

Antioxidant Activity and *in vitro* Fermentation of Dietary Fiber Extracts from Durum Wheat Bran

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Abstract The aim of this paper was to select a dietary fiber of durum wheat bran among several types which have different functional and nutritional characteristics. The potential of antioxidant activity of soluble (SDF) and insoluble (IDF) dietary fiber has been evaluated. The suspensions were later fermented by *Bifidobacterium* and lactic acid bacteria strains to evaluate the effect of these fibers on the growth of these strains of bacteria. Wheat bran was hydrolysed *in vitro* using gastric and pancreatic enzymes. The soluble and insoluble fibers were obtained by precipitation with ethanol. All the bran extracts exhibited appreciable total phenolic content (1.50 ± 0.095 – 1.02 ± 0.25 mg gallic acid equivalent/g bran), total flavonoid content (Quercetin equivalent 0.52 ± 0.012 – 0.46 ± 0.19 mg/g bran) and DPPH radical cation scavenging activity (IC_{50} 1.48 ± 0.34 – 3.6 ± 0.18 mg/g). Insoluble dietary fiber exhibited high antioxidant potential and significantly more than soluble dietary fiber. Among the four probiotic strains tested, *Lactobacillus acidophilus* showed in IDF media a higher maximum growth. For most of the tested strains, growth on the SDF was less than on IDF ($p < 0.05$).

Keywords: antioxidant activity, dietary fiber, durum wheat, fermentation, phenol compounds

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1. Introduction

Epidemiological studies have strongly suggested that diets rich in cereals play a crucial role in the prevention of chronic diseases such as cardiovascular disease and certain types of cancer [9]. The beneficial health effects occurred due to the intake of diets rich in cereals have mainly been ascribed to dietary fiber or to some of the components associated with the fiber including phenolic acids [15]. Dietary fiber comprises a group of low-calorie carbohydrates which have chemical structure that cannot be digested by human gastric intestinal tract due to the lack of the digestive enzymes needed for its hydrolysis. These low-calorie carbohydrates that can be found in dietary fiber (DF) include cellulose, lignin, hemicellulose, pectins, gums and other polysaccharides associated to plant. It is conventionally classified in two categories according to their water solubility: (i) insoluble dietary fiber (IDF) (cellulose, part of hemicellulose and lignin) and (ii) soluble dietary fiber (SDF) (pentosans, pectins, gums, mucilage) [16].

Oxidative stress has been defined as a disturbance to the equilibrium status of pro-oxidant and antioxidant systems due to the excess formation of free radicals and decrease the activity of antioxidant defense systems. Excess reactive oxygen species (ROS) are toxic as they can attack and damage cellular constituents such as DNA, proteins, carbohydrate, nucleic acid, and membrane lipids,

leading to cell death and tissue injury [12]. Therefore, oxidative stress was implicated in several chronic diseases including cancer, diabetes, Alzheimer's disease, coronary heart diseases, and aging [6]. Some studies suggested that dietary antioxidants may reduce the risks of these diseases and improve general human health [45].

Supplementation with additional amounts of natural antioxidants or use of synthetic low molecular weight antioxidant molecules at an appropriate concentration may offer a relatively simple and effective way to control oxidative stress [11]. Phenolic antioxidants are reported to be able to quench the oxygen derived free radicals as well as substrate-derived free radicals by donating a hydrogen atom or an electron to a free radical, protect cell constituents against oxidative damage and, therefore, limit the risk of various diseases associated to oxidative stress [3].

Several investigations have been conducted to study antioxidant properties of wheat and wheat bran [22]. It is widely accepted that phenolic compounds, including ferulic, vanillic, p-coumaric, caffeic, and chlorogenic acids, are rich in the bran portion of cereal kernels and may contribute to the total antioxidant activities of wheat [32]. Among these phenolic compounds, ferulic acid (FA) is the predominated phenolic acid and ester-linked to the arabinose residues in wheat bran cell wall arabinoxylan [16]. Feruloyl oligosaccharides (FOS) can be released from wheat bran either by mild acid hydrolysis or by treatment with a mixture of polysaccharide hydrolysing enzymes, such as fungal hydrolases [42].

