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Enhancement of Chemical Composition and Nutritive Value of Some Fruits Pomace by Solid State Fermentation

Mahmoud A. E. [a,*]; Omer H. A. A. [b]; Mohammed A. T. [a]; Ali M. M. [a]

[a]Biochemistry Department, Genetic Engineering and Biotechnology Research Division, [b]Animal Production Department, Agricultural and Biological Research Division, National Research Centre, Dokki 12622, Giza, Egypt.

Abstract

Agricultural wastes recycling represents a critical point in sustainable development approaches since waste management is a must for conservation of natural resources and for protecting the environment. Production of livestock is limited by the production of animal feed. Solid State Fermentation (SSF) of agro-industrial pomace represents an eco-friendly and cheap approach for recycling of agro-industrial pomace into better quality animal feed. In the present study, the ability of bioconversion of pomegranate, orange, grape and mango pomace into value-added animal feed by SSF of the yeast *Kluyveromyces marxianus* NRRL Y-8281 was evaluated. Chemical analysis, cell wall constituents, energetic and nutritive values of each pomace before and after fermentation were reported. Results showed that fermentation increased protein and fat contents and decreased crude fiber content and cell wall constituents in all pomace except for mango pomace whose crude fiber and cell wall constituents were increased after fermentation. Carbohydrate content decreased in all pomace except for pomegranate pomace, while, ash content decreased after fermentation in all pomace except for mango pomace. Moreover, energetic and nutritive values increased after fermentation. SSF of pomegranate, orange, grape and mango pomace by the yeast *K. marxianus* presents a new eco-friendly valorization technique for converting these wastes into value-added products allowing their use as animal feed or compost.

Keywords: Fruit pomace; Solid state fermentation; Chemical composition; Cell wall constituents; Energetic values; Nutritive value

*Corresponding author e-mail: ab_essam@yahoo.com.
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Introduction

Food processing industries including fruit and vegetable processing is the second largest generator of wastes into the environment. It is estimated that about 25% - 30% of vegetables and fruits total weight is discarded as non-edible pomace during food products manufacturing. This huge amount of pomace -together with wastes produced during harvesting- is pumped into the environment resulting into serious environmental pollution problems if not utilized or disposed-off properly [1, 2].

Solid state fermentation (SSF) is the fermentation process carried out in the absence, or near-absence of free water; however, enough moisture level should be maintained to support the microbial growth and metabolic activity [3]. The substitution of synthetic substrates by agro-industrial residues is considered a valuable approach that does not only eliminate the environmental pollution caused by these wastes, but also allows for their valorization [4]. Moreover, SSF can improve the chemical composition of the waste regarding its bioavailability releasing its contained energy present in its sequestered form while reducing the concentration of antinutritional factors which can successfully help in solving the problem of scarcity of livestock feed and soil fertilizers that are based on natural bases [5, 6].

The aim of the present work was to evaluate the role of SSF of different fruits pomace using the Generally Regarded As Safe (GRAS) yeast, *K. marxianus*, on the chemical composition, energetic and nutritive values in a trial for their bioconversion into a value-added animal feed.

Experimental

Materials

Fruits pomace

Pomegranate, orange, Grape and Mango pomace were freshly collected from local juice extraction shops. They were washed with tap water, sliced, crushed in a mixer and stored till used in a deep freezer at −20 °C.

Microorganisms

Kluyveromyces marxianus NRRL Y-8281 strain was obtained from Agricultural Research Service, Peoria, Illinois, USA.MethodsSolid state fermentation

Solid state fermentation was carried out according to the method reported by Mahmoud, Fathy, Rashad, Ezz and Mohammed [7]. Briefly, 5g of sterilized pomace were used as a solid support for cultivation of 1 mL of inoculum containing about 108 cells/ml. Incubation was done at static incubator for 48 hours at 45°C.

Chemical composition of unfermented (UF) and fermented (F) pomace

For both UF and F pomace, the official methods reported by the Association of Official Analytical Chemist [8] were followed for analysis of moisture, crude protein (CP), crude fat (CF) and ash contents.

Cell wall constituents including neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose and cellulose were determined according to Goering and Van Soest [9] and Van Soest, Robertson and Lewis [10].

Gross energy (GE) in Kcal/ Kg DM was calculated according to Blaxter [11], while, Digestible energy (DE) in Kcal/ kg DM, Metabolizable energy (ME) in Kcal/ kg DM, Total digestible nutrients (TDN %), Digestible crude protein (DCP %) and Net energy (NE) in Kcal/ kg DM were calculated according to National Research Council [12].

