PRODUCTION AND EVALUATION OF FENNEL (*FOENICULUM VULGARE*, Mill.) GROWN WITH NATURAL FERTILIZERS

By

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ABSTRACT

This work was carried out during 2006/2007, 2007/2008 seasons at Faculty of Agriculture, Kafrelsheikh University, Egypt to study the effect of some bio, organic and chemical fertilizers on the vegetative growth, seed yield, essential oil productivity, chemical composition and nutritive value of fennel (*Foeniculum vulgare*, Mill). Data showed that, plants fertilized with compost + biofertilzers combined with either yeast, amino acids, humic acid or seaweed extract gave results parallel with or surpassed the others which were fertilized with full dose of NPK in most cases for the determined parameters in the two seasons. The determined parameters were growth characters i.e. plant height, number of branches per plant, number of umbels per plant, umbels weight per plant and per fed and fresh and dry weights per plant; as well as seeds and essential oil characters i.e. weight of 100 seeds, seed yield per plant and per fed, essential oil percentage and yield (per plant and fed) and N, P, K, chlorophyll a and b contents in plant herb.

Compost+biofertilizer+yeast treatment gave the highest protein content among all biofertilization treatments. Furthermore, non significant difference was detected for essential oil percentage between NPK and compost+biofertilizer+yeast treatments in both seasons, so that it could be chosen for nutritional evaluation. Fertilization led to increasing of unsaturated fatty acids especially, oleic acid which decreasing saturated fatty acids. Compost+biofertilizer+yeast treatment had the highest level of unsaturated fatty acids followed by NPK. Trans-anethole, carvone, fenchone and methyl chavicol were identified as the highest main constituents level, which represented about 83.4, 86.1 and 84.7% of total constituents for control, NPK and compost+biofertilizer+yeast samples; respectively.

The results showed also that NPK treatment gave the highest amount of all indispensable amino acids compared with other samples. In addation, it had the highest amino acid scores of the indispensable

amino acids. First limiting amino acid was for (methionine+cystine). NPK treatment showed the highest C-PER and biological value of the samples. Organoleptic evaluation of bread sticks revealed that substitution with 5% fennel seed powder for either NPK or compost+biofertilizer+yeast treatments gave similar overall acceptability over control and good acceptance for taste and odor.

Keywords: *fennel, Foeniculum vulgare, production, fertilization, chemical composition, amino acid, fatty acid, essential oil and bread sticks.*

INTRODUCTION

With increasing concerns about the environment and return back to use herbs in pharmaceuticals and cosmetics in the last few years, use of the natural resources, less use of chemicals have become increasingly important goals of sustainable agriculture in Egypt. The intensive use of expensive mineral fertilizers in recent years, which not yet increase the production costs but also causes environmental pollution problems as pollution rates in soil, water and air could be lowered as a result of decreasing the applied chemical fertilizers (Alaa El- Din, 1982). Chemical fertilizers at extremely high rates for a long time decreased the potential activity of micro-flora and stability of soil organic matter. Bio fertilizers and organic fertilizers offer a safe option for reducing agrochemical fertilizers. In addition, it fulfills the nutrient requirements of various crop species and increase both crop yield and nutrient composition (Pokorna, 1984).

Fennel (*Foeniculum vulgare*, Mill.) is one of the important minor spices in Egypt and is native to southern Europe (especially the Mediterranean) and Southwestern Asia. It is a member of the family Apiaceae, formerly Umbelliferae. The foliage and seeds have pleasant aroma and largely used to impart flavor to a number of foods, such as soups, sauces, pickles, breads, cakes, etc. (Simandi *et al.,* 1999). Fennel oil is a rich source of anethole and is largely used as a flavoring agent in culinary preparations, confectionary, cordials and liqueurs and occasionally employed in scenting soaps (Anonymous, 1988).

Fennel extracts have several functional properties, such as anti-inflammatory, antispasmodic, carminative, diuretic, expectorant, laxative, analgesic, stimulant of gastrointestinal mobility and for the treatment of nervous disturbances (Jahromi *et al.,* 2003). The chemical constituents and antimicrobial properties of the seed essential oil are well studied (Beaux *et al.,* 1997; Coelho *et al.,* 2003).

This study aim to use natural substitutes for chemical fertilization and evaluate nutritive value of the produced seeds.

MATERIALS AND METHODS

A field trial was achieved in 2006/2007, 2007/2008 seasons at Faculty of Agriculture, Kafresheikh University, Egypt to study the effect of some bio, organic and chemical fertilizers on the vegetative growth, seed yield, essential oil productivity, and chemical composition of *Foeniculum vulgare,* Mill. Also, fennel seeds were chemically and nutritionally evaluated.

The planting seeds were supplied from the National Research Center, Dokki, Egypt and sown in a clay soil for two seasons on November 15th. Plots were 2 x 2m with four rows at 50 cm apart in each plot, and 50 cm between the seed hills within the row. One month later, the hills were thinned at two plants/ hill as every plot contained 16 hills / plot and replicated 3 times in a completely randomized block design.

Table (1): Physical and chemical analysis of the used soil (average of both seasons).

Sand %	Silt %	Clay %	Soil texture	EC mmhos/cm	pH	Available N %	Total P ppm	OM %
5.13	52.33	41.57	Silty clay	0.45	738	0.18	28	1.41
Soluble cations (meq/l)				Soluble anions (meq/l)				
Na+	K+	Ca++	Mg++	CO_3^-	HCO_3^-	Cl^-	$SO4^{--}$	
1.05	0.08	2.00	1.00	-	2.81	0.81	0.51	

Table (2): Chemical analysis of the used compost (average of both seasons).