Interestingly, in vitro studies, FOS were found to be more effective antioxidants towards low density lipoproteins (LDL) oxidation and DPPH free radical scavengers than the free ferulic acid [20]. The importance of 'dietary fiber-antioxidant compounds' complex has been recently emphasized by some researchers [10,25]. Increasing the amount of dietary fibers (prebiotic) or antioxidant compounds in food has also come into prominence [1].

Prebiotic fermentation in the large bowel affects microbial activity and leads to production of short-chain fatty acids (SCFA). Acetate, propionate and butyrate are the major SCFA liberated due to carbohydrate fermentation which play a significant role in physiological level [26]. Prebiotics are food components that escape hydrolytic/enzymatic digestion, are fermented by colonic bacteria, and selectively stimulate growth and/or activity of bacteria (eg, *Lactobacillus* and *Bifidobacterium* spp.) that benefit colon and host health [41].

Wheat bran is a rich renewable biomass but still insufficiently used. The aim of the present study was to determine the phenolic content and the antioxidant activity of the soluble and insoluble dietary fiber extracted from wheat bran fractions as well as the ability of beneficial bacteria to grow in these substrates. These investigations may play a key role in recommending varieties for dietary and industrial purposes, since dietary sources of antioxidants have got special attention due to their role in prevention of coronary heart diseases and cancer. Characterization of extract bran may provide useful information for its potential in nutraceuticals and functional foods.

2. Materials and Methods

2.1. Materials

Wheat bran used for the present study was obtained from Flour Milling Metidji, Mostaganem, Algeria. The bran used corresponds to the entire outer envelope of hard wheat grains (*Triticum durum*). Wheat bran was milled and passed through a 0.05 mm sieve. α -amylase Termamyl (E.C. 3.2.1.1 from porcine pancreas 30U/mg; product code A3176), protease (E.C. 3.4.21.62; from *Bacillus licheniformis* 9U/mg; product code A3403), amyloglucosidase (E.C. 3.2.1.3; from *Aspergillus niger* 70U/mg; product code A7420) were purchased from Sigma Chemical Company, MO, USA. All other chemicals and solvents were of analytical grade.

2.2. Isolation of Soluble (SDF) and Insoluble Dietary Fiber (IDF) from Wheat Bran

Soluble and insoluble fibers of bran fractions were obtained by hydrolyzing the samples with α -amylase and amyloglucosidase as developed by Prosky et al. [33], with minor modifications. Wheat bran (100 g) was autoclaved for 45 min at 121°C in order to destroy endogenous enzymatic activities [47] and subsequently swollen at 60°C for 6 h in water (1 L) with continuous stirring. Then, α -amylase (7.5 mL) was added in the suspension. Beakers with 1 L wheat bran suspension were heated in a boiling water bath for 40 min and shaken gently every 5 min. The pH was adjusted to 7.5 with 275 mM NaOH, and the

samples were incubated with protease (3.0 mL) at 60°C for 30 min with continuous mild agitation. After the pH had been adjusted to 4.5 with 325 mM HCl, amyloglucosidase (3.5 mL) was added and the mixture was incubated at 60°C for 30 min with continuous mild agitation. The suspension was centrifuged (10,000g, 10 min). The supernatant was precipitated with 4 volumes of ethanol (95% V/V) for 1 h to separate the soluble fiber, whereas the residue was collected as insoluble fiber [16]. The supernatant was filtered and dried at 103°C. The residue was stirred in hot distilled water, washed repeatedly with large volumes of hot water, and then washed with cold distilled water. Finally, the residue was washed twice with hot distilled water, 95% (v/v) ethanol and acetone, respectively and then dried at 40°C overnight in a vacuum oven. 1 g of insoluble fiber was suspended in 1 mL of methanol; after centrifugation for 10 min at 2500 g, the supernatant was used as IDF.

