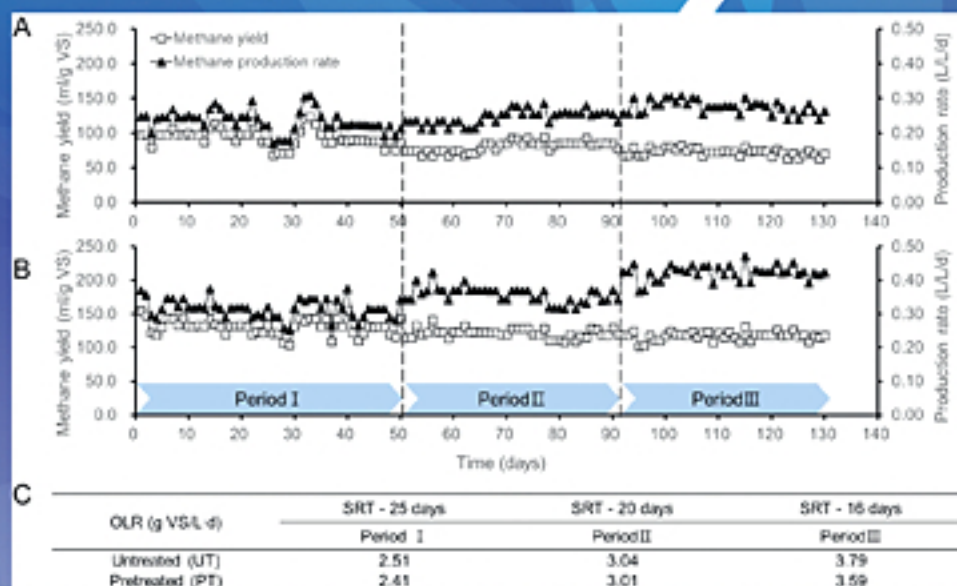


# BIORESOURCE TECHNOLOGY

applied microbiology ■ bioconversion/biocatalysis ■  
 biofuels ■ biological engineering ■ biological waste treatment ■  
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## Effect of pH on volatile fatty acid production from anaerobic digestion of potato peel waste

Yu Lu, Qi Zhang, Xiangyou Wang, Xiaonan Zhou, Jiyong Zhu

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# Effect of pH on volatile fatty acid production from anaerobic digestion of potato peel waste



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## ARTICLE INFO

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Potato peel waste  
Volatile fatty acid production  
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## ABSTRACT

In this study, potato peel waste was used as feedstock to produce volatile fatty acids (VFAs) by anaerobic digestion. The effects of different pH levels (pH 5.0, pH 7.0, pH 11.0, and uncontrolled pH) on VFA concentration and composition, intermediate products, and metabolic state were evaluated. The results showed that the highest total VFA production was achieved with pH 7.0 (41.9 g COD/L and 632.2 mg COD/g VS<sub>red</sub>), followed by that with uncontrolled pH. Butyric acid was the dominant product under acidic pH, whereas acetic acid dominated under alkaline pH. The type of acidogenic fermentation at pH 7.0 was the mixed-acid type. The change in NADH level in the mixed-acid type of fermentation consisted of small fluctuations, enhancing the stability and efficiency of fermentation. The enzymatic activities of acetate kinase and butyrate kinase were slightly inhibited at pH 5.0 and 11.0, resulting in relatively low VFAs production.

## 1. Introduction

Nearly one-third of global food production—from agricultural production to consumers—is lost or wasted annually (Food and Agriculture Organization of the United Nations, 2011). China has a small food waste per capita (55 kg annually), but owing to its large population base, total food waste is about 195 Mt annually (Braguglia et al., 2018). About 56% of food waste in China is attributed to vegetables and fruits, which are identified as high-potential sources for generating valuable compounds (Braguglia et al., 2018; Sindhu et al., 2019). With the strategy of developing potato as a staple food in China, potato as a major food crop has become an increasingly essential vegetable in the human diet. About one-third of potatoes are used for fresh consumption (Zhu et al., 2016). With regard to transport and storage, some decaying or germinating potatoes have to be discarded; with regard to daily consumption, most potatoes need to be peeled, resulting in a large amount of potato peel residue. Potato waste residue has high contents of moisture and starch, protein, non-starch polysaccharide, and other nutrients, rendering it ideal as a carbon source for fermentation (Liang et al., 2016; Sepelev and Galoburda, 2015). It can be used to produce lactic acid by mixed culture fermentation (Liang et al., 2015; Liang et al., 2016), as culture media for bacterial cellulose production (Abdelraof et al., 2019), as feedstock for biobutanol or bioethanol production (Chohan et al., 2020; Hijosa-Valsero et al., 2018; Khawla et al., 2014), as base materials for biodegradable films (Xie et al.,