N	P	K	Ca	Mg	Fe	Zn	Mn	O.M	C/N ratio	pH	EC (dS/m)
(%)					(ppm)			(%)			
1.47	0.95	1.185	4.63	0.89	4309.35	215.4	461	37.1	15.45:1	7.55	5.35

The used fertilization treatments were as follows:

a- Organic fertilizer of (compost) was applied at the rate of 10 m^3 /fed., during soil preparation on November in the two seasons.

b- Biofertilizer was a mixture of *Bacillus megatherium* P.D.B., *Azospirillum lipoferum* and *Azotobacter chroococcum* at rate of one liter of solution to 200 liter of water /fed., as a soil drench (Eweda, 1990) applied in two doses, the first one was after one month from sowing and the second was two months later.

c- Chemical fertilizer or NPK as listed under tables was a mixture of ammonium sulphate (20.5%N), calcium super phosphate (15.5%

P_2O_5) and potassium sulphate (48% K_2O) at the rates of 300, 300 and 80 kg/fed., respectively as a full dose, added in two equal doses, the first one was one month after sowing and the second was two months later.

d- Active dry yeast (*Saccharomyces cerevisiae*) was added monthly at rate of 5g per one liter of water as a foliar spray (Ahmed, 1998).

e- Humic acid was added monthly at the rate of 1 ml from the commercial product Mega power-x (19% humic acid) per one liter of water (recommended dose) as a foliar spray.

f- Amino acids was added monthly at the rate of 2g from the commercial product called Amino Total (40% total amino acids) per one liter of water (recommended dose) as a foliar spray.

g- Seaweed extract was added monthly at the rate of 2ml from the commercial product Algreen per one liter of water (recommended dose) as a foliar spray.

The experimental design was a complete randomized block with three replicates and the treatments were control (without fertilization), NPK (full dose), C+B (compost + biofertilizer), C+B+Y (compost + biofertilizer + yeast), C+B+AA (compost + biofertilizer + amino acids), C+B+HA (compost + biofertilizer + humic acid) and C+B+SE (compost + biofertilizer + seaweed extract). The common agricultural practices i.e. watering, weed control, etc. were done whenever plants needed. Duncan's Multiple Range Test according to Snedecor and Cochran (1982) was used to compare the mean values of the treatments.

The complete blooming was on March 1st in both seasons as the data of plant height, branches number/plant and umbels number/plant were recorded. At the end of the experiment (after ripening of seeds), data of umbels weight/ plant, weight of 100 seeds, seed yield per plant and fed; herb fresh and dry weight/plant were recorded. Also, chlorophyll a and b were determined in fresh leaves according to Moran (1982). Total nitrogen was determined in dried samples of plant aerial parts (A.O.A.C., 2000). Phosphorus was determined in aerial parts calorimetrically according to Murphy and Riley (1962). Potassium was determined using flame photometer according to Pearson (1976).

Evaluation of fennel seeds:

A mixture of fennel seeds obtained from two seasons was used for seed evaluation as follow:

Gross chemical composition of fennel seeds:

Moisture, crude protein, ether extract, ash and crude fibers of fennel seeds were determined according to the method of A. O. A. C. (2000). Total carbohydrates were determined by phenol- sulphuric acid according to the method outlined by Dubois *et al.* (1956). The available carbohydrates were calculated by subtracting the percentage of crude fibers from the percentage of total carbohydrates content.

Minerals determination:

Fennel seed powders were prepared for minerals determination according to the method of the A. O. A. C. (2000). Total phosphorus were determined by ascorbic acid technique using the colorimetric method that described by Murphy and Riley (1962). Potassium content of samples was estimated using Flame Photometer (Flame Photometer 410, Sherwood, UK). Ca, Mg, Fe, Zn, Cu and Mn of samples were conducted using the Atomic Absorption Spectrophotometer (Perkin Elmer Model 2180) at Soil Dept., Fac. of Agric., Kakrelsheikh Univ., as given by Pearson (1976).

Determination of fatty acids:

Fatty acids composition of ether extract for fennel seeds was extracted using soxhlet apparatus and determined by gas liquid chromatography (GLC) technique, Model Shimadzu-4 CM (PEF) equipped with PID detector and glass column 2.5mm X 3 mm i.d according to the methods described by Radwan (1978) and Patterson **(1989)** at Central Laboratory, Faculty of Agriculture, Alexandria Univ., Egypt.

Extraction of the essential oil:

The seeds of fennel were hydrodistilled in a Clevenger's type apparatus for 6 h. Yellow colored oil, with characteristic odor and sharp taste, was obtained. It was dried over anhydrous sodium sulphate to remove traces of moisture and stored in a refrigerator in the dark at 4 °C until use. Essential oil percentage, yield/ plant and per fed were calculated (Clevenger European Pharmacopoeia procedure, 1983).

Chemical analysis of essential oil:

The chemical analysis of fennel seeds essential oil was undertaken by Gas Chromatography (GC) and Gas Chromatography–Mass Spectroscopy (GC–MS) techniques. A Finnigan MAT SSQ 7000 mass spectrometer was coupled with a Varian 3400 gas chromatography. Analysis was performed in National Research Center, Giza, Egypt according to the methods outlined by Singh *et al.* (2006).

Determination of fennel seeds amino acids:

Amino acids except tryptophan were determined in fennel seeds meal according to the method described by Sadasivam and Manickam (1992) using amino acid analyzer, BECKMAN, Model 118/119 CL at Central Laboratory, Faculty of Agriculture, Alexandria Univ., Egypt.