Statistical analysis

Data were expressed as Mean±Standard Error Mean and analyzed statistically using independent sample T-test for comparison between the fermented and unfermented pomace groups. Differences were considered significant at $P<0.05$.

Results and Discussion

Zero hunger is the second goal of the 17 goals set by UN for achieving sustainable development. One tool to fight hunger is to increase livestock production, however, the latter is restricted by shortage and high price of animal feed. The utilization of non-conventional feed resources can be used to ensure continuity of livestock production. Agro-industrial wastes, which are obtained during harvesting or processing of fruits and vegetables, are considered competitive renewable, non-conventional animal feed resources [13].

The chemical composition, cell wall constituents, energetic and nutritive values of different unfermented

(UF) and fermented (F) pomace were reported in this study.

Pomegranate fruits peel is an inedible part obtained during processing of pomegranate juice. The incorporation of the available, inexpensive, nutrient-rich pomegranate peel into the foodstuff is of a great economic and nutritive values [14].

The moisture content of unfermented pomegranate pomace was found to be 70.93% (Table 1). Crude protein, CF, FC and CC were found to be 8.31, 17.12, 1.44 and 70.18% on dry matter basis, respectively. While, ash represented 2.95% on dry matter basis. This chemical composition resembles that reported by Besharati and Abdi [13] except for moisture (5.4%) and ash (9.2%) contents. Also, Aguilar, Aguilera-Carbo, Robledo, Ventura, Belmares, Martinez, Rodríguez-Herrera and Contreras [15] reported CF, FC, and ash contents of 16.3, 1.26 and 3.4%, respectively. Moreover, the cell wall constituents were found to be 38.63, 25.05, 4.42, 13.58 and 20.63 for NDF, ADF, ADL, HC and cellulose, respectively (Table 1). Values of NDF and ADF are in the same range reported by Besharati and Abdi [13], while that of lignin is similar to that reported by Kushwaha, Bera and Kumar [16]. Fermentation of pomegranate pomace with *K. marxianus* resulted in an increase in CP, FC and CC (10.34, 1.71 and 72.88%, respectively). While, a decrease in CF (to 12.56%) and ash (to 2.51%) was observed. In addition, a decrease in NDF, ADF and ADL (to 36.05, 20.89 and 3.65, respectively) was detected. Nevertheless, HC and cellulose contents increased to 15.16 and 17.24, respectively.

These findings resemble those of pomegranate pomace fermented by *Saccharomyces cerevisiae* reported with Mohammad, Yousif, Yaseen, Gdallah, Shouk and Abdel Fatah [17] in terms of increasing crude protein and decreasing ash contents. However, they contradict with the decreased FC and CC and the increased CF contents. Also, SSF of pomegranate pomace with *Aspergillus niger* strain GH1 was reported to increase CP, CF and ash contents while decreasing the total sugars leaving ash contents nearly unchanged [15].

SSF of pomegranate pomace with *K. marxianus* did not only affected its chemical composition, but also improved its energetic and nutritive values increasing the GE, DE, ME and NE from 4228, 3214,

Table 1 Chemical analysis, cell wall constituents, energetic and nutritive values of unfermented (UFPP) and fermented (FPP) pomegranate pomace

Item	UFPP	FPP	Item	UFPP	FPP
Moisture (%)	70.93 ± 0.005[b]	73.11 ± 0.049[a]			
Chemical analyses on dry matter basis (%)					
OM	97.05 ± 0.025[b]	97.49 ± 0.012[a]	**FC**	1.44 ± 0.219[b]	1.71 ± 0.306[a]
CP	8.31 ± 0.107[b]	10.34 ± 0.092[a]	**CC**	70.18 ± 0.173[b]	72.88 ± 0.094[a]
CF	17.12 ± 0.023[a]	12.56 ± 0.011[b]	**Ash**	2.95 ± 0.025[a]	2.51 ± 0.012[b]
Cell wall constituents					
NDF	38.63 ± 0.150[a]	36.05 ± 0.225[b]	**HC**	13.58 ± 0.179[b]	15.16 ± 0.364[a]
ADF	25.05 ± 0.029[a]	20.89 ± 0.139[b]	**Cellulose**	20.63 ± 0.035[a]	17.24 ± 0.190[b]
ADL	4.42 ± 0.063[a]	3.65 ± 0.052[b]			
Energetic values (kcal/kg DM)					
GE	4228 ± 1.764[b]	4291 ± 0.882[a]	**ME**	2635 ± 2.0[b]	2674 ± 1.0[a]
DE	3214 ± 1.453[b]	3261 ± 0.882[a]	**NE**	1476 ± 1.0[b]	1497 ± 0.577[a]
Nutritive values					
TDN	72.54 ± 0.032[b]	73.61 ± 0.021[a]	**DCP**	4.56 ± 0.092[b]	6.29 ± 0.081[a]

