Nutrient Content and *In-vitro* Digestibility of Potato Waste Fermented with *Saccharomyces cerevisiae*

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Abstract

A study was carried out to evaluate the effects of *Saccharomyces cerevisiae* on fermenting potato waste (PW), and the *in-vitro* digestibility of the fermented potato via gas production. Potato waste was assigned to three treatments: PW plus zero media (P0), PW plus 5 % sugar solution (PS) and PW + 5 % sugar solution + yeast (PSY); the treatments were replicated six times and fermented for 0, 24, 48, 72 and 96 hours in a two-factor factorial design (CRD) factorial. Because of higher crude protein, ether extract and lower crude fibre contents, fermented PW at 72 hours was used for the *in-vitro* gas production for determination of metabolizable energy (ME), *in-vitro* dry matter digestibility (IVDMD) and *in-vitro* organic matter digestibility (IVOMD). The results of PW fermentation over time revealed that there was no interaction ($P>0.05$) between treatments and the time of fermentation, hence main factors were separately analysed. The dry matter (DM), crude protein (CP) and ether extract (EE) of PSY were significantly ($P<0.05$) higher than values across P0 and PS. The proximate values and fibre components were highest ($P<0.05$) at 72 hours of fermentation. Similarly, the *in-vitro* gas produced by PSY at 2h was highest ($P<0.05$) across treatments. However, no difference ($P>0.05$) was observed during the remaining incubation periods. The IVDMD and IVOMD digestibility of P0, PS and PSY were similar ($P>0.05$). It was therefore concluded that inoculating potato waste with *Saccharomyces cerevisiae* and fermented for 72 hours improved nutrient contents and digestibility.

Keywords: nutrient content, digestibility, gas production

Introduction

Potato is a staple food crop that is consumed worldwide. It is ranked between the fourth and fifth staple food crops in the world (Kareem & Baba, 2017). Processing of potatoes into finished products produces large quantities of waste, which is mainly composed of starch, proteins, minerals and amino acids (Li *et al.,* 2011). It is relatively a good source of dietary fibre as well as insoluble cellulose and lignin (Al-Weshahy *et al.,* 2013). The fibre content may reach 40g kg^{-1} (Curti *et al.*, 2016), depending on the method of processing. In European countries, low-grade and cull potatoes are fed to ruminants. However, potato is rarely used in the poultry feed industry. The use of potatoes in pig and poultry diets is limited due to the presence of toxic solanine and chaconine contents (Heo *et al.,* 2014).

Fermentation is used to improve storage quality, reduce anti-nutritional factors (Adegunloye & Oparinde, 2017) and improve

nutrient contents via solid-state fermentation (Akintomide & Antai, 2012). The fermentation process allows microorganisms to grow and multiply by utilizing and converting carbohydrates to lactic acid and carbon (iv) oxide. Digestive enzymes are not efficient in breaking down plant fibre (Dhingra *et al.,* 2012). However, enzymes secreted by microbes are capable of breaking down bound nutrients in organic complexes (Flint & Bayer, 2008). In particular, *Saccharomyces cerevisiae* has been used intensively to ferment food materials and food wastes like cassava and potato peels for the sole purpose of either improving protein content or reducing anti-nutritional factors (Kareem & Baba, 2017).

Although PW contains a high amount of energy due to the high content of starch, it is poor in soluble sugar content. The objective of this study is to evaluate the effect of yeast (*Saccharomyces cerevisiae*) on nutrient contents and *in-vitro* gas production of potato waste supplemented with or without soluble sugar solution.

Materials and methods

Treatments and experimental design

The study was carried out at the Department of Animal Science, Universiti Putra Malaysia. Potato waste was sourced from the local processing plant. The waste was largely composed of potato peels, tubers (flesh) and low-grade or rejected fries. However, PW collected from the processing plant was not fresh. Commercial Baker's yeast and sugar granules were used to prepare the experimental diets. The number of yeast used as inoculants was calculated, using a Haemocytometer.