Chemical score (CS), Biological value (BV) and protein efficiency ratio (C-PER):

According to Pellet and Young (1980) amino acid score is defined as milligrams of indispensable amino acids per gram nitrogen in tested protein divided by milligrams of indispensable amino acid per gram nitrogen in the protein reported by FAO/WHO (1985).

Biological value of fennel seeds protein was calculated as given by Mitchell and Block (1946) and El-Bana *et al.* (2007). Protein efficiency ratio of fennel seed protein was computed according to Hsu *et al.* (1978) procedure.

Preparation of bread sticks using fennel seeds powder:

The basic formula used in bread sticks preparation was as follows:

Ingredients:	Wheat flour72%	Sugar	Fat	Salt	Dry yeast
Amounts:	1.0 kg	80.0 g	100.0 g	5.0 g	6.0 g

Fennel seeds powder was substituted the base flour at three different levels (5, 10 and 15%). The control dough was prepared from 100% wheat flour. Dough sticks preparation was preformed as described by Aper and Bezaro (1990).

Sensory analysis:

Organoleptic evaluation of bread sticks was performed by a semi-trained panel of judges using ten-point hedonic-scale ratings for color, taste, odor, texture and overall acceptability with 10 being the highest score, extremely liked, and 1 being the lowest score, extremely disliked, (**Watts *et al.*, 1989**).

RESULTS AND DISCUSSION

Effect of the used fertilization treatments on growth characters:

Data in Table (3) clear that, the used fertilizers significantly increased plant height, number of branches and herb fresh and dry weights over control in both seasons. C+B+AA treatment gave the tallest plants in the two seasons; while C+B+Y treatment gave the tallest plants

only in the second one. The highest branch number per plant resulted from plants treated with full dose of NPK, C+B+Y and C+B+HA in the two seasons, but in the second season only C+ B+SE treatment gave the tallest plants. Also, the highest umbel number per plant resulted from plants treated with full dose of NPK in the two seasons and C+B+Y in the second one only. The heaviest umbels per plant were obtained when C+B+Y treatment was used in the two seasons. As for herb fresh and dry weights data showed that, the highest values were obtained from plants treated with C+B+HA in the two seasons. The increase in yield was attributed to the plant growth promoting substances by root colonizing bacteria more than the biological nitrogen fixation (Okon, 1985).

Table (3): Effect of fertilizers on some growth characters of fennel (*Foeniculum vulgare*) during the two seasons.

Treatments	Plant height (cm)	Branch No. /plant	Umbels No. /plant	Umbels weight /plant (g)	Herb F.W. /plant (g)	Herb D.W. /plant (g)
First season						
Control	48.00f	1.67d	13.33e	14.04f	50.60f	24.66g
NPK	89.67d	6.67a	68.33a	142.13c	112.01c	46.47d
C+B	77.33e	4.67c	24.00d	48.24e	81.72e	31.35f
C+B+Y	102.30b	6.67a	52.67b	174.67a	153.01b	54.22b
C+B+AA	110.30a	5.33bc	46.33c	157.95b	150.97b	50.77c
C+B+HA	102.30b	6.33ab	27.67d	70.55d	189.29a	77.83a
C+B+SE	97.00c	4.33c	27.67d	79.96d	84.43d	37.00e
Second season						
Control	62.67d	2.00c	9.67e	10.18f	47.27g	23.18e
NPK	93.00c	5.67a	59.00a	122.72c	114.94d	56.09c
C+B	95.00c	4.33b	20.33d	40.87e	96.48f	47.05d
C+B+Y	111.33ab	5.67a	61.33a	203.42a	118.91c	58.07c
C+B+AA	115.00a	4.67b	45.33b	154.54b	125.06b	63.93b
C+B+HA	105.00b	5.67a	35.33c	90.10d	167.09a	81.37a
C+B+SE	92.33c	5.00ab	24.00d	69.36d	99.47e	48.82d

Means in the same column followed by the same letter are not significantly different according to DMRT at ($P > 0.05$). NPK (full dose), C+B (compost + biofertilizer), C+B+Y (compost + biofertilizer + yeast), C+B+AA (compost + biofertilizer + amino acids), C+B+HA (compost + biofertilizer + humic acid) and C+B+SE (compost + biofertilizer + seaweed extract).

The superiority of biofertilizers may be due not only to its ability to fix nitrogen but also through growth promoting substances (indol-3-acetic acid, gibberellins and cytokinins) (Pareek *et al.*, 1996 and Zahir *et al.*, 1997), or indirectly by a change in the microflora of the rhizosphere (Barea and Brown, 1974). Also, El- Kassas (1999) found that the highest number of branches, plant height and yield of fennel seeds was obtained with plants grown on soils fertilized with compost mixed with bacteria. Humic substances can have a direct effect on plant growth, assuming a hormonal action of humic substances (Varanini and Pinton, 1995). Also, Delfine *et al.* (2005) found that, the foliar application of humic acid on wheat caused a transitional production of plant dry mass with respect to unfertilized control and split soil N application. These results are in harmony with those of Mona *et al.* (2008) on Fennel and Salvia and Azzaz *et al.* (2009) on fennel plant.

Effect of the used fertilization treatments on seed characters:

Data in Table (4) show that all treatments surpassed the control in all seed characters during the two seasons. The heaviest 100 seeds resulted from the treatment of C+B+AA in both seasons. The highest seed yield per plant and per fed resulted from plants treated with full dose of NPK (No significant differences were found among them in most cases), C+B+Y and C+B+AA in the first season; and full dose of NPK, C+B+Y, C+B+AA, C+B+HA, C+B+SE treatments in the second one. The increase in seeds yield with applying bacteria may be due to the promoting root growth which in turn enhanced nutrients and water uptake from the soil as well as the decrease in soil pH which lead to solubility of nutrients and increased nutrients availability and supply (Lin *et al.*, 1983 on *Zea mays* and *Sorghum bicolor* and Salem, 1986). In this respect, Atta *et al.* (1999) found non significant differences in fennel yield due to fertilization with inorganic and organic nitrogen sources. These results are in accordance with those of Mona *et al.* (2008) on Fennel and Salvia.

