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Unlocking the Potential of Agro-Waste: Cucurbita pepo Peel as a Superior Fermentation Medium for Yeast Production

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INTRODUCTION & AIM

The escalating global population and industrialization have placed immense pressure on natural resources, concurrently leading to a surge in agro-industrial waste generation. The conventional disposal methods for these byproducts often entail significant environmental burdens and economic losses, prompting an urgent need for sustainable and innovative valorization strategies. Repurposing these wastes into valuable products aligns with the principles of the circular economy, offering dual benefits of waste reduction and resource creation. Within this paradigm, the transformation of low-cost, readily available agricultural residues into fermentation feedstocks for microbial biomass production, such as *Saccharomyces cerevisiae*, represents a particularly promising avenue, contributing to both environmental sustainability and industrial economic viability.

Saccharomyces cerevisiae, commonly known as baker's yeast, is a ubiquitous microorganism with extensive applications across various industries, including food and beverage, biofuel production, and pharmaceuticals, primarily due to its metabolic versatility and robust growth characteristics. Industrial-scale production of *S. cerevisiae* biomass traditionally relies on relatively expensive and often edible carbon sources, such as molasses or glucose. This reliance creates a direct competition with food security and can significantly impact production costs. Therefore, the exploration of alternative, non-edible, and economically viable substrates for yeast cultivation is imperative to enhance the sustainability and cost-effectiveness of *S. cerevisiae* biomass production, paving the way for more resilient bioprocesses.

Among the vast array of agricultural wastes, *Cucurbita pepo* (pumpkin) peel stands out as a promising candidate. Annually, substantial quantities of pumpkin are processed, generating significant amounts of peel that are largely underutilized or discarded. This byproduct is rich in carbohydrates and other essential nutrients, making it a potentially excellent substrate for microbial fermentation. This study aimed to investigate the valorization potential of *Cucurbita pepo* peel as a low-cost and sustainable fermentation medium for the production of *Saccharomyces cerevisiae* biomass. We conducted a comprehensive comparative analysis of the peel extract's performance against the more valuable pumpkin pulp juice, while also optimizing key fermentation parameters, including initial sugar concentration and the influence of various nitrogenous sources, to maximize yeast yield and productivity.

METHOD

2.1. Plant Material and Sample Preparation

Cucurbita pepo peel (cultivated in Algeria) was purchased from various agricultural product joint markets within the Biskra region of Algeria in July, 2025. The Cucurbita pepo were manually peeled, and the peel fraction was isolated. The peels were washed extensively with destilled water and then subjected to open-air drying at ambient temperature (25°C) until completely dry. The dried material was subsequently pulverized into a fine powder using an electronic home grinder for 20 minutes. The resulting powder was then passed through a sieve (0.5 mm) to obtain a uniform particle size.

2.2. Extraction of *Cucurbita pepo* peel sugar

For extraction of the sugars from the peel, the samples were subjected to heat treatment with hot air at different temperatures (60, 100, and 140°C) and different substrate loading (5, 10, and 15%) in an Universal Oven UF55 (Memmert, Germany) with an incubation time of 1h. The peel juice obtained was filtered and centrifuged at 4000 rpm for 20 min. A suitable portion of *Cucurbita pepo* peel fruit peel juice was diluted to the desired concentration of reducing sugars for use as the carbon source in the fermentation medium.

2.2. Extraction of *Cucurbita pepo* pulpe sugar

The fruits pulps were manually cut into cubes and desiccated for 72 h at 60°C in a drying oven with a cold air current. The ratio of added tap water and dried fruit pulp was 2:1. Heat was applied to the mixture at a temperature of 100 °C for 45 min with constant stirring. The solid residue was separated by filtration. Cellulosic debris was separated from the mixture using a centrifuge at 4000 rpm for 20 min, while the supernatant was used later as the carbon source in the fermentation mediums.

2.3. Microorganism and growth media

The yeast strain Saccharomyces cerevisiae (S. cerevisiae) ATCC 4226 used in this study was maintained at 4°C on Luria-Bertani agar medium (LBAM) containing the following components (g/L): peptone, 10 (Sigma); NaCl, 10 (Prolabo); glucose, 20 (Sigma); yeast extract 5 (Biokar) and agar, 15 (Sigma). The culture was periodically sub-cultured to maintain the cultures active and suitable for fermentation.

