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Single Cell-Protein Production from Potato (*Solanum tuberosum* L.) Processing Waste by using *Candida utilis* NRRL Y-900

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ABSTRACT: Suitability and availability of potato processing wastes for the production of single-cell protein by using *Candida utilis* NRRL Y-900 were investigated for biomass production. Mixed effluent (pulp-peel-starch) from holding tanks at a potato-processing plant was used as a fermentation substrate. A number of different fermentation parameters; incubation period, incubation temperature, pH and inoculum size were investigated. Maximum biomass yield (g/l) and crude protein (%) were obtained after 72 hr incubation period. A fermentation temperature of 30°C gave the highest protein yield and biomass productivity. The microorganism revealed a high growth rate at pH 5.0. An inoculum size of 4% (v/v) showed a high biomass and protein contents. All fermentation parameters were optimized (C/N ratio), and a batch of potato processing waste effluent was fermented using two different techniques (shaking flasks and bioreactor) resulting in biomass yield 12.5% and 18.07 g/L, respectively. While crude protein gave 57.19 and 55.69%, respectively.

Keywords: *Candida utilis*, microbial protein, potato processing waste, Single-cell protein.

INTRODUCTION

The increasing demands for food and feed has motivated scientists to search for protein production improvement. The possibility of producing microbial protein from agricultural byproducts and effluents by using industrial fermentation is considered to be one of the most advanced approaches. Single-cell protein are defined as; the dried biomass of microorganisms, which can be used as a protein source in human nutrition and/ or in animal feed (Yunus et al., 2015). SCPs are defined as microbial protein derived from algae, yeasts, mushrooms, or bacterial strains (Spalvins et al., 2018). These microorganisms can be used as value-added ingredient in foods and feeds (Anneli et al., 2017). In recent years, one of the most used microorganisms in single cell-protein production is *Candida* sp. (Yunus et al., 2015).

The usage of microbes to be cultivated on cheap and abundant carbon sources makes this alternative moreover interesting. Yeast is the most favorable microorganism for microbial protein production due to its high nutritional characteristics and consumer acceptability (Lapeña et al., 2020). Microbial protein is an option with benefits that include microbe's short time generation, high protein productivity, high content of amino acids profile, and high ability of sustainable production (based on environmental and growth conditions), (Manoel, Cristina et al., 2018).

Potatoes (*Solanum tuberosum* L.) are one of the most widely consumed vegetables worldwide (Amado et al., 2014). The world production of potatoes in 2017 was 4325478 tons (FAO STAT, 2017). Most of the liquid and solid wastes from potatoes arise from peeling, trimming, slicing, cleaning, and rinsing operations which creates a pollution problem. This has resulted in environmental problems associated with waste generated by such manufacturing processes (Helal et al., 2020).

The main objective of this study is to investigate the suitability and availability of potato processing wastes (pulp, peels, and starch) resulting from washing and blanching processes in chips industries to produce single-cell protein by using yeast strain (*Candida utilis* NRRL Y-900). Also, the optimum environmental and growth fermentation parameters to produce the maximum biomass yield and crude protein were studied.

MATERIALS AND METHOD

Microbial strain and culture conditions

Microorganism

One yeast strain used in this investigation, named *C. utilis* NRRL Y-900 was purchased from The Northern Regional Research Laboratory (NRRL), Peoria, Illinois, U.S.A. Yeast culture was activated on a liquid medium composed of 3.0 g yeast extract,

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3.0 g malt extract, 5.0 g peptone, and 10.0 g glucose which dissolved in 1 L of distilled water. The medium was adjusted to pH 5 and then incubated at 30°C for 48 hrs (Ordaz et al., 2001).

Preparation of potato processing waste

Potato processing waste used in the investigation was prepared as follows: Potato processing waste was air dried, then dried in a ventilated oven at 65 °C until dryness. The samples were ground in a hummer mill (BRAUN, Germany) and kept in a tightly closed bottle at -18 °C in freezer.