Effect of the used fertilization treatments on seed essential oil contents:

Data presented in Table (4) revealed that all treated plants with fertilizers gave the highest values compared with untreated ones in the two seasons. The highest values for essential oil percentage, yield per plant (ml) and per fed (L) resulted from full dose of NPK, C+B+Y, C+B+AA and C+B+HA treatments in the first season; whereas in the

second one the highest values for the corresponding characters were just obtained from full dose of NPK and C+B+Y treatments. Organic acids dissolve minerals by a combined action of complexation and acid attack (Barman *et al.*, 1992). The promoting effect of Azospirillum and soil yeast could be attributed to the biologically active substance produced by these biofertilizers such as auxins, gibberellins, cytokinins, amino acids and vitamins (Hegazi, 2004). These results are in agreement with those of Mona *et al.* (2008) on Fennel and Salvia and Azzaz *et al.* (2009) on fennel plant.

Table (4): Effect of fertilizers on seeds and essential oil characters of fennel (*Foeniculum vulgare*) during the two seasons.

Treatments	Weight of 100 seeds (g)	Seeds yield /plant (g)	Seeds yield /fed. (kg)	Essential oil (%)	Essential oil yield /plant (ml)	Essential oil yield /fed (L)
First season						
Control	0.72f	12.19d	278.63d	0.44d	0.06e	1.37e
NPK	1.79b	28.75a	657.14a	1.24a	0.36a	8.15a
C+B	0.87e	14.27d	326.09d	0.73c	0.10d	2.36d
C+B+Y	1.49d	28.55a	652.64a	1.24a	0.35a	8.07a
C+B+AA	1.89a	28.41a	649.37a	1.19ab	0.34ab	7.69ab
C+B+HA	1.68c	22.62b	516.95b	1.13ab	0.26b	5.87b
C+B+SE	1.53d	19.25c	439.99c	1.09b	0.21c	4.79c
Second season						
Control	0.70e	10.02c	229.03c	0.67f	0.07e	1.52e
NPK	1.76b	25.56a	584.30a	1.42a	0.35a	8.07a
C+B	0.91d	16.12b	368.45b	0.95e	0.15d	3.50d
C+B+Y	1.52c	24.71a	564.72a	1.39a	0.34a	7.84a
C+B+AA	1.83a	24.84a	567.69a	1.33b	0.34a	7.77a
C+B+HA	1.75b	24.59a	562.13a	1.26c	0.31b	7.08b
C+B+SE	1.46c	21.81a	498.59a	1.16d	0.25c	5.79c

Means in the same column followed by the same letter are not significantly different according to DMRT at (P > 0.05). NPK (full dose), C+B (compost + biofertilizer), C+B+Y (compost + biofertilizer + yeast), C+B+AA (compost + biofertilizer + amino acids), C+B+HA (compost + biofertilizer + humic acid) and C+B+SE (compost + biofertilizer + seaweed extract).

Effect of the used fertilization treatments on N, P and K and chlorophyll a and b contents in plant herb:

Data in Table (5) showed that all treatments significantly increased N, P, K and chlorophyll a & b contents over control in the two

seasons. The treatments of full dose of NPK, C+B+Y, C+B+AA and C+B+HA gave the highest nitrogen percent in the two seasons. In contrast, C+B+SE treatment gave the highest phosphorus percentage in the first season while this resulted from C+B in the second one. The highest potassium values resulted from full dose of NPK and C+B+AA treatments in the first season and full dose of NPK and C+B+Y in the second one. These results may be due to that organic and bio fertilizers were sufficient to supply similar macro- and micro nutrients uptake by fennel plants. These results are in agreement with those obtained by Buntain and Chung, (1994), Damato *et al.* (1994) and Azzaz *et al.* (2009) on fennel plant.

Table (5): Effect of fertilizers on N, P and K (%), and chlorophyll a and b (mg/g f.w.) of fennel (*Foeniculum vulgare*) during the two seasons.

Treatments	N (%)	P (%)	K (%)	Chlorophyll a (mg/g f.w)	Chlorophyll b (mg/g f.w)
First season					
Control	1.86c	0.12e	2.13f	1.050c	0.217d
NPK	2.92a	0.19d	3.02a	1.190a	0.360a
C+B	2.29b	0.28b	2.37e	1.123b	0.280c
C+B+Y	2.86a	0.24c	2.72cd	1.187a	0.343a
C+B+AA	2.84a	0.22c	2.93ab	1.193a	0.343a
C+B+HA	2.80a	0.27b	2.79bc	1.163ab	0.297bc
C+B+SE	2.37b	0.32a	2.56d	1.140ab	0.300b
Second season					
Control	2.09d	0.10d	2.23f	1.017e	0.190e
NPK	3.05a	0.16c	3.25a	1.163a	0.317a
C+B	2.54c	0.29a	2.79e	1.090d	0.233d
C+B+Y	3.02ab	0.20bc	3.19ab	1.160ab	0.300ab
C+B+AA	3.03ab	.0.17bc	3.10bc	1.143b	0.283b
C+B+HA	3.01ab	0.21bc	2.95d	1.110c	0.263c
C+B+SE	2.83b	0.23b	3.02cd	1.123c	0.243d

Means in the same column followed by the same letter are not significantly different according to DMRT at ($P > 0.05$). NPK (full dose), C+B (compost + biofertilizer), C+B+Y (compost + biofertilizer + yeast), C+B+AA (compost + biofertilizer + amino acids), C+B+HA (compost + biofertilizer + humic acid) and C+B+SE (compost + biofertilizer + seaweed extract).