-Values are given as mean±Standard Error Mean of three batches.
-Means bearing different superscripts in the same raw are significantly different ($P < 0.05$).
OM: Organic Matter; **CP:** Crude Protein; **CF:** Crude Fiber; **FC:** Fat content; **CC:** Carbohydrate content; **NDF:** Neutral detergent fiber**; ADF:** Acid detergent fiber**; ADL:** Acid detergent lignin**; HC:** Hemicellulose; **GE:** Gross Energy; **DE:** Digestible energy; **ME:** Metabolizable energy; **NE:** Net energy; **TDN:** Total digestible nutrients; **DCP:** Digestible crude protein.

2635 and 1476 kcal/kg DM to 4291, 3261, 2674 and 1497 kcal/kg DM, respectively, in addition to increasing the TDN and DCP from 72.53 and 4.56 to 73.61 and 6.29, respectively.

About 85% of total orange fruit weight is discarded as a by-product (orange pomace) during orange processing into orange-based products [18]. Considering its high content of nutritive compounds, orange pomace can be regarded as a renewable resource of animal feed.

Chemical composition of orange pomace revealed that moisture represents 69.57%. While, CP, CF, fat, CC and ash contents represent 13.9, 10.95, 5.17, 63.79 and 6.19%, respectively (Table 2). These data are close to those reported by Fegeros, Zervas, Stamouli and Apostolaki [19] stating CF, FC and CC of 11.15, 4.92 and 59.33%, respectively. On the other hand, Scerra, Caridi, Foti, Sinatra and Caparra [20] reported that on dry matter basis, CP, fat and ash contents represents 5.62, 1.62 and 5.72% of orange pulp. Moreover, NDF, ADF and ADL were found to be 35.13, 19.42 and 3.38, while, HC and cellulose were 15.71 and 16.04 (Table 2). Also, the findings are close to some extent those reported by Romelle, Ashwini Rani and Manohar [21] who reported values of 9.73, 8.7, 5.17, 14.19 and 53.27% for crude protein, crude fat, ash, crude fiber and carbohydrate contents. The values of HC and cellulose are very close to those reported by Mamma, Kourtoglou and Christakopoulos [22] (13.8 and 16.2, respectively). NDF and ADF were reported to be 14.49 and 11.15 [20].

Fermentation of orange pomace reflected an increase in crude protein (18.48%), fat (5.63%) and HC (16.32%) contents, with simultaneous decrease in CF (9.17%), carbohydrate (60.9%), ash (5.82%), NDF (34.12%), ADF (17.8%), ADL (3.07%) and cellulose (14.73%). Nevertheless, fermentation also improved energetic and nutritive values increasing GE from 4373 to 4481 Kcal/kg DM; DE from 3324 to 3405 Kcal/kg DM; ME from 2725 to 2792 Kcal/kg DM; NE from 1526 to 1564 Kcal/kg DM; TDN from 75.01 to 76.88 and DCP from 9.32 to 13.21 (Table 2).

AboSiada, Negm, Basiouny, Fouad and Elagroudy [23] reported an improved chemical composition of orange pomace by SSF of *Trichoderma reesei* through decreasing CF from 14.69 to 0.13 g% and CC content from 7.28 to 0.38 g% while increasing CP content from 24.13 to 24.84 g%.