Preparation of acid hydrolyzate

For hydrolysis, 12.5 g of potato processing waste was added to 100 mL of 4% H_2SO_4 and heated to 98-100°C on water bath for 30 min. At end of the reaction, the remaining solids were separated by filtration with cheese cloth followed by filter paper (Whatman No.1), then neutralized to pH 5 with 5% NaOH. The resulting hydrolysate was treated with active charcoal to reduce its content of inhibiting substances, then filtrated through cotton and filter paper (Whatman No.1). The filtrated hydrolysate was used for yeast propagation (Korish and EL-Sanat, 2007).

Yeast cultivation

Inoculum

Yeast inoculums was prepared using the following medium: 0.3 g yeast extract, 0.3 g malt extract, 0.5 g peptone, 1 g glucose, and 100 mL of distilled water. The pH of the medium was adjusted to 5. One loop full from slant agar culture (48 hrs) was used to inoculate 50 ml of the sterilized medium in a 250 mL conical flask. The flasks were placed on a water bath shaker (Lab-Line, shaker bath, USA) at 30°C and 150 rpm for 24 hrs. The Concentration of the organism was adjusted to 4- 4.5 g dry cells/l to inoculate the fermentation medium (Rajoka et al., 2005).

Growth medium

The following mediums were used for yeast propagation according to Abu EL-Khair, (1992). Ammonium sulphate (2.3g), Yeast extract (3.0 g), and potassium phosphate (2.0 g) were added to one liter of the hydrolysate containing 23.2 g/L of reducing sugars. Also, the standard glucose medium was prepared by adding 23.2 g/L glucose. The pH was modified to 5, then sterilization took place at 121 °C for 20 min. Fifty milliliters of the media were placed into a 250 mL conical flask and inoculated using 4% (v/v) inoculum size for each flask (hydrolyzate and standard glucose mediums). The flasks were incubated in an incubator (Lab Line, Shaker bath, USA) with orbital shaking with a shaking rate 150 rpm at 30°C for 96 hrs. At end of the incubation period, yeast biomass was recovered by centrifuge (Center Sigma, Labor Centrifugen, Germany), at 5000 rpm for 15 min. Yeast cells were washed twice with distilled water and dried at 105°C until constant weight for further analysis.

Yeast culture conditions

In the shaking flasks experiment, different incubation temperatures (25, 30, and 35°C) were tested to study their effect on biomass yield and protein production to choose the best incubation temperature. Also, fermentation was carried out at various pH values (4, 4.5, 5, 5.5, and 6). The investigated inoculum sizes were 2, 4, 6, 8, and 10% (v/v). The incubation periods were tested also from 24 to 96 hrs. Samples were withdrawn at the end of incubation period, analysed to identify the optimum growth conditions to be compared with the bioreactor experiment.

Growth in fermentor as batch culture

A fermentor (Micro DCU – 100 B. Braun Biotech. International, Germany) was used in this investigation. The working volume was 3 litters. The fermentation medium was prepared using optimum ingredients resulting from the shaking cultures experiment and agitated at 500 rpm. The temperature and pH value were controlled automatically at 30°C and 5.0; respectively. The aeration (PO_2) rate began at 98.6 % at the first day and decreased at the second day to 54.2% till reached 1.3% up to the end of incubation time. The Medium was inoculated with 120 ml of inoculum (previously prepared on a shaker for 24 hrs with 150 rpm). At the end of the incubation period, the biomass was harvested by centrifugation at 5000 rpm for 15 min to determine yeast growth, protein content, consumed, and residual sugars.

Gross chemical composition

Moisture, ash, crude protein, ether extract and crude fibres of potato processing waste and dried cells of yeast were carried out in accordance with A.O.A.C (2000). The starch content was determined by using Kim and Hamdy, (1985) method. Total carbohydrates were calorimetrically using phenol-sulphuric acid as given by Dubois et al., (1956). Absorbance was measured using spectrophotometer (Model 120-02-U.V- Visible) at 490 nm. Reducing sugars were determined according to method outlined by Miller, (1959). Absorbance was measured at 575 nm and reducing sugars were measured as glucose from standard curve.