2.3. Total Phenolic Content

The Folin-Ciocalteu reagent was used to determine the total phenolic content according to the method of Singleton et al. [38]. 0.5 mL of sample extract (soluble or insoluble fibers) was mixed with 0.5 mL of Folin-Ciocalteu reagent and 0.5 mL of 10% (w/v) sodium carbonate was added. After incubation for 60 min at room temperature in the dark, the absorbance was measured at 760 nm using Jenway-6715 Spectrophotometer (England). Gallic acid as an external standard was used ($R^2 = 0.999$). The phenolic contents were expressed as gram of gallic acid equivalent (GAE).

2.4. Flavonoid Content

The flavonoid content of the plant extracts was determined using the $AlCl_3$ method Woisky & Salatino [43]. 2 mL of sample solution (soluble or insoluble fiber) was mixed with 2 mL of 2% aluminum chloride methanolic solution. The absorbance of mixture was measured at 430 nm after 30 min of incubation at room temperature. The flavonoid content was expressed as gram of quercetin equivalent (QE).

2.5. DPPH Scavenging Activity

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging capacities of wheat bran extracts were estimated by the reduction of the reaction color between DPPH solution and sample extracts as previously described by Arnous et al. [2] with some modifications.

A final concentration of DPPH solution used was 60 μ M. 3.9 mL solution of DPPH was mixed with soluble (SDF) and insoluble (IDF) sample extract (0.1 mL) at different concentrations or methanol as negative control. The mixture was kept in the dark at ambient temperature and then read at 517 nm with a blank contain only DPPH solution and methanol. Antioxidant activity was expressed as percentage DPPH scavenging relative to control using the following equation:

$$\text{DPPH scavenging activity (\%)} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample})}{\text{Absorbance of control}} \times 100.$$

2.6. In Vitro Fermentation of Dietary Fiber

2.6.1. Microorganisms and Inoculas

Lactobacillus acidophilus LbA-CECT4529 (Complutense university, Madrid, Spanish); *L.rhamnosus* LBRE-LSAS (Abdelhamid Ibn Badis uni-versity, Mostaganem, Algeria); *Bifidobacterium animalis subsp lactis* Bb12 and *B. bifidum* Bb 443 (Chr-Hansen, laboratory, Danmark) were used for this study. The *Lactobacillus* and *Bifidobacterium* cultures were stored at -80°C in MRS broth (Difco laboratories sparks, MD, USA) containing 15% (w/v) glycerol. *B. bifidum* Bb 443 required 0.05% L-cysteine HCl for growth in MRS medium. The inoculums were prepared by transferring glycerol stock culture (100 μl) of each strain in 10 mL of liquid MRS medium for preculture and were subsequently incubated at 37°C for 24h in anaerobic conditions.

2.6.2. Basal media and Fermentation Procedures

500 mL of media were prepared using distilled water containing 2% peptone, 2% yeast extract and the 10% (v/v) of soluble (supernatant) or 10% (w/v) insoluble fiber (residue) separated before. The pH of the media were adjusted to 6.5 and media were sterilized at 121°C for 15 min. Bottles were inoculated with a 1% (v/v) of lactic acid bacteria and incubated at 37°C for 30 h. Growth of each strain was monitored by measuring pH and the optical density (OD) of the cultures at 0, 3, 6, 9, 12, 24 and 30h at 600 nm of appropriate dilutions of cells. The centrifuged fermented media (10min, $5000\times g$) were stored at -20°C for later analysis. All fermentations were carried out in duplicate.

2.6.3. Gas Chromatography–mass Spectrometry (GC–MS)

The culture supernatant was acidified with 50% sulphuric acid and extracted with diethyl ether [13] and analysed for short chain fatty acid (SCFA) by GC–MS analysis was carried out with an Perkin Elmer clarus 500 N Series gas chromatograph (Fison Instruments, Italy) coupled to an MD 800 Series mass-selective spectrometer by maintaining, capillary column injector (30 m x 0.25 mm) and detector temperatures at 120, 220 and 230°C , respectively [18] using helium as the carrier gas (3 mL/min). Acetate, propionate and butyrate (10 μmol each/mL in diethyl ether) were used as standards. Quantity of individual SCFA in the sample was estimated by using peak area standard curve.