2.4. Fermentations

Cultures were activated in the semi-synthetic medium (SSM) containing (g/L): glucose, 10 (Sigma); yeast extract, 0.5 (Biokar); (NH4) 2SO 4, 10 (Sigma); MgSO 4.7H 2O, 3 (Merck); KH 2PO 4, 6 (Sigma); NaCl, 0.1 (Prolabo); CaCl 2.H 2O, 0.1 (Fluka). In all the experiments, the inocula were prepared by incubation at 30 ºC; a fermentation medium containing Cucurbita pepo peel juice served as the carbon source. Then, pumpkins peel juice was supplemented with different nitrogen sources: yeast extract (Biokar), ammonium sulfate (Sigma), urea (Sigma), peptone (Sigma), casein hydrolysate (Sigma) and corn steep liquor (Sigma). The nitrogen sources were tested individually at equivalent 0.217% nitrogen level (nitrogen concentration in SSM). From the results, the initial Cucurbita pepo peeljuice sugar concentration was 50 g/L. The pH of the production medium (OFI juice) was adjusted to 4.5 prior to sterilization. The solutions of nitrogen sources were sterilized separately. Fermentations were done in 500 mL Erlenmeyer flasks containing 50 mL medium. All experiments were conducted in triplicate.

RESULTS & DISCUSSION

3.1. Cell mass production from Cucurbita pepo fruit peel juice

The potential of Cucurbita pepo fruit peel juice as a fermentation substrate was determined after a heat temperature extraction step. The capacity of S. cerevisiae for cell mass production was tested in a medium containing Cucurbita pepo fruit peel juice as the carbon source using the optimal conditions obtained with the production of cell mass from Cucurbita pepo fruit juice (inoculum age, 24 h; temperature, 30 °C and agitation, 200 rpm). To investigate the influence of initial sugar concentration on cell mass production, S. cerevisiae was cultivated for 24 h with Cucurbita pepo fruit peel juice at various sugar concentrations (2.5 to 15%).

Table 1 Kinetic parameters of growth of S. cerevisiae using different sugar concentrations of *Cucurbita pepo* fruit peel sugar;

Sugar concentration (%)	Cell mass (g/L)	Yield (g/g)	Productivity (g/L/h)
2.5	1.3	0.54	0.1
5	6.4	0.32	0.34
10	12.5	0.13	0.54
15	12.8	0.17	0.44

3.2 Effect of nitrogen source on cell mass production

The availability and type of nitrogen are critical determinants of yeast growth and metabolic activity, impacting the synthesis of vital compounds such as amino acids and enzyme cofactors. Our findings clearly demonstrate that the choice of nitrogen source profoundly influences the final cell mass achieved during baker's yeast cultivation.

Table 2. Kinetic parameters of growth of S. cerevisiae on *Cucurbita pepo* juice supplemented with different nitrogen sources.

Cucurbita pepo juice	Cell massa (g/L)	Yield (g/g)	Productivity (g/L/h)
fruit juice + Urea	26.43	0.29	0.45
fruit juice + $(NH_4)_2SO_4$ +yeast extract	20.24	0.38	0.34
fruit juice + Peptone	28.53	0.25	0.49
Peel juice + Urea	25.45	0.27	0.48
Peel juice + $(NH_4)_2SO_4$ +yeast extract	20,83	0.36	0.42
Peel juice + Peptone	29	0.19	0.51

CONCLUSION

addressing the environmental impact of *Cucurbita pepo* waste, this research presents a strategy for its valorization through reuse, reprocessing, and conversion into beneficial products. We focused on the feasibility of producing baker's yeast from *Cucurbita pepo* waste, utilizing its sugars as a carbon source for Saccharomyces cerevisiae. Beyond the fruit, the study also establishes *Cucurbita pepo* peel as a promising, cost-effective substrate. Investigating various nitrogen sources for direct fermentation of *Cucurbita pepo* juice, we identified Corn Steep Liquor (CSL) as an optimal and economical replacement for more expensive alternatives like casein hydrolysate and yeast extract. Collectively, these findings strongly suggest that *Cucurbita pepo* juice holds considerable promise for industrial-scale baker's yeast production using S. cerevisiae.

FUTURE WORK / REFERENCES

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