Nucleic acid determination

The nucleic acid content was determined according to Otera et al., (1983).

Amino acids determination

Amino acids composition of protein from *Candida utilis* biomass were determined using Amino Acid Analyzer (AAA) model (Biochrome 30) according to the method given in A. O. A. C (2000).

Calculations of fermentation parameters

The following equations are used to calculate the fermentation parameters according to (Solomon and Layokun, 1988).

- Reducing sugar uptake rate (g/L.h) =
- Consumption (%) =
- Specific productivity of protein (g/g cell.h) × 10-2 =
- Biomass yield from reducing sugars (g/g) =
- Specific growth rate (g/L. h) =
- Total crude protein per liter (TCPL) =
- Yield as of theoretical value (%) =
- Yeast yield efficiency ratio (YER) =

*Theoretical yield (0.5 g biomass/ g glucose); (Parajò et al., 1994).

Statistical Analysis

The results were statistically analyzed by using General Linear model, adapted by statistical package for the Social Sciences (Spss, 1997) for user's Guide Duncan Multiple Range Test was used to test the difference among means (Duncan, 1995).

RESULTS

Proximate composition of dried potato processing waste

The proximate composition of dried potato processing is given in Table (1). Total carbohydrates (63.06%) were the major compound followed by crude fibres (13.07%), total ash (10.45%), crude protein (9.67%), total lipids (3.75%) and reducing sugars (5.14%) on a dry weight basis. Abd EL-Latif et al., (1996), reported that the chemical compositions of potato processing waste obtained from potato processing mills were as follow: protein (8.10 %), reducing sugars (8.10 %), and ash (4.9 %).

The effect of fermentation parameters on biomass production

The Incubation period

The influence of incubation period on the fermentation parameters was investigated. Maximum protein production and biomass yield were obtained when the culture medium was kept at 30 °C. The result showed that the maximum crude protein production occurred at 48 h of the fermentation period and no further changes were observed at 60 and 72 h (Table 1). Adoki, (2008) studied Candida species in waste conversion for SCP-enriched feed supplement production and found maximum biomass production after 96 h of fermentation, which was comparable with others. Ravinder et al. (2009) studied the effect of the fermentation period on production. The effect of the incubation period on the fermentation process was studied. Biomass produced by Candida utilis was significantly the highest (9.25 g/L), biomass yield from reducing sugars (0.63 g), and yeast yield efficiency ratio (45.88) after 3 days of the incubation compared to the other periods. Moreover, the extreme period, i.e., 1st and 2nd days of incubation period tended to reduce the yeast yield. The decrement of the cell yields after such a suitable incubation period could be explained based on of cell lysis which may attribute to the substrate consumption within 3 or 4 days where the additional growth of yeast was assumed to be accomplished at the expense of yeast biomass. No significant difference in protein percentage was found among the 2nd, 3rd and 4th days of incubation period. This incubation period was also recommended by Irfan et al. (2011) on *C. utilis* and Midney, (1997), on Saccharomyces cerevisiae. Kurbanoulu, (2000), illustrates the biomass yields of *C. utilis* NRRL Y- 900 when were grown for different periods. The maximum biomass yield and protein percentage were obtained after 72 hrs, which recorded 6.8 g l-1 and 49.8%; respectively. Somda et al., (2018) reported that 72 hrs of incubation was sufficient to give the highest biomass yield (6.48±0.03 g/L).

Table 1. *Proximate composition of dried potato processing waste*

Components[1]	Wet weight (%)	Dry weight (%)
Moisture	52.35 ± 0.00	0.00
Crude protein	4.61 ± 0.00	9.67
Ether extract	1.79 ± 0.00	3.75
Reducing sugars	2.45 ± 0.09	5.14
Total ash	4.98 ± 0.10	10.45
Crude fiber	6.23 ± 0.20	13.07
Total carbohydrates[2]	63.06 ± 0.00	30.04

1- Means ± standard deviation of means of three determinations.