2020.), as a potential source for the extraction of steroidal alkaloids and starch (Hossain et al., 2014; Torres et al., 2020), as a precursor to synthesizing biochar (Sun et al., 2017; Yang, et al., 2018), and for biogas production by anaerobic digestion (AD) (Liang et al., 2015; Liang and Mcdonald, 2015).

An alternative approach to potato waste management is AD, which consists of a series of reactions: hydrolysis, acidogenesis, acetification, and methanogenesis. Notably, hydrolysis and acidogenesis of mono-phasic digesters for potato waste can be completed quickly, resulting in the rapid accumulation of volatile fatty acids (VFAs) and further inhibiting the activity of methanogenic microorganisms (Kaparaju and Rintala, 2005; Pistis et al., 2013). Compared with end products (methane), intermediate products — VFAs, can be more valuable substrates for some advanced products (Dai et al., 2020). Thus, potato peel waste (PPW) is an ideal feedstock for the production of VFAs by mixed culture fermentation. There are some advantages in this way, including ease of degradation, thus requiring no pretreatment, and the lack of need for an additional methanogenic inhibitor to stop the conversion of short-chain fatty acids to methane.

As potential and renewable carbon sources, VFAs can have wider applications, such as the biosynthesis of polyhydroxyalkanoates (PHAs) (Lee et al., 2014), biological removal of nutrients from wastewater (Zheng et al., 2010; Li et al., 2011), or bioenergy (Fei et al., 2011; Zong et al., 2009). Controlling the composition of VFAs affects the performance of downstream processing (Jankowska et al., 2015). Bengtsson

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### Effects of initial microbial community structure on the performance of solid-state anaerobic digestion of corn stover

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# Effects of initial microbial community structure on the performance of solid-state anaerobic digestion of corn stover

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## ABSTRACT

High organic loading can easily lead to the accumulation of volatile fatty acids (VFAs) during the early stage of solid-state anaerobic digestion (SS-AD). The accumulated VFAs inhibit the activity of methanogens resulting in digestion failure. This problem represents a major obstacle to the industrialization of SS-AD. A strategy to improve the initial microbial community structure was proposed to prevent acid inhibition in the early stage of SS-AD. To obtain inocula with different initial microbial community structures, the inoculum was treated with acetic acid to increase the abundance of acid-tolerant methanogens and then mixed with the untreated inoculum in different proportions. The effects of the initial microbial community structure on the performance of SS-AD of corn stover were investigated. The results showed that the concentrations of VFAs in the reactors inoculated with the acid-tolerant inoculum alone (treatment 100%) were significantly lower than those of the reactors inoculated with the original inoculum alone (treatment 0%) during the early stage of SS-AD. The peak values of the methane contents and daily methane yields of the reactors inoculated with the acid-resistant inoculum occurred on day six, which was four days earlier than in the reactors inoculated with the original inoculum alone. The results of this study verified that an appropriate initial microbial community structure prevented acid inhibition during the start-up stage and improved the performance of the SS-AD process.

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## 1. Introduction

As fossil energy sources are being depleted, the development of clean, renewable energy has become increasingly important. Lignocellulosic biomass resources, such as agricultural wastes and energy crops, are effective and promising alternatives to fossil fuels (Ahmad et al., 2018). After treatment by chemical, physical, or biological means, lignocellulosic biomass can be converted into biogas, liquid fuel, and briquetting fuel (Sun et al., 2019). In China, the annual output of crop straw is about 10 billion tons. In most cases, however, crop straw is burnt in open fields, resulting in significant environmental problems (Mao et al., 2019). Therefore, it is essential to find an environmentally friendly approach to dispose of crop straw.