As for chlorophyll content, data showed that all treated plants gave a higher chlorophyll a and b contents than control in the two seasons. In the first season, all treatments gave higher chlorophyll a contents except for C+B treatment, which recorded the least chlorophyll a content, whereas in the second one the full dose of NPK and C+B+Y treatments recorded the highest chlorophyll a content. The highest values of chlorophyll b resulted from full dose of NPK, C+B+Y and C+B+AA treatments in the first season and full dose of NPK and C+B+Y treatments in the second one. The growth-promoting effect of seaweed extracts (*Laminaria saccharina*, *Fucus vesiculosus* and *Ascophyllum nodosum*) may be due largely to the cations present, alginic acid and its salts which were indicated as being the main organic compounds responsible for reducing the effect of the metals with mustard plants. It is suggested that alginic acid competes with the plants by ion-exchange for the metals in the extract (Blunden, 2006 on black mustard).

Chemical composition of fennel seeds:

Chemical composition of fennel seeds presented in Table (6) showed that, C+B+Y treatment gave the highest protein content (28.68%) followed by C+B+S treatment (28.49%). The highest total carbohydrate content was found in control sample (61.43%) compared with C+B+HA treatment which gave the lowest content (51.81%). The results also showed also that C+B+HA treatment gave the highest fiber and ash contents of 15.97 and 11.17%; respectively. Also, from Table (4) it can be resulted that no significant differences were detected in essential oil content between NPK and C+B+Y treatments in the two seasons. Furthermore, C+B+Y treatment gave the highest protein content among all biofertilization treatments, so that it could be chosen for further work. These results were higher than those reported by Moreau *et al.* (1966) and Abou-Zied, (1974). Abou-Raiia *et al.*, (1991) reported that fennel seeds were rich in total carbohydrates (61.0%) and low in total soluble sugars (7.6%).

Minerals content:

Data given in Table (7) show that NPK treatment gave the highest levels of K, P, Ca and Cu; while C+B+Y treatment gave the highest Mg, Fe, Zn and Mn contents compared to control. This may be due to that P, K and Ca are the main constituents of NPK fertilizer which led to increasing plant uptake of these elements. These results are in line with those reported by Özcan and Akbulut (2007) and Özcan *et al.*

(2008). Abou-Raiia *et al.*, (1991) reported that fennel seeds were rich in Ca, P and Mg and contain considerable amounts of K, Fe and Zn.

Table (6): Chemical composition of fennel (*Foeniculum vulgare*) seeds.

Constituents (%)	Fertilization treatments						
	Control	NPK	C+B	C+B+Y	C+B+ AA	C+B+HA	C+B+S
Moisture	11.13ns	11.21	11.01	11.45	11.26	11.48	11.13
Dry matter	88.87ns	88.79	88.99	88.55	88.74	88.52	88.87
Crude protein	23.14e	27.71c	28.04b	28.68a	25.78d	28.29ab	28.49ab
Ether extract	6.26d	8.07b	8.74a	7.04c	7.42c	8.34ab	8.73a
Ash	10.10b	10.30b	9.37c	9.34c	10.22b	11.17a	9.56c
Total carbohydrate	61.43a	53.32d	53.35d	55.33c	56.05b	51.81e	53.65d
-Avail. Carbohy.	54.67a	40.20e	42.32c	41.44d	44.72b	35.84g	39.20f
-Crude fibers	6.76f	13.12d	11.03e	13.89c	11.33e	15.97a	14.45b

Values having the same letter(s) within a row are not significantly different at ($P > 0.05$).

NPK (full dose), C+B (compost + biofertilizer), C+B+Y (compost + biofertilizer + yeast), C+B+AA (compost + biofertilizer + amino acids), C+B+HA (compost + biofertilizer + humic acid) and C+B+SE (compost + biofertilizer + seaweed extract).

Table (7): Effect of fertilizers on minerals content (mg/100g dry weight) of fennel seeds.

Treatments / Minerals	Control	NPK	C+B+Y
K	1.594	2.110	1.720
P	479.0	584.0	513.0
Mg	325.0	388.0	399.0
Ca	1.296	2.940	2.150
Fe	16.94	19.30	20.65
Zn	3.37	3.76	3.95
Cu	1.17	1.82	1.71
Mn	6.63	6.75	6.82

NPK (full dose) and C+B+Y (compost + biofertilizer + yeast).

Fatty acids composition of fennel seed fixed oil:

Fatty acids composition of treated and untreated fennel seeds are shown in Table (8). The data referred that ten saturated and unsaturated fatty acids were identified in fennel seed fixed oil. Total unsaturated

fatty acids recorded about 51.284%. Linoleic acid was the dominant unsaturated fatty acid, which recorded about 44.157% in untreated samples; while, saturated fatty acids recorded 48.716%. Stearic acid was the dominant saturated fatty acid which represented about 36.052% in control samples.

Fertilization led to increasing unsaturated fatty acids especially; oleic acid and decreasing saturated fatty acids. C+B+Y treatment gave the highest level of unsaturated fatty acids (79.543%) and the lowest level of saturated ones (20.457%). Oleic acid was the highest unsaturated acid, which reached about 68.078% followed by linoleic acid (8.769%). Meanwhile, lauric acid was highest saturated fatty acids (8.864%). Samples fertilized with NPK recorded the second level of unsaturated fatty acids (76.762%). Oleic acid was the dominant acid which recorded 66.488% followed by Lauric acid (11.991%) and linoleic acid the third (9.439%) position.