2- Total carbohydrates= 100- (moisture+ crude protein+ crude lipids+ total ash+ crude fiber).

Incubation temperature

The results in Table (2) showed that 30°C was the optimal temperature for yeast growth, where it gave the significantly highest amount of biomass yield (9.45 g/L), consumption (86.81%), crude protein (45.30%) and yeast yield efficiency ratio (46.92%). Increasing and decreasing in cultivation temperature (25 and 35°C) caused a decrease in biomass produced by Candida utilis (7.79 and 7.93 g/L); respectively. Babu and Ilyas, (2017) and Yunus et al., (2015) revealed that maximum protein production and cell growth were observed at 30 °C as an optimum incubation temperature (EL-Masry et al., 1991); but the biomass yield was higher (9.45 g/L) compared to (4.98 g/L) in the literature. Also, Husseiny et al. (2016) revealed that average temperatures 28ºC to 32ºC were efficient in producing biomass and protein by mixed fermentation by A. niger and C. utilis. Rajoka et al. (2005) reported that, when incubation temperature increased above 35°C, the production of crude protein gradually decreased. However, using low incubation temperature (25°C), led to the enzyme activities being expectedly a low giving no impact on the enhancement of crude protein productivity. Normally high temperature can cause the inactivation of enzymes of the metabolic pathways; while low the temperature may not permit flow of nutrients across cell membrane, resulting in high demand for maintenance energy. Also, the data in Table (4) indicated that the highest protein content was observed at the same temperature (30ºC) which recorded 45.30%; while decreased significantly at 25 or 35ºC.

Table 2. *Influence of incubation period on biomass and protein production by Candida utilis*

Fermentation parameters	Incubation period (hrs.)*			
	24	48	72	96
Biomass produced (g/L)	4.66^{d}	6.43^{c}	9.25^{a}	8.15^{b}
Residual sugars (g/L)	5.86^{a}	3.66^{bc}	3.03^{c}	2.25^{d}
Reducing sugar consumed (g/L)	17.33^{c}	19.53^{b}	20.16^{ab}	20.90^{a}
Reducing sugar uptake rate (g/L.h)	0.72^{a}	0.41^{b}	0.28^{c}	0.22^{d}
Consumption (%)	74.69^{d}	84.19^{c}	86.89^{b}	90.08^{a}
Specific productivity of protein (g/g cell. h)×10^{-2}	1.60^{a}	0.94^{b}	0.63^{c}	0.47^{d}
Biomass yield from reducing sugar (g/g)	0.27^{c}	0.32^{bc}	0.46^{a}	0.39^{b}
Specific growth rate (g/L.h)	0.19^{a}	0.13^{b}	0.13^{b}	0.09^{c}
Yield as of theoretical value (%)	0.54^{d}	0.66^{c}	0.92^{a}	0.78^{b}
Crude protein (%)	38.49^{b}	45.16^{a}	45.30^{a}	44.97^{a}
Total crude protein (g/L)	1.79^{d}	2.90^{c}	4.19^{a}	3.66^{b}
Yeast yield efficiency ratio	26.88^{d}	32.92^{c}	45.88^{a}	38.99^{b}

* Values are means of three determinations.

Values having the same case letter(s) within rows are not significantly different (P>0.05).