2.7. Statistical Analysis

The data obtained in this study were expressed as the mean of triplicate determinations. Analysis of variance (ANOVA) was employed to analyze the results. P values <0.05 were considered to be significant.

3. Results

3.1. Yield of Fiber in Durum Wheat Bran

The amount of soluble fiber (SDF) and insoluble fiber (IDF) has been determined according to the gravimetric enzymatic method as previously described [33]. The fiber composition of wheat bran was found to be contain IDF ($0.325 \pm 0.37\text{g/g}$ fresh material) and SDF ($0.025 \pm 0.29\text{g/g}$ fresh material). Our data about SDF and IDF content of durum wheat bran are similar to those reported in the literature [8].

3.2. Total Phenolic Content (TPC)

The assessment of phenolic contents in different samples is influenced by the polarity of extracting solvents and the solubility of these compounds in the solvent used for the extraction process [39]. Therefore, it is hard to select an appropriate solvent for the extraction of phenolic contents from all samples. The content of total phenols in bran extracts were determined using the Folin–Ciocalteu assay, expressed as gallic acid equivalent (GAE). Table 1 illustrates that significant differences ($p < 0.05$) in total phenols contents were observed. The results also showed that the total phenolic compounds varied greatly among different extracts. From the same table it is clear that the insoluble fiber contained higher amount of phenols than the soluble extract ($1.50 \pm 0.095\text{ mg/g}$ of GAE, $1.02 \pm 0.27\text{ mg/g}$ of GAE for insoluble and soluble respectively).

3.3. Total Flavonoid Content (TFC)

Flavonoids are common secondary metabolites presented in plants [5]. Total flavonoids content of wheat bran extracts samples was analyzed by AlCl_3 method with quercetin as standard. In this study, Total flavonoids content varied in soluble fiber SDF and insoluble fiber IDF extracts, where it ranged from 0.52 ± 0.012 to $0.46 \pm 0.119\text{ mg EQ/g}$ in soluble and insoluble fibers extract respectively. It is obvious that, SDF showed general higher content of total flavonoid than IP ($p \geq 0.05$) (Table 1).

Table 1. TPC, TFC, and IC_{50} values of DPPH of IDF and SDF extract from wheat bran.

Extract	TPC (mg GAE/g DW)	TFC (mg QE/g DW)	IC_{50} (mg/mL)
IDF	1.50 ± 0.095	0.46 ± 0.119	1.482 ± 0.34
SDF	1.02 ± 0.25	0.52 ± 0.012	3.585 ± 0.18

3.4. DPPH Scavenging Activity

The DPPH method is commonly used for determination of free radical scavenging activity of antioxidants. DPPH (1,1-diphenyl-2-picrylhydrazyl) is a very stable organic free radical compound and presents the ability of accepting an electron or hydrogen radical. The capacity of soluble and insoluble fibers extracts from durum wheat bran to scavenge the stable DPPH radical is shown in

Figure 1. The IC_{50} value is defined as the concentration of the sample at which the inhibition rate reaches at 50% and is expressed in mg/mL. Table 1 shows a comparison of the IC_{50} values. The dietary fibers extracts showed a high antioxidant activity for DPPH assay. For both IDF and SDF extracts from bran samples showed strong DPPH free radical scavenging activities (21.93 ± 0.47 – $93.02 \pm 0.62\%$ and 10.71 ± 0.12 – $86.78 \pm 1.25\%$, respectively), concentration were within the range of 0.1 to over 100 mg/mL (Figure 1). Insoluble fiber showed higher antioxidant activity than

soluble fiber ($P < 0.05$), that is manifested by low values of IC_{50} where the values of IC_{50} ranges from 1.48 ± 0.31 to 3.58 ± 0.15 mg/mL for soluble and insoluble fibers respectively.