Table (8): Fatty acids composition (% of total fatty acids) of fennel seeds fixed oil.

Treatments / Fatty acids	Control	NPK	C+B+Y
Saturated acids			
Caproic ($C_{6:0}$)	0.969	1.349	0.817
Caprylic ($C_{8:0}$)	0.485	1.119	0.531
Capric ($C_{10:0}$)	0.621	0.214	0.204
Lauric ($C_{12:0}$)	4.073	11.991	8.864
Myristic ($C_{14:0}$)	0.970	0.428	0.694
Palmitic ($C_{16:0}$)	5.546	6.424	7.611
Stearic ($C_{18:0}$)	36.052	1.713	1.736
Total saturated acids	48.716	23.238	20.457
Unsaturated acids			
Palmitoleic ($C_{16:1}$)	1.891	0.835	2.696
Oleic ($C_{18:1}$)	5.236	66.488	68.078
Linoleic ($C_{18:2}$)	44.157	9.439	8.769
Total unsaturated acids	51.284	76.762	79.543
Total fatty acids	100.0	100.0	100.0

NPK (full dose) and C+B+Y (compost + biofertilizer + yeast.

Generally, all treatments led to increasing unsaturated fatty acids especially oleic acid. In this concern, Cosge *et al.* (2008) found that the petroselinic ($C_{18:1\ c6}$), oleic ($C_{18:1\ c9}$), linoleic ($C_{18:2}$), and palmitic ($C_{16:0}$) acids corresponded approximately 97% as the principal fatty acids in sweet fennel seed. Abou-Raiia *et al.,* (1991) reported that the major fatty acid components of fennel seeds are ($C_{18:1}$) (71.31%) and ($C_{18:2}$) (11.66%). Yetim *et al.* (2008) determined fatty acid composition of cold pressed fennel seed oil in Turkey. They found that total unsaturated fatty acids were 93.98% and total saturated fatty acids were 6.01%. Oleic acid was the dominant acid which recorded about 79.49% followed by linoleic acid recording 13.49%.

Chemical constituents of essential oil:

The components identified in the essential oil are listed in Table (9). The essential oils exhibited light yellow color and typical fennel odor. The essential oil yields of control, NPK and C+B+Y samples were 0.44, 1.24 and 1.24 ml/100g seeds; respectively (Table 4). The data cleared also that trans-anethole, carvone, fenchone and methyl chavicol were identified as the highest level main constituents which represented about 83.4, 86.1 and 84.7% of total constituents for control, NPK and C+B+Y treatments; respectively.

α-thujene, camphene, sabinene, α-terpinene, α-terpineol and methyl eugenol were detected in treated samples with high amounts comparing to control. The major components of fennel seed are phenylpropanoid derivates: trans-anethole and methyl chavicol. Other major components of fennel include α-phellandrene, fenchone, and α-pinene (Piccaglia and Marotti, 2001; Diaz-Maroto *et al.,* 2006; Özcan *et al.,* 2006). In this concern, Telci *et al.* (2009) found that the content of trans-anethole, the main component, varied between 81.6 and 87.85%, and the variation was statistically insignificant during maturation stages. Some components, particularly monoterpenes, α-pinene, β-myrcene, limonene, and α-terpinene, varied significantly ($p < 0.05$) during maturation stage. Also, Cosge *et al.* (2008) reported that the ratios of essential oil from sweet and bitter fennels were found similar (average of 3.00%). Trans-anethole, estragole and fenchone were found to be the main constituents in both fennels. The compound with the highest value in the two oil samples was trans-anethole as 95.25% (sweet) and 75.13% (bitter); while estragole was found in bitter fennel oil in a remarkable amount (15.51%), sweet fennel oil contained small amounts of estragole

(2.87%). Fenchone was found <1% in sweet and approximately 5% in bitter fennel. P-anisaldehyde in bitter fennel essential oil, and α-pinene and γ-terpinene in sweet fennel essential oil were not recorded, and these compounds were found very low or <1%.

Table (9): Chemical constituents of fennel (*Foeniculum vulgare*) seed essential oil by GC-MS.

Constituents	Fertilization treatments		
	Control	NPK	C+B+Y
3-Methylbutanal	0.1	Tr	0.1
α-Thujone	Tr	0.1	0.2
α-Pinene	0.2	0.2	0.2
Camphene	Tr	0.2	0.1
Sabinene	Tr	0.1	0.1
β-Pinene	0.2	0.3	0.3
Myrcene	0.1	0.2	0.1
Δ-3-Carene	0.1	Tr	0.2
α -Terpinene	Tr	0.1	0.1
p-Cymene	3.1	3.3	3.1
Limonene	3.1	3.5	3.5
1,8-Cineole	0.1	Tr	0.1
Trans- β -Ocimene	0.1	0.1	Tr
γ-Terpinene	2.1	2.2	2.0
Fenchone	8.6	8.9	9.0
Linalool	1.2	1.0	1.1
Camphene	0.3	0.3	0.2
Carvone	30.0	31.0	28.7
β-Terpineol	Tr	Tr	0.2
Terpinen-4-ol	0.2	0.1	Tr
α -Terpineol	Tr	0.1	0.2
Methyl chavicol	4.7	5.1	5.0
Fenchyl acetate	0.2	0.2	0.3
Cuminal	0.4	0.2	0.1
cis-Anethole	0.4	0.5	0.4
p-Anisaldehyde	0.5	Tr	0.5
trans-Anethole	40.1	41.1	42.0
Thymol	0.1	0.1	0.2
Methyl eugenol	Tr	0.1	0.3
α -Copaene	0.2	0.2	0.2
β-Caryophyllene	0.2	0.3	0.2
Total	96.3	99.5	98.7

Trace = 0.01%.
NPK (full dose) and C+B+Y (compost + biofertilizer + yeast).