Anaerobic digestion (AD) is a green technology for converting organic wastes into biogas; the process can be used to generate electricity using combined heat and power generation systems (Ge et al., 2016; Veluchamy and Kalamdhad, 2017). Based on the total

solids content (TS), AD can be classified into liquid-AD (L-AD) and solid-state anaerobic digestion (SS-AD). For L-AD, the TS is usually 15% or less, whereas SS-AD has a TS of more than 15% and as high as 35% (Li et al., 2011; Zhu et al., 2010). In recent years, SS-AD has become a trending research topic due to its advantages over L-AD, including lower water demand, smaller reactor size, less wastewater discharge, and easier handling of the digestion residue (Xu et al., 2014a,b; Yang and Li, 2014). However, some problems have not been solved in SS-AD at both the laboratory and industrial scales. Among these issues, acid inhibition of methanogens caused by the accumulation of volatile fatty acids (VFAs) will result in poor start-up performance, which affects the biogas production rate and efficiency (Ajay et al., 2011). AD is a complex biotransformation system that includes the participation of several microbial communities. In the early stage of SS-AD, the activity of methanogens is often inhibited by the accumulation of intermediate metabolites due to the high organic loading rate and insufficient mixing caused by the high TS content (Li et al., 2020). Research has been conducted to address these problems. For example, co-digestion of different feedstocks can be used to balance the acidogenesis and methanogenesis processes (Brown and Li, 2013; Latha et al., 2019;

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# Biosystems ENGINEERING



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## Soil organic matter prediction using smartphone-captured digital images: Use of reflectance image and image perturbation

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## Variable selection for the determination of the soluble solid content of potatoes with surface impurities in the visible/near-infrared range

Minjie Han, Xiangyou Wang, Yingchao Xu, Yingjun Cui, ... Lixia Cui

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## Research Paper

# Variable selection for the determination of the soluble solid content of potatoes with surface impurities in the visible/near-infrared range



Minjie Han, Xiangyou Wang, Yingchao Xu<sup>\*</sup>, Yingjun Cui, Liang Wang, Danyang Lu, Lixia Cui

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Chemometric methods

Non-destructive quality assessment of the inner content of potatoes is a key challenge in automatic grading of agricultural quality, especially when potatoes have surface impurities. This study compares different partial least-square regression (PLSR) models for the prediction of soluble solid content (SSC) of potatoes under conditions of surface cleanliness and surface impurities. Smoothing and spectral preprocessing with first-order derivatives and variable sorting for normalization (VSN) can effectively eliminate spectral noise. Variable selection algorithms were used to extract effective variables in order to further optimise the prediction models. The results showed that the method of the variable combination population analysis—iteratively retains informative variables (VCPA-IRIV) is the best method for selecting valid variables, and that the 35-variable VCPA-IRIV-PLSR prediction model could predict the potato SSC with a predictive correlation coefficient ( $R_p$ ), root-mean-square error of prediction ( $RMSE_p$ ), and residual predictive deviation (RPD) values of 0.831, 0.461<sup>°Brix</sup> and 1.798, respectively. Therefore, the experimental results show the feasibility and applicability of the proposed SSC prediction method for potatoes with surface impurities using near-infrared spectroscopy.

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## 1. Introduction

Potatoes represent the world's fourth largest staple crop after rice, wheat and maize, and they are also one of the most essential sources of carbohydrates, proteins and vitamins for human nutrition (Navarre et al., 2009). The global potato production is one of the largest among all crops. Indeed, the potato production in 2018 reached 368 million tons, of which about 5% was used as seedlings (FAOSTAT, 2018). Several

indicators have been proposed for potato quality assessment in commercial potato production, harvesting, and storage. In particular, the soluble solid content (SSC) is a key indicator of the internal potato quality, as this indicator is directly related to the potato nutritional value and flavor (Sanchez et al., 2020b). However, conventional assessment methods for the internal potato quality are mostly destructive and inefficient. In practical potato production, the quality assessment system should have good accuracy, high speed, and low cost. Such goals can be achieved using NIR spectroscopy techniques which are widely used as they need no sample preparation and for their advantages of being non-destructive, efficient, fast, accurate,

