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Integrated process standardisation as zero-based approach to bitter cassava waste elimination and widely-applicable industrial biomaterial derivatives

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ABSTRACT

Integrated standardised methodology for biopolymer derivatives (BPD) production from novel intact bitter cassava was demonstrated by desirability optimisation of simultaneous release, recovery, cyanogenesis (SRRC) process. BPD were evaluated for yield and colour using buffer (0, 2, 4% v/v), cassava waste solids (15, 23, 30% w/w), and extraction time (4, 7, 10 min). Nearly all the root was transformed into BPD, with higher yield and colour in comparison to starch extrinsically processed. Maximum global desirability, predicted efficient material balance, buffer 4.0% w/v, cassava waste solids 23% w/w and extraction time, 10 min, producing BPD yield, 38.8% wb Validation using buffer, 3.3% w/v, cassava waste solids, 30% w/w and extraction time, 10 min, produced 40.7% wb BPD. SEM, DSC, TGA, FTIR and moisture barrier analyses revealed a uniform microstructure and high thermal stability of BPD and film, thus demonstrating efficient performance of the standardised integrated methodology. Hence, processing intact cassava root as a standardised integrated methodology could be used to produce sustainable low cost BPD for a broad range of applications.

Methodologies designed around standard integrated procedures, matching zero-based approach to contamination, are novel strategies, and if used effectively can eliminate cassava wastes and recover BPD resources as sustainable biomaterials.

Contents

1. Introduction . . . 140
2. Materials and methods . . . 140
  2.1. Integrated process methodology for production of novel intact BC-BPD . . . 140
    2.1.1. Intact bitter cassava preparation . . . 140
    2.1.2. Integrated process methodology . . . 140
  2.2. Optimisation via desirability approach and statistical analysis . . . 141
    2.2.1. Factorial and box-behnken response surface experimental design . . . 141
    2.2.2. Simultaneous optimisation using desirability function . . . 141
  2.3. Standardisation of integrated process methodology by validation of optimal models' . . . 142
  2.4. Impact of standardisation on biopolymer derivatives and packaging film moisture barrier properties . . . 142
    2.4.1. Effect on total cyanide decontamination and BPD appearance . . . 142
    2.4.2. Microstructure and chemical . . . 142
    2.4.3. Thermal . . . 142
    2.4.4. Moisture adsorption . . . 143

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2.4.5. Film preparation . . . 143
2.4.6. Film moisture barrier characterisation . . . 143
2.4.7. Moisture barrier modelling . . . 143
3. Results and discussion . . . 143
3.1. Integrated process methodology for production of novel intact bitter cassava biopolymer derivatives (BC-BPD) . . . 143
3.2. Optimisation of BPD production by desirability . . . 143
3.3. Standardisation of integrated process methodology by validation of optimal models' . . . 144
3.3.1. Optimal model's validation . . . 144
3.3.2. Standardisation of integrated process methodology . . . 146
3.4. Impact of standardisation on biopolymer derivative properties and packaging film moisture barrier properties . . . 146
3.4.1. Appearance . . . 146
3.4.2. BPD dull colour and total cyanogen decontamination . . . 146
3.4.3. Microstructure and chemical . . . 147
3.4.4. Thermal . . . 148
3.4.5. BPD moisture adsorption behaviour . . . 148
3.4.6. Film moisture barrier properties . . . 148
4. Conclusion . . . 149
Acknowledgements . . . 149
References . . . 149

1. Introduction

Environment-borne cassava wastes represent a potential economic source of biopolymer derivative cellulose, hemicellulose, pectin, lignin and starch [6,21]. Cassava waste solids could support the sustainable production of low-cost industrial bioproducts such as food and non-food added value products. The global turnaround concept of regarding waste as a worthless material to the idea of a high demand secondary material resource has widened value-added waste research. Currently, research emphasis is focused more on waste minimisation than waste recycling [18].

Among the cassava varieties, bitter cassava contributes a greater amount of disposed environmental waste, >16% [36] as compared to sweet cassava, 0.5% [16]. Unfortunately, bitter cassava (BC) waste minimisation, has not yet received much attention, therefore the environmental accumulation of BC wastes has been inevitable. Traditionally, there have been initiatives to transform BC into food and other low-value products such as fermented crude ethanol and flour [35], gari [1]. However, total cyanogens, inherent in these varieties and poor processing methodologies have impeded the efforts with negative environment impacts. Meanwhile, sweet cassava starch production, using reinforcements and modifications of biopolymer derivatives (SC-BPD) for various applications have also been studied [27,38]. Although, such procedures require high energy leading to higher production costs. Moreover, starch processing using added cellulose materials, have been limited by non-uniformity and less compatibility [5,25], requiring further additional chemical and physical modifications and costs. Recently, a novel methodology, using simultaneous release, recovery and cyanogenesis (SRRC), to transform intact BC wastes into safe (total cyanogens, <1.0 ppm) BPD with significant high yields, has been reported [36]. Due to these findings, SRRC methodology could be successfully employed to produce safe intact BC-BPD.

Standardising methods of producing materials could ease the choice and cost of formulations, by defining the design space [8,14], processing parameters and material functional properties, which could lead to the engineering design of tailored food and non-food added value products. Design of experiments (DOE) has been successful in simultaneous investigation of the effect of multiple variables, to determine the most efficient and economic matrix formulations needed for optimal formulations [30,2,33]. Robust production processes provide methodologies for balancing desired material properties with processing parameters, marginal costs and maximum functionality. Desirability function approach is extensively employed in the optimization of multiple response processes, in which the operating parameters provide the "most desirable" responses [20,22]. In this study "Pareto front approach" was explored to determine possible optimal solutions known as Pareto solutions or Pareto fronts. According to [34], allocations to parameter choices are made in such a way that tradeoffs ensure unequal distribution, in which one factor is constrained in place of the alternative so as to find feasible choices that lie on the Pareto front. It is worth noting that choices on a Pareto frontier are Pareto efficient and non-dominated by any other choice.

In order to broaden ways of modifying native polysaccharides and produce new materials for the utilisation of cassava in food packaging and other potential industries, customised methods that ensure combined release of BPD are necessary.

To the best of our knowledge SRRC, integrated process, optimisation of BC-BPD production, to minimise production costs, and standardisation of design methodology have not been studied. Thus, it was justifiable to develop a standardised integrated sustainable low-cost methodology to produce BPD from novel intact BC root.

The purpose of this study was to develop an integrated standardised process methodology for novel intact BC-BPD recovery, and evaluate its impact on BPD. The optimum processing parameters necessary to obtain maximum yield and colour as defined by maximum global desirability, and development of a standardised methodology by validation of optimal BPD were investigated. The potential of applying BC-BPD as food and non-food material was determined by assessing the effect of standardised methodology on BPD's quality (physical, chemical and safety), and film moisture barrier characteristics.

2. Materials and methods

2.1. Integrated process methodology for production of novel intact BC-BPD

2.1.1. Intact bitter cassava preparation

Bitter cassava, Tongolo, procured from farmers' fields, Northern Uganda was separated from soil debris, placed in ice boxes, transported to the laboratory and kept at −20 °C for further use.

2.1.2. Integrated process methodology

Production of biopolymer derivatives followed the procedure developed earlier for peeled and intact roots via the simultaneous release, recovery and cyanogenesis (SRRC) process [36] with slight