Protein quality of fennel seeds:

A- Amino acids composition:

The amino acid requirements are the logical yard-sticks by which protein quality can be estimated and the relative quantities of the various amino acids, in particular the essential amino acids, in the food could be used as reliable estimators of actual protein quality (Alsmeyer *et al.*, 1974).

Amino acids composition of fennel seed samples (control, NPK and C+B+Y) and casein are presented in Table (10). It could be observed that, NPK treatment contained the highest amount of all indispensable amino acids compared with those of other samples.

Table (10): Amino acids composition (g amino acid/100g protein) of fennel (*Foeniculum vulgare*) seeds.

Amino acids	Control	NPK	C+B+Y	Casein
Indispensable A. A				
Valine	5.44	5.70	5.63	5.42
Leucine	6.15	7.10	6.25	9.00
Isoleucine	4.21	4.66	4.38	5.01
Phenyl alanine	3.80	4.28	3.75	4.47
Threonine	3.54	3.88	3.75	3.43
Methionine	1.88	2.00	1.88	2.96
Lysine	4.77	6.10	5.00	7.51
Total indispensable A. A.	29.79	33.72	30.64	37.80
Dispensible A. A.				
Aspartic acid	8.42	11.78	11.25	5.97
Glutamic acid	15.21	18.50	18.75	17.53
Serine	5.11	5.66	5.63	5.59
Proline	5.50	5.81	5.63	5.92
Glycine	6.68	6.11	6.88	1.72
Alanine	5.01	5.00	5.00	2.65
Cystine	1.13	1.34	1.25	0.30
Tyrosine	2.13	2.73	2.50	4.97
Arginine	4.22	4.35	4.38	4.22
Histidine	1.64	2.11	1.88	2.63
Total dispensable A. A.	55.05	63.39	63.15	51.50
Total amino acids	84.84	97.11	93.79	89.30

NPK (full dose) and C+B+Y (compost + biofertilizer + yeast).

On the other hand, standard casein protein was the highest among all of others. Also, it could be concluded that control samples contained the lowest amount of total amino acids compared with those of others. All samples and casein contained more amounts of dispensable amino acids (51.50 to 63.39%) than indispensable amino acids (29.79 to 37.80%). In this respects, Abou-Raiia *et al.,* (1991) reported that fennel seeds contained high amounts of isoleucine and histidine.

The nutritive value of any protein depends primarily on its capacity to satisfy the needs of indispensable amino acids for human being. Thus, the amino acid requirements are the logical factors by which protein quality can be measured (Bhushan, 1991).

B- Amino acids score (AAS):

The amino acids score can be considered as an imperfect indicator of protein quality, but it is still the best one based on amino acids composition (Pellett and Young, 1980).

The amino acids score of the indispensable amino acids sample and casein are given in Table (11). The results revealed that, casein had more amino acids score of the indispensable amino acids than other samples. Furthermore, NPK treatment contained the highest amount of amino acid scores of the indispensable amino acids compared with those of other treatments. The lowest amino acids score were found in control. First limiting amino acid score was recorded for (methionine + cystine). NPK treatment markedly increased the amino acids score of samples.

Table (11): Chemical scoring*, computed protein efficiency ratio (C-PER) and biological value (BV) of fennel seed protein.

Indispensable A.A	Control	NPK	C+B+Y	Casein	FAO/WHO pattern (g/16g N)
Leucine	87.86	101.43	89.29	128.57	7.0
Isoleucine	105.25	116.50	109.50	125.25	4.0
Lysine	86.73	110.91	90.91	136.55	5.5
Methionine+cystine	86.00	95.43	89.43	93.14	3.5
Phenylalanine+tyrosine	98.83	116.83	104.17	154.33	6.0
Threonine	88.50	97.00	93.75	85.75	4.0
Valine	108.80	114.00	112.60	108.40	5.0
C-PER	2.13	2.46	1.91	2.52	
BV	72.33	75.80	70.01	76.42	

Chemical scoring* was calculated as a percentage of the FAO/WHO (1985) recommended amino acids. BV= 49.9 + 10.53 (C-PER). NPK (full dose) and C+B+Y (compost + biofertilizer + yeast).

C- The computed protein efficiency ratio (C-PER):

The computed protein efficiency ratio (C-PER) of different samples were lower than that of standard casein protein (C-PER = 2.52) as given in Table (11). The lowest C-PER value was recorded for control (2.13), while the highest one was recorded for NPK treatment (2.46). Generally, NPK treatment increased the C-PER of the samples.

D- Biological value (BV):

The biological values of protein for different samples are shown in Table (11). Biological values are very useful parameter for evaluating the effect of processing on food protein quality (Abd Alla, 1981). The results revealed that, the NPK treatment showed the highest biological value compared with other samples. These results may be related to the (C-PER) which was higher in NPK treatment than other samples.

Organoleptic evaluation of bread sticks:

Data in Table (12) show organoleptic evaluation of bread sticks prepared from wheat flour substituted with three concentrations of fennel powder, which was fertilized with NPK and C+B+Y compared with control. Data revealed that color and texture of control samples were higher than those of substituted samples either fertilized with NPK or C+B+Y. On contrary, taste and odor of bread sticks substituted with fennel seeds powder either fertilized with NPK or C+B+Y were better than those of control.

Table (12): Organoleptic properties of bread sticks prepared from wheat flour substituted with different levels of chemical (NPK) and biofertilizers (C+B+Y) fennel seeds.