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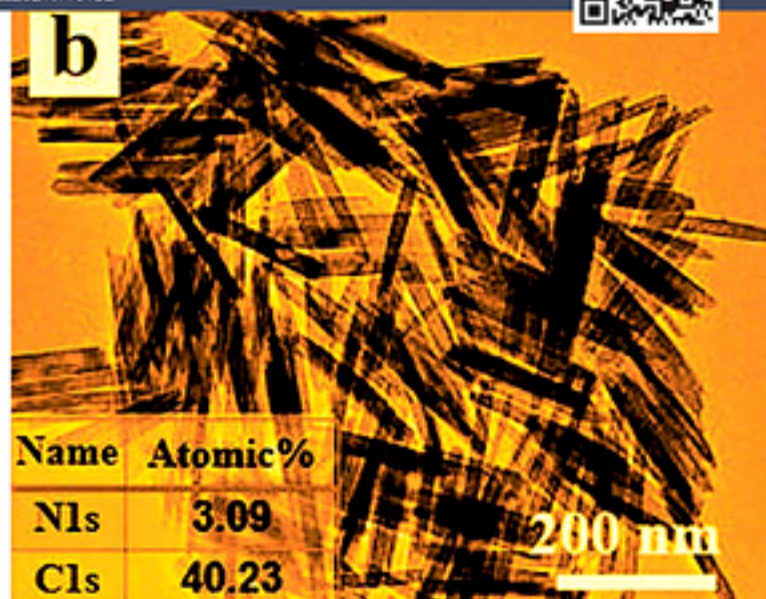
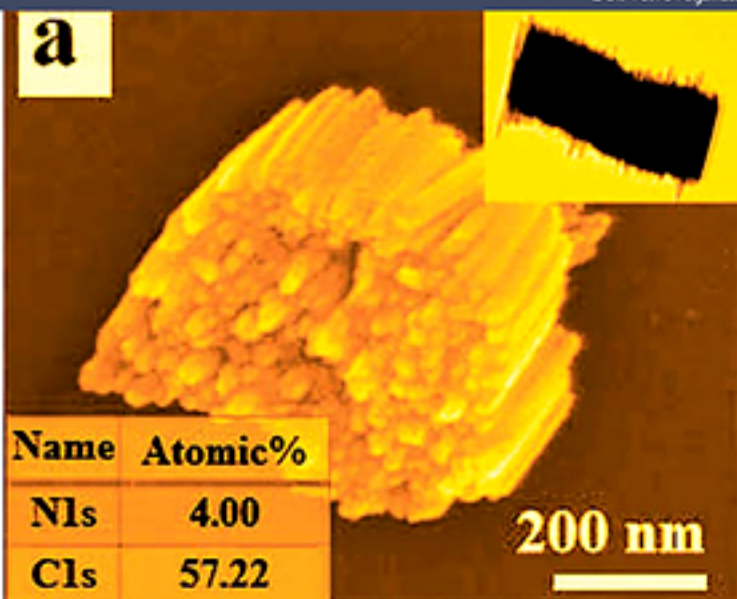
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# materials & DESIGN

EDITOR-IN-CHIEF: Alexander M. Korsunsky



COVER IMAGE:  
Qizhi Ren et al, Fig 1 (a) SEM micrographs of orderly accumulation. Inset: the corresponding TEM image. (b) TEM micrographs of disintegration and the corresponding atomic percentages of N and C.  
DOI: 10.1016/j.matdes.2021.110132



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## Enhanced mechanical properties, water resistance, thermal stability, and biodegradation of the starch-sisal fibre composites with various fillers

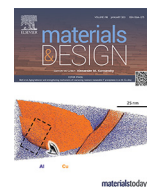
Maocheng Ji, Fangyi Li, Jianyong Li, Jianfeng Li, ... Ziyu Guo

Article 109373

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# Enhanced mechanical properties, water resistance, thermal stability, and biodegradation of the starch-sisal fibre composites with various fillers



Maocheng Ji<sup>a,b</sup>, Fangyi Li<sup>a,b,\*</sup>, Jianyong Li<sup>a,b,\*</sup>, Jianfeng Li<sup>a,b</sup>, Chuanwei Zhang<sup>c</sup>, Kaiqiang Sun<sup>a,b</sup>, Ziyu Guo<sup>a,b</sup>