Fermentations conditions: Reducing sugars content 23.2 g/L, Shaking rate 150 rpm, Ammonium sulphate 0.429 g/L, Inoculum size 4% (v/v) and Initial pH 5.

pH

The biomass yield of *C. utilis* after grown on various pH values are shown in Table (3). The highest biomass yield, consumption, biomass yield from reducing sugar and yeast yield efficiency ratio were obtained at pH 5.0. Similar results were also found by Mohamed, (1999), who found that highest biomass obtained when the pH was adjusted to 5.0. Adoki, (2008), reported that optimum growth condition for *C. utilis* cultivated on orange, plantain and banana processing wastes was at pH 4.6 which is nearly in agreement with these data. At pH 4.5, 5.0 and 5.5, very low protein content was detected comparing with pH

at 4.0 and 6.0. This may be due to the effect of neutral pH values (6-7) on biomass and protein formation comparing with acidic or alkaline pHs. Also, a parallel decrease in fermentation products (growth yields, protein production) was recorded as the pH value from 6-3 (El-Deek et al., 2009). Jalasutram et al., (2013) found that low protein percentage was detected due to inhibition of enzymatic activities that contribute to the protein production at high alkaline and acidic pHs.

Table 3. *Influence of incubation temperature on biomass and protein production by Candida utilis*

Fermentation parameters	Incubation temperature (C)*		
	25	30	35
Biomass produced (g/L)	7.79^{b}	9.45^{a}	7.93^{b}
Residual sugars (g/L)	3.42^{b}	3.06^{b}	4.20^{a}
Reducing sugar consumed (g/L)	19.78^{a}	20.14^{a}	18.99^{b}
Reducing sugar uptake rate (g/L.h)	$0.27^{N.S}$	0.28	0.26
Consumption (%)	85.25^{b}	86.81^{a}	81.85^{c}
Specific productivity of protein (g/g cell.h)×10^{-2}	0.59^{b}	0.63^{a}	0.60^{b}
Biomass yield from reducing sugar (g/g)	0.39^{b}	0.47^{a}	0.42^{b}
Specific growth rate (g/L.h)	0.11^{b}	0.13^{a}	0.11^{b}
Yield as of theoretical value (%)	0.79^{a}	0.56^{b}	0.57^{b}
Crude protein (%)	42.71^{b}	45.30^{a}	43.01^{b}
Total crude protein per liter	3.32^{b}	4.28^{a}	3.41^{b}
Yeast yield efficiency ratio	39.38^{c}	46.92^{a}	41.75^{b}

*Values are means of three determinations.

Values having the same case letter(s) within rows are not significantly different (P>0.05).

Fermentations conditions: Reducing sugars content 23.2 g/L, Shaking rate 150 rpm, Incubation period 3 days, Ammonium sulpahte 0.429 g/L, Inoculum size 4% (v/v) and Initial pH 5.

Inoculum size

The data presented in Table (4) showed the effect of different inoculum size on the growth and protein content of *C. utilis*. The obtained results revealed that the highest biomass yield (9.32 g/L) and total crude protein per liter (4.01) were obtained at inoculum size 4% (v/v). No significant difference was found for biomass yield obtained at 6.0 and 8.0% inoculum size; both came in the second order. While, biomass yield obtained at 2.0 and 10.0% inoculum size were significantly the lowest. The attainment of optimum growth at the production stage could depend on the inoculum age and size of the seed culture because they can affect the overall production yield and cost of the fermentation process (Fatemeh et al., 2019). Kurbanoulu, (2000) cultivated *C. utilis* NRRL Y-900 on horn hydrolysate with inoculum volume 5% (v/v). Yunus et al., (2015) used *C. utilis* and *Rhizopus oligosporus* as the microbial culture and wheat bran as the substrate and found that an inoculum size of 10% v/v can lead to the production of the highest level of protein.

Table 4. *Influence of pH values on biomass and protein production by Candida utilis*