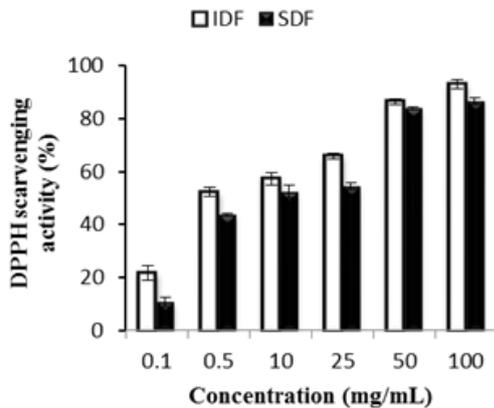


Figure 1. Antioxidant activity of soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) of durum wheat bran

3.5. Growth of Lactobacillus and Bifidobacterium Strains in Insoluble Dietary Fiber

The increases in cell densities for two strains of *Lactobacillus* and two strains of *Bifidobacterium* after 30h

of growing in presence of 10% (w/v) of insoluble fiber (IDF) of wheat bran are shown in Figure 2. A lag phase was not observed in any of the cultures, which grow exponentially after 2 h of inoculation. The maximum cell concentration was reached after approximately 12 h in all cases. *Lb. acidophilus* LbA CECT 4529 maximum growth (Table 2) was registered after 30 h in IDF. Similar growth was observed in the presence of *Lb. rhamnosus* (LBRE-LSAS) and *B. animalis lactis* (Bb12) with optical density ranges from 4.49 to 3.96 respectively. The lower growth rate was observed for *B.bifidum* Bb.443.

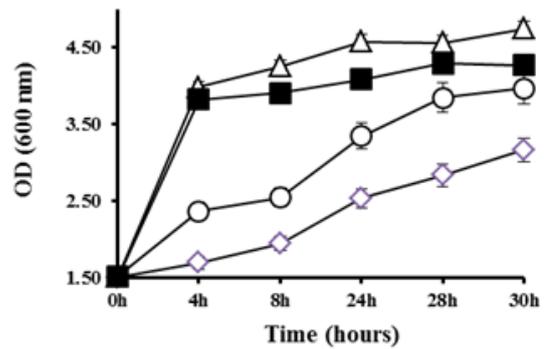


Figure 2. Growth of Lactobacillus and Bifidobacterium strains (Δ *Lb. Acidophilus*, ■ *Lb rhamnosus*, ○ *B. animalis lactis*, ◆ *B. bifidum*) in insoluble fiber of wheat bran

Table 2. Growth characteristics of *Lactobacillus* and *Bifidobacterium* strains in IDF or SDF of wheat bran

Microorganism	Dietary fibre	Absorbance at 600 nm (30h)	pH (30h)	SCFA identified (%)		
				Acetate	Propionate	Butyrate
Control	IDF	1.50 ± 0.02	6.50 ± 0.01	-	-	-
	SDF	0.59 ± 0.49	6.50 ± 0.01	-	-	-
LbA-CECT 4529	IDF	4.74 ± 0.31	4.45 ± 0.10	84.72	10.41	4.86
	SDF	1.78 ± 0.5	5.26 ± 0.15	82.25	12.09	5.64
LBRE-LSAS	IDF	4.26 ± 0.36	4.55 ± 0.46	90.97	9.02	-
	SDF	1.95 ± 0.19	5.41 ± 0.46	83.45	16.54	-
Bb12	IDF	3.96 ± 0.65	4.98 ± 0.23	74.76	13.55	11.68
	SDF	1.35 ± 0.14	5.80 ± 0.11	100	-	-
Bb. 443	IDF	3.16 ± 0.69	5.79 ± 0.12	100	-	-
	SDF	1.73 ± 0.49	5.34 ± 0.14	89	10.99	-

Reported values were corrected for the blank tube values. Control is media with IDF or SDF and without microorganism inoculation.