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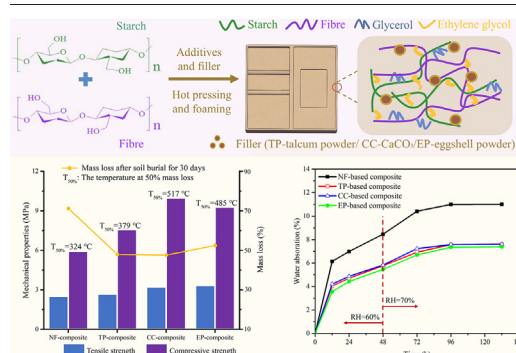
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## HIGHLIGHTS

- A filler-reinforced rapidly degradable starch-fibre composite with open-cell structures was prepared.
- Both bio-fillers and inorganic fillers can improve the mechanical properties, thermal stability and water resistance.
- Bio-fillers were advantageous for rapid biodegradation.
- Bio-fillers (eggshell powder) have the potential to replace inorganic fillers (talcum powder and CaCO<sub>3</sub>).

## GRAPHICAL ABSTRACT



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Starch-sisal fibre composite

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Water resistance

Thermal stability

Biodegradation

## ABSTRACT

The poor performance and high cost of the starch-sisal fibre composites with open-cell structures prevent their usage as biodegradable biomass to replace plastics. Therefore, inorganic fillers [talcum powder (TP), CaCO<sub>3</sub> (CC)] and a bio-filler [eggshell powder (EP)] were added, and the resulting mechanical properties, water resistance, thermal stability and biodegradation characteristics were compared. Results show that the tensile strength of the EP-composite increases by 34% and the compressive strength of the CC-composite increases by 69% when compared with those of the non-filler (NF) composite. The mechanical properties of the composites improved because of the reduction of starch crystallinity and the formation of new hydrogen bonds. The EP-composite offered optimal cushioning owing to its uniform and dense open-cell structures. Besides, the CC- and EP-composites offered better thermal stability. The composites with fillers were more waterproof than the NF-composite (by approximately 33%). After conducting biodegradability tests for 30 days, the EP-composite lost 67% of its mass, which was more than those associated with the TP- and CC-composites and can be attributed to the presence of organic matter in the EP-composite. These results demonstrate the potential of EP to replace CC and TP for reinforcing the starch-sisal fibre composites with open-cell structures.

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## 1. Introduction

The abuse of petroleum-based plastics has resulted in serious environmental and public health problems [1], increasing the demand for

completely degradable biomass materials to replace plastics [2,3]. Therefore, starch-sisal fibre composite materials have attracted considerable attention because they are renewable, abundant and biodegradable [4–6]. However, starch and plant fibre are hydrophilic and exhibit poor mechanical and thermal properties, limiting their application [7,8]. Physical and chemical methods have been applied to modify starch and plant fibre for improving their mechanical properties,

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by  Yao Yu,  Jiong Yu,  Zhigang Chen,  Jia Wu and  Yeqing Yan

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## Disassembly Sequence Planning for Intelligent Manufacturing Using Social Engineering Optimizer

by  Cheng Zhang,  Amir Mohammad Fathollahi-Fard,  Jianyong Li,  Guangdong Tian and  Tongzhu Zhang



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*Symmetry* 2021, 13(4), 661; <https://doi.org/10.3390/sym13040661> - 12 Apr 2021

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## Article

# Disassembly Sequence Planning for Intelligent Manufacturing Using Social Engineering Optimizer

Cheng Zhang<sup>1,2</sup>, Amir Mohammad Fathollahi-Fard<sup>3</sup>, Jianyong Li<sup>1,\*</sup> , Guangdong Tian<sup>1,2,4,\*</sup> and Tongzhu Zhang<sup>4,5</sup>

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**Abstract:** Product disassembly and recycling are important issues in green design. Disassembly sequence planning (DSP) is an important problem in the product disassembly process. The core idea is to generate the best or approximately optimal disassembly sequence to reduce disassembly costs and time. According to the characteristics of the DSP problem, a new algorithm to solve the DSP problem is proposed. Firstly, a disassembly hybrid graph is introduced, and a disassembly constraint matrix is established. Secondly, the disassembling time, replacement frequency of disassembly tool and replacement frequency of disassembly direction are taken as evaluation criteria to establish the product fitness function. Then, an improved social engineering optimizer (SEO) method is proposed. In order to enable the algorithm to solve the problem of disassembly sequence planning, a swap operator and swap sequence are introduced, and steps of the social engineering optimizer are redefined. Finally, taking a worm reducer as an example, the proposed algorithm is used to generate the disassembly sequence, and the influence of the parameters on the optimization results is analyzed. Compared with several heuristic intelligent optimization methods, the effectiveness of the proposed method is verified.