Fermentation parameters	pH value				
	4.0	4.5	5.0	5.5	6.0
Biomass produced (g/L)	7.63^{b}	7.95^{b}	9.87^{a}	8.42^{b}	7.86^{b}
Residual sugars (g/L)	6.77^{a}	3.57^{b}	3.15^{c}	3.42^{bc}	4.08^{b}
Reducing sugar consumed (g/L)	16.43^{c}	19.63^{ab}	20.04^{a}	19.78^{a}	19.14^{b}
Reducing sugar uptake rate (g/L.h)	0.23^{c}	0.27^{ab}	0.28^{a}	0.27^{ab}	0.27^{ab}
Consumption (%)	70.81^{d}	84.61^{b}	86.40^{a}	85.25^{ab}	82.50^{c}
Specific productivity of protein (g/g cell.h)×10^{-2}	0.67^{a}	0.56^{c}	0.60^{b}	0.59^{b}	0.65^{ab}
Biomass yield from reducing sugar (g/g)	0.46^{ab}	0.40^{c}	0.49^{a}	0.42^{b}	0.41^{c}
Specific growth rate (g/L.h)	$0.11^{N.S}$	0.11	0.14	0.11	0.11
Yield as of theoretical value (%)	0.93^{ab}	0.81^{b}	0.98^{a}	0.84^{b}	0.82^{b}
Crude protein (%)	48.32^{a}	40.57^{d}	42.90^{c}	43.09^{c}	46.96^{b}
Total crude protein per liter	3.68^{b}	3.22^{c}	4.23^{a}	3.62^{b}	3.69^{b}
Yeast yield efficiency ratio	46.43^{b}	40.49^{d}	49.25^{a}	42.56^{c}	41.06^{cd}

Values are means of three determinations.

Values having the same case letter(s) within rows are not significantly different (P>0.05).

Fermentations conditions: Reducing sugars content 23.2 g/L, Shaking rate 150 rpm, Incubation period 3 days, Ammonium sulpahte 0.429 g/L, Inoculum size 4% (v/v) and Temperature 30 °C.

Optimizing single cell protein production from potato processing waste hydolysate via bioreactor and shaking flasks comparing with standard glucose medium

Apparent from the results that, bioreactor method significantly gave the highest biomass yield followed by shaking method (potato processing waste hydrolysate), then shaking method (standard glucose medium). It may be due to that potato processing waste hydrolysate contained some nutrients caused enhancing for yeast growth and crude protein formation compared with standard glucose medium. While, shaking method (potato processing waste hydrolysate) Significantly gave the highest protein percentage followed by bioreactor method at the same medium, then shaking method (glucose medium). It may be due to that bioreactor method gave optimum aeration level for yeast growth to give maximum biomass yield. While, yeast didn't utilize all aeration levels to give the optimum protein formation. Meanwhile, glucose medium gave the significantly lowest biomass yield and protein content. These results are not agreed with Parajó et al., (1995), who reported that, no significant difference of biomass yield was detetcted between wood hydrolysate medium and standard glucose medium under the optimum growth conditions.

The comparison of the obtained data presented in Table 5 demonstrates that bioreactor method significantly gave the highest yield of biomass. This may be due to the availability of optimum aeration level which encourage yeast propagation. On the other hand, shaking method of potato processing medium gave the highest protein content; it may be due to aeration levels were low comparing to aeration levels in bioreactor method wherewith caused reduction in biomass production. Contrarily, the results of standard glucose medium were the lower significantly comparing with the potato processing waste hydrolysate medium. This may be due to that potato processing waste hydrolysate medium contained natural components and mineral salts that could enhance yeast stability and growth.

Table 5. *Influence of inoculum size on biomass and protein production by Candida utilis*