3.6. Growth of Lactobacillus and Bifidobacterium Strains in Soluble Dietary Fiber

Figure 3 showed the results obtained for soluble fiber (10% v/v) of wheat bran. Comparatively, growth of all strains was much lower in these media. Approximately after 2 h of incubation, exponential growth was observed for *Lb. rhamnosus* (LBRE-LSAS) in SDF. A lag phase of approximately 4 h was noted in soluble fiber of wheat bran media and there was no significant growth of all the strains. For most of the tested strains, the growth (as OD) on the SDF was significantly lower ($p < 0.05$) than on IDF. The maximum cell concentration of *Lb.rhamnosus* LBRE-LSAS growth (OD of 2) was registered after 24 h in SDF. The growth of all strains was limited, especially for *B. animalis lactis* Bb12 where it was not possible to use the SDF carbohydrates.

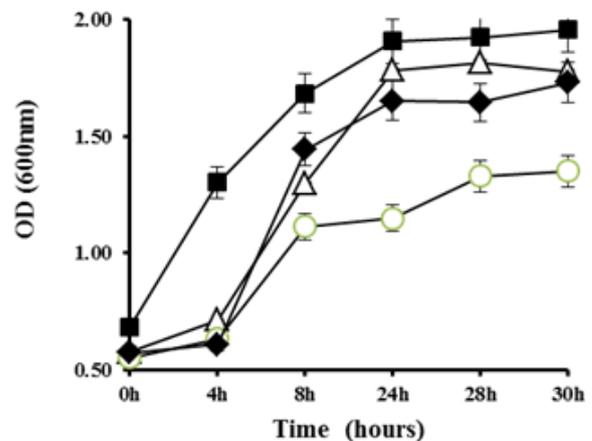


Figure 3. Growth of Lactobacillus and Bifidobacterium strains (Δ *Lb. Acidophilus*, ■ *Lb rhamnosus*, ○ *B. animalis lactis*, ◆ *B. bifidum*) in soluble fiber of wheat bran

3.7. SCFA Production

The decrease of culture pH, which is a result of short-chain fatty acids (SCFA) production by certain bacterial species, has often been used as broad index of the fermentability of various carbohydrates in pure culture. The bacteria produced SCFA in different proportions in all the culture tubes inoculated with dietary fiber as carbon source. The amount of total SCFA produced varied for individual soluble or insoluble dietary fiber. The data is

shown in Table 2. The principal SCFA was acetate with an amount varied from 74% to 100% (Table 2). Acetate, propionate and butyrate acid were found as dominant components in total SCFA during fermentation of soluble and insoluble dietary fiber of wheat bran (Table 2, Figure 4). The higher SCFA concentration produced was demonstrated in IDF medium inoculated by lactic bacteria LbA CECT 4529 strain comparing to all the culture tubes in IDF or SDF ($P < 0.05$) and it produces three acids which is butyric acid was the minor SCFA.