**Keywords:** disassembly sequence planning; social engineering optimizer; swap operator; swap sequence; intelligent manufacturing

## 1. Introduction

With the continuous development of the manufacturing industry, the problems of resource reuse and the potential environmental pollution caused by a large number of end-of-life (EOL) products urgently need to be solved. How to deal with EOL products efficiently and economically has become a research interest. The disassembly of EOL products is an important part of recycling or maintenance [1] and can reduce environmental pollution and promote resource recycling. Disassembly Sequence Planning (DSP) aims to generate the disassembly sequence of parts or sub-assemblies [2] to meet various disassembly requirements, such as disassembly costs, benefits, and disassembly methods.

Early research mainly tends to graph theory research. Henrioud et al. [3] describe the direct-connection relationship between product structures through an association graph model. Sanderson and Homem de Mello et al. [4] propose the AND/OR graph model, which represents the disassembly unit of the product as a node. If the connecting line between the nodes is curved, then the two disassembly units have a logical AND relationship; otherwise, the relationship between the two is OR. Li et al. [5] proposed a hybrid diagram that can be used to represent the dynamic changes in geometric constraints and

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# Hyperspectral reflectance imaging for water content and firmness prediction of potatoes by optimum wavelengths

Lixia Cui<sup>1</sup> · Xiangyou Wang<sup>1</sup> · Yingchao Xu<sup>1</sup> · Yanxing Li<sup>1</sup> · Minjie Han<sup>1</sup>

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## Abstract

This article presents a method for nondestructively determining water content and firmness of potatoes using hyperspectral imaging (HSI) in the visible near-infrared (VIS/NIR) and short-wave infrared (SWIR) bands. Potatoes were scanned to acquire their hyperspectral images. First derivatives (FD), Savitzky–Golay (SG) smoothing, standard normal variable (SNV) and multiplicative scatter correction (MSC) were used to process the spectral data. Competitive adaptive weighted sampling (CARS) was employed to extract the effective wavelengths. Prediction models were established using several algorithms. The SG-CARS-partial least-squares regression (PLSR) model presented the best performance in the VIS/NIR band; the corresponding  $R^2_p$ , root mean square error of the prediction set (RMSE<sub>p</sub>), and residual predictive deviation (RPD) values for water content and firmness were 0.9219 and 0.9118, 0.0034 and 0.0640 Newton (N), and 2.5780 and 2.4353, respectively. In the SWIR band, the FD-CARS-PLSR prediction model performed best; the  $R^2_p$  values for water content and firmness were 0.9313 and 0.9317, respectively, the RMSE<sub>p</sub> values were 0.0025 and 0.0216 N, and RPD values were 2.7453 and 2.7531. This study confirmed the feasibility of the HSI technology for nondestructively determining water content and firmness of potatoes.

**Keywords** Hyperspectral imaging · Potatoes · Water content · Firmness · Effective wavelengths · Prediction model

## 1 Introduction

Potatoes are the main source of dietary starch, along with rice, maize, and wheat. A potato contains abundant nutrients, including starch, protein, and carbohydrates (Zhang et al. 2017), giving it a high economical and nutritional value. The water content of potatoes is an important index of their freshness. It affects the taste and appearance, and the customers' purchasing decision is directly influenced by the firmness of potatoes. Water content and firmness are two important indexes to evaluate potato freshness. Therefore, the determination of the water content and firmness of potatoes are of great significance. There are several methods to determine water content and firmness of potatoes, such as the drying and weighing method, and the Magness-Taylor method (Hertog et al. 2004). The traditional detection methods cannot meet the requirements of the rapid development in the potato industry because of their low efficiency and the

damage caused to potato samples, although these methods can accurately detect the internal quality of potatoes (Liu et al. 2017). In this context, nondestructive testing can be an approach for assessing the internal quality of potatoes.