Potato waste (PW) was subjected to three (3) treatments: PW + zero media (P0), PW + 5 % sugar solution (PS) and PW + 5 % sugar solution + yeast (PSY). The treatments were replicated six times, while fermentation time was randomly assigned to the treatments in a completely randomized design (CRD). The quantity of substrate, incubation temperature, fermentation period and general preparation procedure was according to Aruna *et al.* (2017) except that substrate was not autoclaved before fermentation. The PW was inoculated to contain 1×105 cfu/g (Abdul Rahman *et al.,* 2017) and subjected to a solid-state fermentation method. The PW were placed in conical flasks then covered with a thin layer of paraffin and incubated at 27°C for 0, 24, 48, 72 and 96 hours.

In-vitro gas production

The *in-vitro* digestibility by gas production experiment was conducted following the general procedure (Menke & Steingass, 1988). Exactly 200 mg DM of the fermented sample was incubated with rumen fluid + buffer solution. The rumen fluid was sourced from a rumen-fistulated donor bull in Ladang 15. Since the samples fermented at 72 hours recorded the highest CP, EE and lower crude fiber (CF), it was selected for the *in-vitro* gas production determination. The samples were replicated into four and run twice. Readings of gas were recorded at 2, 4, 6, 24, 48, and 72 hours. Residues were analysed to calculate the dry matter digestibility, while the organic matter digestibility was calculated using the formula below:

IVOMD=14.88 +0.8893GP+0.0448CP+0.0651A;
where GP = gas production at 24 hours, CP = crude protein, A = ash.

Similarly, metabolizable energy (ME) was calculated using the formula below:

$$ME = -0.27+0.1546\ IVOMD -0.0133A + 0.0169EE + 0.0009CP;$$

where IVOMD= *in-vitro* organic matter digestibility at 24 h of incubation, A= ash, EE= ether extract, CP= crude protein.

Chemical analysis

The proximate components and fibre fractions of the cell wall for the fermented PW was analysed according to AOAC (2012) and Van Soest *et al.* (1991), respectively.

Statistical analysis

Data collected on proximate components, fibre fractions and gas production volumes were subjected to analysis of variance (ANOVA) using a general linear model (GLM) of the Statistical Analysis System (SAS, 2011). The model used was a two-factor factorial design, thus:

$$Yijr = \mu + ti + dj + (td)ij + eijr,$$

where Y= dependent variable, μ =effect of overall mean, t= effect of treatment, d= effect of fermentation time, td= effect of interaction between treatment and fermentation time, and e= effect of the error term.

Means were differentiated using a Duncan Multiple Range Test (DMRT) (Duncan, 1955).

Results

Nutritive values of fermented potato waste

There was no interaction between treatments and duration of fermentation on the nutrient chemical values of potato waste (P>0.05). All results were presented based on the main effects (treatment and duration) in Table 1, and Table 2, respectively.

The nutritive values of fermented PW across treatments showed significant differences (P<0.05) across all nutrients except for NDF and ADF contents (Table 1). The PSY had the highest DM by 4%; 0.5%, ash by 0.3%; 0.2%, CP by 0.3%; 0.1% and crude fat by 0.09%; 0.04% content compared to P0 and PS, respectively. However, P0 had the highest CF content. The ADL value observed for P0 was significantly higher (P<0.05) than ADL values recorded for PS and PSY treatments.

The nutrient contents across fermentation periods were significantly different (P<0.05) except for values for NDF, ADF and ADL (P>0.05) (Table 2).

All treatments fermented for 72 hours had the highest DM (38.1%), ash (3.23%), CP (8.9%) and crude fat (0.48%) contents compared to potato waste fermented for 0, 24, 48 and 96 hours.

Table 1. Nutritive values of fermented potato waste treated with sugar solution and yeast (g/100g)

Parameters (%)	Treatments		
	P0	PS	PSY
Dry matter	35.6±0.11^{c}	36.18±0.25^{b}	39.72±0.07^{a}
Ash	2.84±0.04^{c}	2.96±0.05^{b}	3.13±0.05^{a}
Crude protein	8.24±0.08^{b}	8.41±0.08^{a}	8.5±0.09^{a}
Ether extract	0.25±0.03^{c}	0.3±0.03^{b}	0.34±0.03^{a}
Crude fibre	5.13±0.06^{a}	4.76±0.14^{b}	4.68±0.16^{b}
NDF	38.78±1.56	39.45±1.43	40.65±1.61
ADF	11.27±0.15	11.54±0.21	11.74±0.22
ADL	32.39±0.87^{a}	30.28±1.09^{b}	30.27±1.26^{b}

$^{a, b, c}$ Means values with different superscripts between the rows differed significantly (P<0.05). NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin. Note: values are presented as mean ±SEM. P0: Control, PS: with 5% sugar solution, & PSY: with 5% sugar solution + yeast.