Scerra, Caridi, Foti, Sinatra and Caparra [20] reported that SSF of orange peel with *Penicillium roqueforti* Pr2, improved the chemical composition

Table 2 Chemical analysis, cell wall constituents, energetic and nutritive values of unfermented (UFOP) and fermented (FOP) orange pomace

Item	UFOP	FOP	Item	UFOP	FOP
Moisture (%)	69.57 ±0.089 b	75.65 ± 0.009 a			
		Chemical analyses on dry matter basis (%)			
OM	93.81 ± 0.00 b	94.18 ± 0.017 a	**FC**	5.17 ± 0.065 b	5.63 ± 0.039 a
CP	13.90 ± 0.058 b	18.48 ± 0.124 a	**CC**	63.79 ± 0.07 a	60.90 ± 0.082 b
CF	10.95 ± 0.049 a	9.17 ± 0.006 b	**Ash**	**6.19 ± 0.00A**	**5.82 ± 0.017B**
		Cell wall constituents			
NDF	35.13 ± 0.364	34.12 ± 0.081	**HC**	15.71 ± 0.543	16.32 ± 0.006
ADF	19.42 ± 0.179 a	17.80 ± 0.087b	**Cellulose**	16.04 ± 0.029 a	14.73 ± 0.046 b
ADL	3.38 ± 0.150	3.07 ± 0.04			
		Energetic values (kcal/kg DM)			
GE	4373 ± 4.177 b	4481 ± 2.027 a	**ME**	2725 ± 4.359 b	2792 ± 2.082 a
DE	3324 ± 3.179 b	3405 ± 1.764 a	**NE**	1526 ± 2.309 b	1564 ± 1.528 a
		Nutritive values			
TDN	75.02 ± 0.074 b	76.87 ± 0.035 a	**DCP**	9.32 ± 0.049 b	13.21 ± 0.107 a

-Values are given as mean±Standard Error Mean of three batches.
-Means bearing different superscripts in the same raw are significantly different ($P < 0.05$).
OM: Organic Matter; **CP:** Crude Protein; **CF:** Crude Fiber; **FC:** Fat content; **CC:** Carbohydrate content; **NDF:** Neutral detergent fiber**; ADF:** Acid detergent fiber**; ADL:** Acid detergent lignin**; HC:** Hemicellulose; **GE:** Gross Energy; **DE:** Digestible energy; **ME:** Metabolizable energy; **NE:** Net energy; **TDN:** Total digestible nutrients; **DCP:** Digestible crude protein.

through increasing the CP, FC, NDF and ADF. Also, Srilatha, Nand, Babu and Madhukara [24] reported that SSF of orange pomace by the combined growth of *Sporotrichum*, *Aspergillus*, *Fusurium* and *Penicillium sp*. increases CP from 9.18 to 12.45% and decreases cellulose (from 10.2 to 7.25%), HC (from 9.15 to 7.09%) and FC (from 15.49 to 13.44%).

Several industries such as wine industry produce substantial amounts of grape pomace that is of low nutritional value to be used as animal feed. The most employed method to get rid of grape pomace is to spread it on open areas which leads to serious environmental problems. Utilization of grape pomace as a solid support for SSF is a promising technique for its disposal with simultaneous improvement of its value [25]. Various chemical composition profiles have been reported for grape pomace depending on the cultivar, growth conditions and processing techniques applied [18].

Analysis of the chemical composition of grape pomace (Table 3) revealed that CP, CF, FC, CC and ash represented 13.23, 13.4, 5.82, 64.48 and 3.07% on dry matter basis, respectively. While, NDF, ADF, ADL, HC and cellulose represented 37.73, 21.65, 3.79, 16.08 and 17.86%, respectively. Moreover, gross, digestible, metabolizable and net energies were found to be 4527, 3441, 2821 and 1580 kcal/kg DM, respectively. Also, TDN and DCP were equal to 77.67 and 8.75, respectively. Higher protein ratio of 18.8% was reported by Mendes, Prozil, Evtuguin and Lopes [26]. Also, HC and cellulose contents were stated as 20.8 and 12.5%, respectively by Mendes, Prozil, Evtuguin and Lopes [26].

Crude protein and fat content of grape pomace were increased by fermentation (16.11 and 7.65%). On the other hand, CF, CC and ash contents were decreased (12.18, 61.34 and 2.72%, respectively) after fermentation of grape pomace with *K. marxianus* (Table 3). Zepf and Jin [27] enriched grape pomace with protein increasing its ratio from 7% to 27% by SSF of *Aspergillus oryzae* RIB 40. Meanwhile, NDF (35.83%), ADF (20.54%), ADL (3.58%), HC (15.29%) and cellulose (16.96%) were decreased after fermentation. Nevertheless, energetic value (4680, 3557, 2917 and 1633 kcal/kg DM) for GE, DE, ME, NE, respectively) of grape pomace were increased after fermentation with simultaneous increase in nutritive value (from 77.67 and 8.75 to 80.29 and 11.19 for TDN and DCP, respectively) as in table (3).