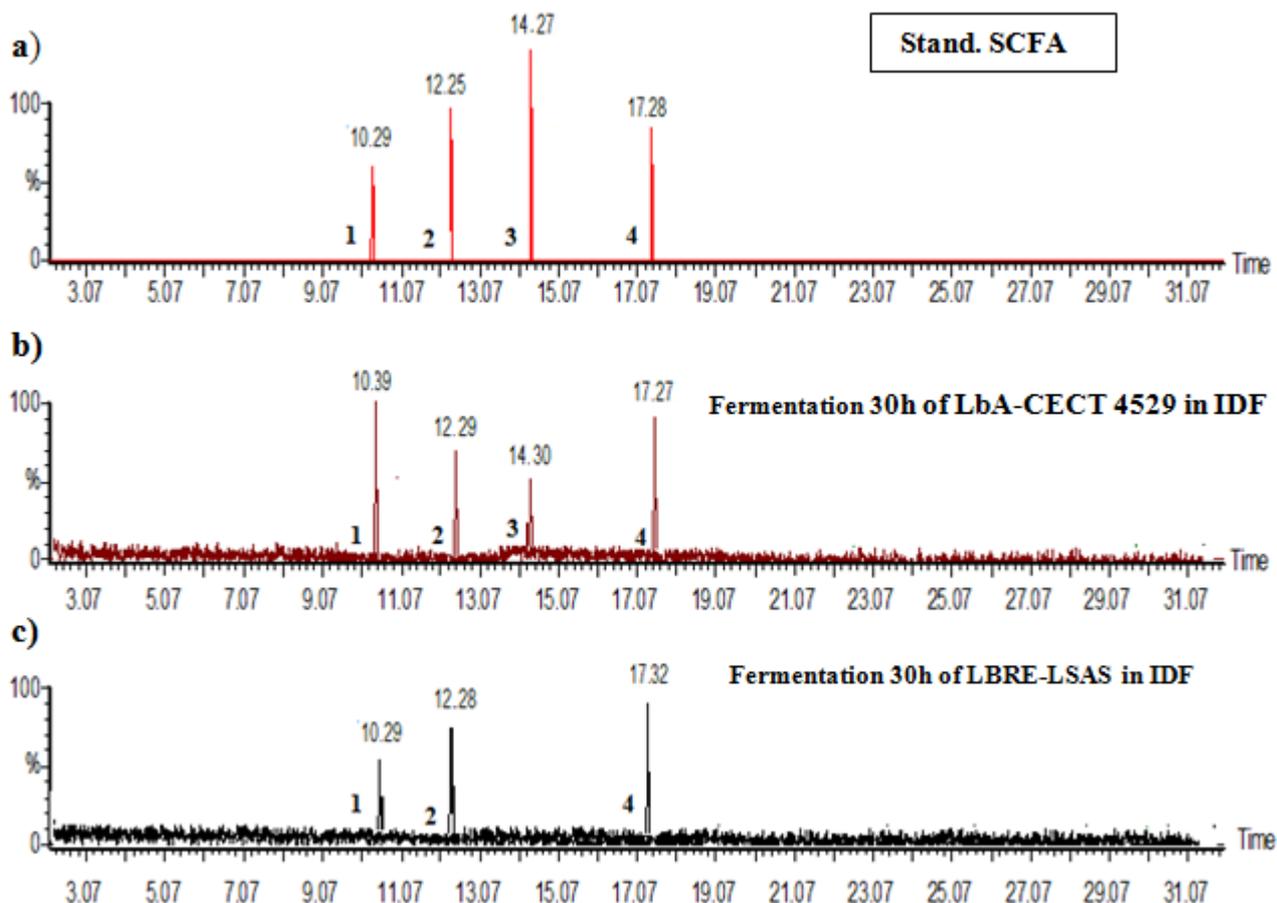


Figure 4. Gas chromatograms of SCFA in standrad solution (a), Insoluble dietary fiber IDF (b,c). Peak followed by the order : 1, acetate ; 2, propionate ; 3, butyrate ; 4 : methylvalerate as an internal standard

4. Discussion

The aim of the present study is to investigate the antioxidant activity and fermentation beneficial bacteria of different dietary fibers extracted from wheat bran via enzymatic hydrolysis including IDF (insoluble dietary fiber, residue) and SDF (soluble dietary fiber, supernatant). It was found that the IDF compounds from wheat bran had a higher antioxidant capacity than those of SDF wheat bran. It is thought that the physical structure of the wheat bran affects its antioxidant capacity. It has been found that the increase in the antioxidant capacity was significantly correlated with the decrease of the standard particle sizes [35]. Cereals and their content of wheat are considered particularly rich in polyphenols products including phenolic acids. In fact, they are extracted from the cell walls by alkaline hydrolysis (insoluble phenolic related walls) [30]. The results of the assessment of polyphenols and flavonoids obtained in this study are similar to those

obtained by other authors on durum wheat [19,36]. However, the study achieved by Kyung et al. [17] on durum revealed higher amount of the total polyphenol content of 3.3 to 3.9 mg EAG /g. Our results agree with those reported by Kim et al. [21] which confirmed that the insoluble extract of wheat bran is rich in phenolic content (2,027mg EAG /g) compared to the soluble extract (0.0039 and 2.027 EAG mg /g). Similarly, Boutigny [4] showed that wheats bran from different regions contain between 0.0045 to 0.096 mg EAG/g and 1699-3161 mg EAG/g for soluble and insoluble polyphenols respectively. It was difficult to compare the results obtained in this study with those of previous studies because of the range of environmental factors, wheat cultivars used, varying testing methods and extraction solvents [48]. Although the use of only one solvent may be favored, the solubility of individual phenolic compounds varies and the results may not be representative of the true phenolic content of a wheat cultivar. As well, the solvents are unlikely to remove the insoluble bound phenolic compounds, so the

antioxidant capacity of this dominant portion of phenols will be significantly underestimated [23,37]. Environment and genotype are also strong factors [27], so even comparisons of the phenolic contents of the same wheat cultivar grown in different locations, or years, become difficult to evaluate.