Fermentation parameters	Inoculum size (mL/100 mL) *				
	2.0	4.0	6.0	8.0	10.0
Biomass produced (g/L)	6.14^{c}	9.32^{a}	7.15^{b}	6.92^{b}	6.20^{c}
Residual sugars (g/L)	8.11^{a}	5.15^{d}	5.82^{c}	5.92^{c}	7.13^{b}
Reducing sugar consumed (g/L)	15.09^{d}	18.05^{a}	17.38^{b}	17.28^{b}	16.07^{c}
Reducing sugar uptake rate (g/L.h)	0.21^{b}	0.25^{a}	0.25^{a}	0.24^{ab}	0.22^{b}
Consumption (%)	65.04^{c}	77.80^{a}	74.91^{b}	74.48^{b}	69.26^{bc}
Specific productivity of protein (g/g cell.h)×10^{-2}	0.60^{a}	0.60^{a}	0.60^{a}	0.59^{b}	0.59^{b}
Biomass yield from reducing sugar (g/g)	0.41^{b}	0.52^{a}	0.41^{b}	0.40^{bc}	0.39^{c}
Specific growth rate (g/L.h)	0.09^{c}	0.13^{a}	0.10^{bc}	0.10^{b}	0.09^{c}
Yield as of theoretical value (%)	0.81^{b}	1.03^{a}	0.82^{b}	0.80^{c}	0.77^{d}
Crude protein (%)	43.15^{a}	43.06^{a}	43.00^{a}	42.25^{b}	42.50^{b}
Total crude protein per liter	2.65^{c}	4.01^{a}	3.07^{b}	2.92^{b}	2.63^{c}
Yeast yield efficiency ratio	40.68^{bc}	51.63^{a}	41.13^{b}	40.04^{c}	38.58^{d}

*Values are means of three determinations.

Values having the same case letter(s) within rows are not significantly different (P>0.05).

Fermentations conditions: Reducing sugars content 23.2 g/L, Incubation period 3 days, Ammonium sulpahte 0.429 g/L, Inoculum size 4% (v/v), Temperature 30 °C, pH 5 and shaking rate 200 rpm.

Chemical composition of biomass produced by Candida utilis

Data presented in Table (6) show chemical composition of biomass produced by *C. utilis* NRRL Y-900 calculated on wet and dry weight basis. The results revealed that crude protein recorded the highest amount of the sample (57.18 % on dry basis). Total carbohydrate was the second component which recorded 32.75 % on dry basis. Ash content was 10.06 %. These results are concurrent with reported by Hamad et al., (2016), who reported that protein content recorded 48.9% for *C. utilis* NRRL Y-1084. Total carbohydrate was ranged between 35.3 and 38.7%. Total ash ranged between 4.8 and 5.8%. Adedayo et al., (2011) reported 5-9.5% ash content in yeasts.

Nucleic acid contents of SCP were found to be 4.47%. These values are less than findings of Midney, (1997), who revealed that nucleic acids content of *Candida arborea* ranged between 7.81 to 9.02 % on dry weight basis. Also, the obtained data had nucleic acids lower than that reported by Somda et al., (2018) *C. utilis* FMJ12 cultivated on mango wastes under solid state fermentation condition revealed nucleic acids contents; 5.28±0.20– 6.60±0.25 % on dry weight basis. Meanwhile, the high nucleic acids contents considered to be toxic for human consumption, but harmless for most of animals. Most of microbial strains nucleic acids content ranged between 6 to 15%. Thus, using *C. utilis* biomass in animal feed is very attractive.

Table 6. *Optimizing single cell protein production from potato processing waste hydolysate via bioreactor and shaking flasks comparing with standard glucose medium*

Fermentation parameters	Shaking experiment		Bioreactor experiment
	Potato waste hydrolysate medium	Standard glucose medium	Potato waste hydrolysate medium
Biomass produced (g/L)	12.50^{b}	10.65^{c}	18.07^{a}
Residual sugars (g/L)	6.19^{a}	0.90^{c}	2.91^{b}
Reducing sugar consumed (g/L)	23.40^{b}	28.7^{a}	26.69^{ab}
Reducing sugar uptake rate (g/L.h)	0.33^{c}	0.40^{a}	0.37^{b}
Consumption (%)	79.06^{c}	96.95^{a}	90.16^{b}
Specific productivity of protein (g/g cell.h)$\times 10^{-2}$	0.79^{a}	0.50^{b}	0.77^{a}
Biomass yield from reducing sugar (g/g)	0.54^{b}	0.37^{c}	0.68^{a}
Specific growth rate (g/L.h)	0.17^{b}	0.15^{b}	0.25^{a}
Yield as of theoretical value (%)	1.08^{ab}	0.74^{b}	1.35^{a}
Crude protein (%)	57.19^{a}	36.23^{c}	55.69^{b}
Total crude protein per liter	7.14^{b}	3.85^{c}	10.06^{a}
Yield efficiency ratio	53.41^{b}	37.10^{c}	67.70^{a}

Values are means of three determinations.