Mango pomace represents about 35 to 60% of total fruit weight and is composed of the peel and the kernel. Since mango peel is high in sugar content and is palatable to ruminants, it could be considered as energy feed for ruminants. However, because of their low protein content, addition of protein source is

Table 3 Chemical analysis, cell wall constituents, energetic and nutritive values of unfermented (UFGP) and fermented (FGP) grape pomace

Item	UFGP	FGP	Item	UFGP	FGP
Moisture (%)	71.64 ± 0.023 ^{b}	76.69 ±0.017 ^{a}			
Chemical analyses on dry matter basis (%)					
OM	96.93 ± 0.026 ^{b}	97.28 ± 0.006 ^{a}	**FC**	5.82 ± 0.079 ^{b}	7.65 ± 0.059 ^{a}
CP	13.23 ± 0.268 ^{b}	16.11 ± 0.072 ^{a}	**CC**	64.48 ± 0.289 ^{a}	61.34 ± 0.015 ^{b}
CF	13.40 ± 0.023 ^{a}	12.18 ± 0.006 ^{b}	**Ash**	3.07 ± 0.026^{A}	2.72 ± 0.006^{B}
Cell wall constituents					
NDF	37.73 ± 0.017 ^{a}	35.83 ± 0.023 ^{b}	**HC**	16.08 ± 0.167 ^{a}	15.29 ± 0.109 ^{b}
ADF	21.65 ± 0.185 ^{a}	20.54 ± 0.087 ^{b}	**Cellulose**	17.86 ± 0.069 ^{a}	16.96 ± 0.133 ^{b}
ADL	3.79 ± 0.115	3.58 ± 0.046			
Energetic values (kcal/kg DM)					
GE	4527 ± 7.024 ^{b}	4680 ± 1.527 ^{a}	**ME**	2821 ± 7.81 ^{b}	2917 ± 1.528 ^{a}
DE	3441 ± 5.364 ^{b}	3557 ± 1.527 ^{a}	**NE**	1580 ± 4.359 ^{b}	1633 ± 1.155 ^{a}
Nutritive values					
TDN	77.67 ± 0.124 ^{b}	80.29 ± 0.031 ^{a}	**DCP**	8.75 ± 0.231 ^{b}	11.19 ± 0.063 ^{a}

-Values are given as mean±Standard Error Mean of three batches.
-Means bearing different superscripts in the same raw are significantly different ($P < 0.05$).
OM: Organic Matter; **CP:** Crude Protein; **CF:** Crude Fiber; **FC:** Fat content; **CC:** Carbohydrate content; **NDF:** Neutral detergent fiber**; ADF:** Acid detergent fiber**; ADL:** Acid detergent lignin**; HC:** Hemicellulose; **GE:** Gross Energy; **DE:** Digestible energy; **ME:** Metabolizable energy; **NE:** Net energy; **TDN:** Total digestible nutrients; **DCP:** Digestible crude protein.

necessary to enhance the nutrient content by fermentation [28].

Crude protein represented 10.59% of mango peel on dry matter basis. While, CF, FC, CC and ash represented 6.14, 1.74, 78.77 and 2.76%, respectively (Table 4). Furthermore, NDF, ADF, ADL, HC and cellulose represented 32.41, 15.03, 2.56, 17.38 and 12.47%, respectively. On the other hand, GE and DE values were 4286 and 3257 kcal/kg DM, where, TDN and DCP were 73.52 and 6.50.

Results of estimating CF and CC are in the same range reported by Munishamanna, Suresha, Veena and Subramanya [28] stating 1.78 and 71.54% for fat and carbohydrate contents, respectively. However, these data are different from those reported by Romelle, Ashwini Rani and Manohar [21] stating crude protein, lipids, ash, fiber and carbohydrate contents of 5.0, 4.72, 3.24, 15.43 and 63.8 g/100g dry peel, respectively.

The chemical composition, energetic value and nutritive value of mango peel were improved by SSF of *K. marxianus* (Table 4). Crude protein, CF, FC and ash were increased (16.77, 6.37, 3.98 and 2.94% on dry matter basis, respectively). While, CC was decreased after fermentation (69.94%). Moreover, all cell wall constituents were increased (32.54, 15.24, 2.6 and 12.64% for NDF, ADF, ADL and cellulose, respectively) except for HC which decreased after fermentation (17.3%). Energetic values (4488, 3411, 2797 and 1566 kcal/kg DM for GE, DE, ME and NE, respectively) as well as nutritive values (77 and 11.75 for TDN and DCP, respectively) were improved.