By investigating the relationship between the levels of total polyphenols and flavonoids and total antioxidant capacity of different extracts of wheat bran, it is found that the results show that there is a low correlation between flavonoid content and total antioxidant capacity. In contrast, the reducing activity is strongly linked to the total polyphenol content with $R^2 = 0.974$. IDF has highest antioxidant than SDF, the synergist substance (IDF and SDF) enhanced the antioxidant activity.

By the comparison of the antioxidant effect of our extracts of wheat bran with those of barley bran [46], it is indicated that the extract of insoluble wheat bran is more active ($IC_{50} = 1.48 \pm 0.31$ mg /mL) than the extracts of barley bran with an IC_{50} of 1.77 ± 0.22 mg /mL. Several factors affect the antioxidant potential and the reduction kinetics, including the conditions of the reaction (time report antioxidant / DPPH, solvent type, pH) and the phenolic content profile [31]. Ferulic acid is the major phenolic acid in the particle of wheat forming 72% of the total phenolic pool and has the essential effect of the antioxidant activity of wheat bran [24]. Other antioxidant compounds present in wheat bran are: sinapic acid, r-coumaric acid, vanillic acid, and caffeic acid, syringic acid and salicylic [40]. These compounds might also contribute to the antioxidant capacity of the bioaccessible fraction.

As it has been shown previously [7], the enzymes had an impact on microorganisms growth, leading to a series of changes such as decreasing the pH and enhanced microbial growth that might be responsible of the more extensive modifications. It has been proposed that the increase of microbial growth and the acidification were related to the higher availability of fermentable carbohydrates, which were released from polysaccharides through the different hydrolytic activities [7]. In our study, the high bacteria fermentation was obtained in the IDF more than in SDF media and this increase in biomass is correlated with decreasing pH and SCFA production such as acetic, butyric, and propionic acids. In this *in vitro* study, it was demonstrated that wheat bran dietary fiber, can be growth stimulators of both Bifidobacteria and Lactobacilli. The same result was reported in the *in vivo* fermentation studies of wheat bran by Bifidobacteria strains (*B. animalis lactis* Bb12 and *B. bifidum* Bb443) and Lactobacilli strains (*Lb. acidophilus* LbA-CECT 4529 and *Lb. rhamnosus* LBRE-LSAS) [15].

It was observed that the decrease of pH due to *Bifidobacterium* and lactic acid bacteria fermentation, leads to the activation of endogenous degrading enzymes such as amylase, pentosanase, and β -glucanase. Sugars released from fibers become available for fermentation by the strains used [14]. The addition of commercial enzymes also affected, through different mechanisms, the balance between insoluble and soluble fiber [34]. Dietary carbohydrates, specifically resistant starches and dietary fiber are substrates for fermentation that produce short chain fatty acids (SCFA), such as acetic, butyric, and

propionic acids [44]. They all act lowering colon pH reducing potential pathogens [28].

5. Conclusion

On behalf of this study, durum wheat bran may be exploited as a potential dietary source of antioxidants for nutraceuticals and functional foods. These results indicated that wheat bran dietary fiber may replace synthetic antioxidant in food formulations and play a major role in human health. In addition, Wheat bran insoluble dietary fiber has the ability to be growth stimulators of both beneficial bacteria Bifidobacteria and Lactobacilli strains. However, attention should be paid to the effect of the reduction of wheat bran particle size on the quality of the final cereal products [29].

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Conflicts of Interest

The authors declare no conflict of interest.

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