Attrib. / Treat.	Color	Taste	Odor	Texture	Overall acceptability
Control	9.3a	8.7b	8.6b	9.2a	9.0a
NPK					
5%	8.4b	9.2a	9.1a	8.3b	8.8abc
10%	7.5c	9.5a	9.4a	7.8c	8.6abc
15%	6.7d	9.5a	9.4a	6.9d	8.1d
C+B+Y					
5%	8.5b	9.4a	9.0a	8.5b	8.9ab
10%	7.7c	9.2a	9.3a	7.5c	8.4cd
15%	6.5d	9.2a	9.4a	6.7d	8.0d

Values are means of values. Values having the same letter(s) within a column are not significantly different at ($P > 0.05$). NPK (full dose) and C+B+Y (compost + biofertilizer + yeast).

Generally, color and texture decreased as substitution of NPK increased; while taste and odor were not affected as a function of increasing substitution percents. Also, no significant differences were found between samples substituted with fennel seeds powder either fertilized with NPK or C+B+Y at all characters. Also, bread sticks substituted with 5% fennel seed powder had similar overall acceptability compared with control samples and good acceptance for taste and odor.

In conclusion, the combined application of yeast, amino acids, humic acid or seaweed extract with compost and efficient biofertilizers could be integrated treatment and safe substitutes to be applied in fennel production to get a yield of good quantity and quality, in addition to keep the environment clean. Fennel seeds are considered as a good source for protein, unsaturated fatty acids and essential oil. Fennel seed powder can be used as food supplements in bakery products.

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الملخص العربي

إنتاج وتقييم الشمر المزروع باستخدام الأسمدة الطبيعية.

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[3]معهد بحوث تكنولوجيا الأغذية – مركز البحوث الزراعية – الجيزة – مصر.

أجرى هذا البحث خلال موسمي ٢٠٠٦/٢٠٠٧ ، ٢٠٠٧/٢٠٠٨م بكلية الزراعة جامعة كفرالشيخ – مصر. لدراسة تأثير كل من السماد الحيوي والعضوي والكيماوي على النمو الخضري ومحصول البذرة وإنتاجية الزيت العطري والتركيب الكيماوي والقيمة الغذائية لنبات الشمر وقد أوضحت النتائج أن:

– النباتات المسمدة بالكمبوست+السماد الحيوي مخلوطا مع كل من الخميرة أو الأحماض الامينية أو حمض الهيوميك أو مستخلص الحشائش البحرية قد أعطت نتائج كانت فئ معظم الأحيان متوازية وأحيانا أخرى تفوقت على الجرعة الكاملة من السماد الكيماوي (NPK) للصفات التي تم قياسها خلال الموسمين. حيث شملت الصفات المقاسه كل من صفات النمو مثل ارتفاع النبات ، عدد الأفرع للنبات ، عدد النورات للنبات ، وزن النورات للنبات وللفدان ، الوزن الطازج والجاف للنبات. كذلك صفات البذور والزيت العطري مثل وزن ١٠٠ ثمرة ، محصول البذور للنبات والفدان ، نسبة الزيت العطري ، محصول الزيت العطري للنبات والفدان وكذلك محتوى النبات من كل من النيتروجين والفوسفور والبوتاسيوم وكلوروفيل أ ، ب في العشب.

– أعطت المعاملة بالكومبوست + السماد الحيوي + الخميرة (C+B+Y) أعلى محتوى للبذرة مقارنه بباقي المعاملات. علاوة على ذلك لم توجد فروق معنوية في نسبة الزيت العطري بين الجرعة الكاملة من السماد الكيماوي (NPK)،معاملة الكومبوست + السماد الحيوي + الخميرة (C+B+Y) خلال الموسمين لذلك تم اختيارها لدراسة خواصها التغذوية.

– أدى التسميد إلى زيادة الأحماض الدهنية غير المشبعة خاصة حمض الأوليك مع انخفاض الأحماض الدهنية المشبعة. وقد أعطت المعاملة بالكومبوست + السماد الحيوي + الخميرة (C+B+Y) أعلى مستوى من الأحماض الدهنية المشبعة يليها المعاملة بالجرعة الكاملة من السماد الكيماوي (NPK).

– وجد أن مركبات trans-anethole ، carvone ، fenchone ، methyl chavicol تمثل المركبات الرئيسية في الزيت العطري للشمر حيث بلغت نسبتها ٨٣,٤ ، ٨٦,١ ، ٨٤,٧% من المكونات الكلية لكل من الكنترول ، الجرعة الكاملة من السماد الكيماوي (NPK) ، الكومبوست + السماد الحيوي + الخميرة (C+B+Y) على الترتيب.

– كما أظهرت النتائج أن الجرعة الكاملة من السماد الكيماوي (NPK) قد أدت إلى زيادة الأحماض الامينية الأساسية للبروتين مقارنة بالمعاملات الأخرى. كذلك أعطت هذه المعاملة أعلى قيمة للرقم الكيماوي للأحماض الامينية الأساسية وكان الحامض الامينى المحدد الأول (المثيونين+السيستين). كما أدت أيضا إلى زيادة نسبة كفاءة البروتين وكذلك القيمة الحيوية للبروتين مقارنه بباقي المعاملات.

– كما اظهر التقييم الحسي للبقسماط المصنع أن استبدال ٥% من دقيق القمح بمطحون الشمر المعامل بالجرعة الكاملة من السماد الكيماوي (NPK) أو الكومبوست + السماد الحيوي + الخميرة (C+B+Y) قد أعطى قبولا عاما مشابها للكنترول وكان مقبولا جيدا بالنسبة للطعم والرائحة.