AboSiada, Negm, Basiouny, Fouad and Elagroudy [23] reported a decrease in CF and CC of mango peel from 16.37 to 0.4 and from 6.85 to 0.16 g%, respectively, by SSF of *Trichoderma reesei* with simultaneous increase in CP content from 21.88 to 30.05 g%. While, Munishamanna, Suresha, Veena and Subramanya [28] enhanced the nutritive value of mango peel by combined cultivation of *Lactobacillus plantarum* and *Saccharomyces boulardii* reflecting a decrease in crude fiber (from 13.1 to 8.12%) and CC (from 71.54 to 69.24%) with an increase in CP (from 4.89 to 7.88%), FC (from 1.78 to 4.18%), ash (from 3.31 to 5.74%) and energy (from 321.74 to 346.1 k. cal/100g). Different chemical composition profiles can be reported for the same fruit pomace by different authors depending on several factors including the fruit variety, cultivation conditions, climatic and harvesting conditions among other factors [29].

Table 4 Chemical analysis, cell wall constituents, energetic and nutritive values of unfermented (UFMP) and fermented (FMP) mango pomace

Item	UFMP	FMP	Item	UFMP	FMP
Moisture (%)	68.57 ± 0.087 ^{b}	75.92 ± 0.069^{A}			
		Chemical analyses on dry matter basis (%)			
OM	97.24 ± 0.023 ^{a}	97.06 ± 0.006^{B}	**FC**	1.74 ± 0.03 ^{b}	3.98 ± 0.035^{A}
CP	10.59 ± 0.159 ^{b}	16.77 ± 0.242^{A}	**CC**	78.77 ± 0.176 ^{a}	69.94 ± 0.225^{B}
CF	6.14 ± 0.003 ^{b}	6.37 ± 0.012 ^{A}	**Ash**	2.76 ± 0.023^{B}	2.94 ± 0.006 ^{A}
		Cell wall constituents			
NDF	32.41 ± 0.237	32.54 ± 0.075	**HC**	17.38 ± 0.404	17.30 ± 0.439
ADF	15.03 ± 0.167	15.24 ± 0.364	**Cellulose**	12.47 ± 0.208	12.64 ± 0.375
ADL	2.56 ± 0.040	2.60 ± 0.011			
		Energetic values (kcal/kg DM)			
GE	4286 ± 2.186^{b}	4489 ± 4.177 ^{a}	**ME**	2671 ± 2.082 ^{b}	2797 ± 4.359 ^{a}
DE	3257 ± 1.527 ^{b}	3411 ± 3.333 ^{a}	**NE**	1496 ± 1.155 ^{b}	1566 ± 2.309 ^{a}
		Nutritive values			
TDN	73.52 ± 0.037 ^{b}	77.00 ± 0.074 ^{a}	**DCP**	6.49 ± 0.136 ^{b}	11.75 ± 0.205 ^{a}

-Values are given as mean±Standard Error Mean of three batches.
-Means bearing different superscripts in the same raw are significantly different ($P < 0.05$).
OM: Organic Matter; **CP:** Crude Protein; **CF:** Crude Fiber; **FC:** Fat content; **CC:** Carbohydrate content; **NDF:** Neutral detergent fiber**; ADF:** Acid detergent fiber**; ADL:** Acid detergent lignin**; HC:** Hemicellulose; **GE:** Gross Energy; **DE:** Digestible energy; **ME:** Metabolizable energy; **NE:** Net energy; **TDN:** Total digestible nutrients; **DCP:** Digestible crude protein.

Improving the nutritive value of agro-industrial pomace through fermentation can be proved by increased carbohydrate content, increased protein content and decreased fiber content making the fermented waste rich in protein and energy sources with increased digestibility [30]. Increased carbohydrate content can be explained by the degradation of polysaccharides under the action of the microbial enzymes. While, the protein content increase can be explained by the increased microbial biomass and its released enzymes [29, 31].

Conclusions

SSF of pomegranate, orange, grape and mango pomace using the GRAS yeast, *K. marxianus*, represents a simple strategy for their bioconversion increasing their opportunity for being used as a value-added animal feed through improving their chemical composition as indicated by increased crude protein and decreased fiber, as well as, increased energetic values and nutritive values.

Conflict of interest

There are no conflicts to declare

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