Table 2. Nutrient contents (g/100g) of potato waste fermented at different periods (0, 24, 48, 72 and 96 hours)

Parameters	Fermentation period (hours)				
	0	24	48	72	96
Dry matter	36.8±0.7^{c}	37.1±0.64^{b}	37.2±0.63^{b}	38.1±0.79^{a}	36.7±0.65^{c}
Ash	2.9±0.05^{bc}	3.0±0.07^{b}	3.0±0.07^{b}	3.23±0.03^{a}	2.79±0.020^{c}
Crude protein	7.98±0.04^{e}	8.16±0.04^{d}	8.52±0.05^{b}	8.9±0.08^{a}	8.4±0.05^{c}
Ether extract	0.09±0.01^{e}	0.23±0.02^{d}	0.32±0.01^{c}	0.48±0.04^{a}	0.37±0.08^{b}
Crude fibre	5.2±0.05^{a}	5.14±0.1^{a}	4.84±0.16^{ab}	4.61±0.52^{b}	4.49±0.28^{b}
NDF	39.81±2.09	40.72±2.12	39.26±2.3	39.61±2.12	38.73±2.07
ADF	11.34±0.29	11.45±0.29	11.56±0.28	11.78±0.01	11.45±0.61
ADL	32.17±1.14	31.63±1.51	30.59±1.54	30.11±1.81	30.10±1.53

$^{a, b, c, d, e}$ Means values with different superscripts between the rows differed significantly (P<0.05). Note: values are presented as mean ±SEM. NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin.

In-vitro gas production, dry matter and organic matter digestibility

The cumulative *in-vitro* gas production at 2 hours for PSY treatment was the highest (13.06±0.29 mL/200mg) compared with P0 and PS treatments (Table 3). There was no statistical difference (P>0.05) in the gas production for all the remaining incubation periods (4, 6, 24, 48 and 72 hours) across the treatments.

The value of ME, IVDMD and IVOMD across the treatments showed no significant difference (P>0.05) (Table 4). The IVDMD value for PS (47.34±2.06) was the highest compared to PSY and P0.

Table 3. *In-vitro* gas production of fermented potato waste incubated at 2, 4, 6, 24, 48 and 72 hours

Incubation period (hours)	Gas production (mL/200mg DM)		
	P0	PS	PSY
2	10.90±0.33^{b}	10.95±0.33^{b}	13.06±0.29^{a}
4	18.07±1.2	18.34±0.69	20.58±0.35
6	25.48±0.4	25.98±0.79	27.98±0.67
24	90.86±1.14	93.72±2.35	94.29±2.1
48	121.8±3.14	122.97±3.4	123.66±2.66
72	139.08±6.12	137.21±5.4	134.53±2.72

$^{a, b,}$ Means values with different superscripts between the rows differed significantly (P<0.05). Note: values are presented as mean ± SEM. P0: Control, PS: with 5% sugar solution, & PSY: with 5% sugar solution + yeast

Discussion

The dry matter, ash, crude protein, and EE contents of PSY were highest compared to PS and P0; therefore, the addition of sugar solution may have helped the readily available microbes in the potato waste to grow.

This situation was further improved by the inoculation of yeast into the potato waste.

Table 4. *In-vitro* dry matter digestibility and *in-vitro* organic matter digestibility of fermented potato

Parameters	Treatments		
	P0	PS	PSY
ME (MJ/kg DM)	14.58±0.16	14.72±0.20	14.81±0.16
IVDMD (%)	42.17±3.18	47.34±2.06	43.77±3.94
IVOMD (%)	96.28±1.02	97.18±1.28	97.80±1.02

ME = metabolizable energy, IVDMD = *in-vitro* dry matter digestibility, IVOMD = *in-vitro* organic matter digestibility. Note: values are presented as mean ±SEM. P0: Control, PS: with 5% sugar solution, & PSY: with 5% sugar solution + yeast.