Values having the same case letter(s) within rows are not significantly different (P>0.05).

Fermentation conditions: Reducing sugars content 29.6 g/L, Initial pH 5.0, Incubation period 3 days, Inoculum volume 4 %(v/v), Shaking rate 200 rpm, 500 rpm for bioreactor experiment, Temperature 30 °C and corn steep liquor 80 mL/L+20 ml mineral salts mixture.

Control conditions: Reducing sugars content 29.6 g/L, Initial pH 5.0, Incubation period 3 days, Inoculum volume 4 %(v/v), Shaking rate 200 rpm, Temperature 30 °C and corn steep liquor 80 mL/L+20 mL mineral salts mixture.

Amino acids composition of SCP from Candida utilis NRRL Y-900

Table (7) showed that, the biomass cells contain essential and non-essential amino acids. It can be concluded that fermentation parameters have significantly affects single cell protein and essential amino acids productivity by *C. utilis* NRRL Y-900. Amino acid concentrations; as isoleucine, leucine, lysine, phenylalanine, threonine, methionine, and valine gave high values comparing with the FAO reference protein and necessary for nutritional demands. Among the amino acids, glutamic acid (8.13%) and aspartic acid (6.79%) were the most abundant dispensable amino acids produced after optimizing fermentation parameters via bioreactor design experiment comparing with FAO reference These results agree with the findings of Somda et al., (2018) who found that the maximum biomass yield production were by yeast strain (*C. utilis*). The prospect of nutritional value of SCP was determined according to amount of lysine and methionine amino acids (Kurbanoglu, 2000). Zheng et al., (2005) and Rajoka et al., (2005) reported that, produced biomass of *C. utilis* consists of all amino acids that are essential for human nutrition, hence our results prove that strain *C. utilis* NRRL Y-900 was appropriate for single-cell protein production.

Table 7. *Chemical composition of biomass produced by Candida utilis*

Components	**Biomass yield***	
	Wet weight	**Dry weight**
Moisture	8.59	0.0
Dry matter	91.41	99.99
Crude protein	52.27	57.18
Ether extract	0.0	0.0
Ash	9.20	10.06
Total carbohydrates	29.94	32.75
Available carbohydrates	29.94	32.75
Crude fibers	0.0	0.0
Nucleic acids	4.08	4.47

*Values are means of three determinations

Table 8. *Amino acids content (g amino acid / 100 g protein) of Candida utilis protein and casein as a reference protein*

Amino acids	***Candida utilis*** **NRRL Y-900**	**FAO Reference**
Indispensable amino acids		
Valine	4.00	4.20
Leucine	5.76	4.80
Isoleucine	3.67	4.20
Phenylalanine	4.02	2.80
Threonine	4.46	2.80
Methionine	1.09	2.20
Lysine	5.69	4.20
Total indispensable A. A	28.69	
Dispensable amino acids		
Aspartic acid	6.97	-
Glutamic acid	8.13	-
Serine	4.11	-
Proline	3.06	-
Glycine	3.46	-
Alanine	4.67	-
Cystine	1.09	2.00
Tyrosine	3.37	2.80
Arginine	3.89	-
Histidine	1.67	-
Total dispensable A. A	40.42	
Total amino acids	69.11	

CONCLUSION

Bioconversion of potato processing wastes have an economically advantageous and reduction of the environmental pollution. Since it contributes a source of polysaccharides that can be hydrolyzed using acid or enzymatic hydrolysis to simple sugars (glucose). The obtained hydrolyzate can be used as a good source for *C. utilis* NRRL Y-900 cultivation for obtaining single cell protein. The resulted biomass had high amount of protein that can be used in animal feed fortification. Also, it can be used as a good source of protein for human nutrition after reducing its content of nucleic acids.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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