as become clear to us through this study, thus saving a large portion of fresh water for human use.

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6. Conflicts of interest

No competing interests are disclosed by the authors.

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