Similarly, the increase in CP of fermented potato waste corroborated some earlier reports that fermentation increases the protein profile of fermented starchy substrates (Aruna *et al.,* 2017; Yuan *et al.,* 2017). Furthermore, Gélinas & Barrette (2007) reported that *Saccharomyces cerevisiae* increased the CP content of potatoes obtained from chips processing company. Although there are conflicting reports on the improvement of protein content during fermentation, the increase in crude protein in the present study could be related to the fact that yeasts were reported to utilise atmospheric nitrogen (Kneip *et al.,* 2007), or get nitrogen from symbiotic relationship (Rizo *et al.,* 2020). It was deduced that since the present experiment was not controlled, indigenous microbes in the PW such as nitrogen-fixing bacteria could have influenced an addition of nitrogen content to the treatments, and yeast may have a synergy effect with bacterial population in situ to improve the protein content. Therefore, the highest CP recorded in PSY could be related to the inoculation with *Saccharomyces cerevisiae*.

The EE content of PS was the highest followed by PSY and P0. Abundant microbes in treatment PS and PSY may have influenced the higher fat content. The cell membrane of yeast is made up of a phospholipid bilayer, hence the change in fat content. The increase in EE content recorded in the current study was earlier observed by Aruna *et al.* (2017) who reported that yam peels fermented with yeast and ammonia sulphate increased fat content significantly at 96 hours.

However, in this study, the highest crude fibre content was observed in potato waste fermented at 0 hours (5.2%). The decrease in microbial growth at 96 hours from 72 hours could be due to the exhaustion of simple fermentable sugar in all the treatments (Karki *et al.,* 2017).

In addition, PSY had the lowest crude fibre content followed by PS and P0. The lower content of crude fibre in PS and PSY was due to improved condition and inoculation which allowed the microorganisms to grow and break down starch faster than the microbes in P0. Unlike non-digestible fibre, starch can be hydrolysed by a starch-hydrolysing enzyme (amylase) that is vastly available in animals, plants and microorganisms. The absence of any significant difference in CF content between PS and PSY was probably due to the limited ability of yeast to break down fibre components (Van Zyl *et al.,* 2012).

In-vitro gas production is used to determine the digestibility of a feed sample. Therefore, the gas produced over time due to microbial fermentation was reported to have a linear correlation to the proportion of organic matter disappearance, rate of passage and digestibility (Zewdie, 2019). A feed that contained high energy and less fibre content as well as less anti-nutrient content tends to

produce more gas as a result of a higher rate of fermentation which is also correlated to the quantity, and types of microbial population (Castro-Montoya *et al.*, 2018). The higher the volume, and rate of gas production during an *in-vitro* fermentation, the higher the digestibility and passage rate of a feed sample in an in vivo experiment. The higher volume of gas production by PSY at 2 hours was an indication that the addition of *Saccharomyces cerevisiae* improved the energy content and digestibility of the substrate.

However, in this study, the gas produced at 4, 6, 24 and 48 hours by PSY treatment was numerically highest compared to P0 and PS. In contrast, gas produced by P0 treatment at 72 hours was numerically highest compared with PS and PSY. The gas recorded by PSY at 2 hours in the present work was similar to the volume of gas production at 3 hours by sweet potato and wild cocoyam peels (Adeyosoye *et al.*, 2010).

The IVDMD observed in this study was within the range reported for alkaloid-rich potato by-products (Joo *et al.*, 2018). The ME and IVOMD value for PSY were numerically higher compared with PS and P0. The values of IVDMD are known to have an inverse relationship to lignin content (Santos *et al.*, 2017). Hence, PO had the lowest IVDMD value compared with PS and PSY.

Conclusion

It was therefore concluded that inoculating potato waste with *Saccharomyces cerevisiae* and fermenting for 72 hours improved nutrient contents and *in-vitro* digestibility.

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