HSI is a green and nondestructive detection technology. By combining imaging and spectral technologies, both the internal and external features of a sample can be captured simultaneously. HSI is characterized by its continuous multi-band, high resolution, simple operation, and high stability, and it is pollution-free and has shown great potential in assessing the quality of agricultural products (Elmasry and Nakauchi 2016; Su and Dawen 2016; Deng et al. 2019; Yuan et al. 2019). Elmasry et al. (2007) applied HSI to predict water content, soluble solid content, and acidity of strawberries; they used the partial least-squares (PLS) method to establish a spectral multivariate correction model for the prediction, with correlation coefficients of 0.9010, 0.8010, and 0.8700, respectively. Xiao et al. (2020) predicted the soluble solid content in *Agaricus bisporus* (a type of mushroom) during its ultrasound-assisted osmotic dehydration based on HSI. The support vector machine preprocessed with orthogonal signal correction provided the best fit for the full-band spectra of the samples tested, with a high

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特约专稿

农业机械底盘技术研究现状与展望

王永生 陈黎涛 杨 洋 刘立超

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# 基于改进 YOLO v4 模型的马铃薯中土块石块检测方法

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**摘要:** 为实现收获后含杂马铃薯中土块石块的快速检测和剔除, 提出了一种基于改进 YOLO v4 模型的马铃薯中土块石块检测方法。YOLO v4 模型以 CSPDarknet53 为主干特征提取网络, 在保证检测准确率的前提下, 利用通道剪枝算法对模型进行剪枝处理, 以简化模型结构、降低运算量。采用 Mosaic 数据增强方法扩充图像数据集(8 621 幅图像), 对模型进行微调, 实现了马铃薯中土块石块的检测。测试表明, 剪枝后模型总参数量减少了 94.37%, 模型存储空间下降了 187.35 MB, 前向运算时间缩短了 0.02 s, 平均精度均值(Mean average precision, mAP) 下降了 2.1 个百分点, 说明剪枝处理可提升模型性能。为验证模型的有效性, 将本文模型与 5 种深度学习算法进行比较, 结果表明, 本文算法 mAP 为 96.42%, 比 Faster R-CNN、Tiny-YOLO v2、YOLO v3、SSD 分别提高了 11.2、11.5、5.65、10.78 个百分点, 比 YOLO v4 算法降低了 0.04 个百分点, 模型存储空间为 20.75 MB, 检测速度为 78.49 f/s, 满足实际生产需要。

**关键词:** 马铃薯; 石块检测; 通道剪枝; YOLO v4

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## Detection Method of Clods and Stones from Impurified Potatoes Based on Improved YOLO v4 Algorithm

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**Abstract:** A method based on improved YOLO v4 algorithm was proposed to realize the rapid detection of clods and stones from impurified potatoes after harvest. The YOLO v4 detection model was built on CSPDarknet53 framework. The channel pruning algorithm was used to prune the model to simplify the structure and the computational cost, while under the premise of detection accuracy. Mosaic data enhancement method was used to expand the image data set (8 621 images), and the model was fine-tuned to achieve the detection of clods and stones from impurified potatoes. The test results showed that when the pruning rate was 0.8, the number of parameters of the model was reduced by 94.37%, the model size was decreased by 187.35 MB, the inference time was reduced by 24.1%, and the floating-point operations per second was compressed by 54.03%. It was shown that the performance of model can be improved by pruning. In order to verify the performance of the model, the model was compared with Faster R-CNN, Tiny-YOLO v2, YOLO v3, SSD and YOLO v4. The results showed that the mean average precision (mAP) of the model was 96.42%, the detection speed was 78.49 f/s, and the model size was 20.75 MB. The mean average precision was 11.2, 11.5, 5.65 and 10.78 percentage points higher than that of the other four algorithms and 2.1 percentage point lower than that of the YOLO v4 algorithm. The detection speed met the practical needs, and it can be applied to post-harvest potato impurity removal.

**Key words:** potatoes; stones detection; channel pruning; YOLO v4

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特约专稿

谷物联合收获机筛分装置研究现状与发展分析

王立军 宋良来 冯 鑫 王启升 李延斌

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# 辊式导流马铃薯定重装袋机设计与试验

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3. 山东思代尔农业装备有限公司, 德州 253600)

**摘要:** 装袋是马铃薯从收获到运输、储藏的重要环节。为解决现有马铃薯装袋机效率低、损伤率高的问题,设计了一种高效、低损的辊式导流马铃薯定重装袋机,主要由支撑装置、分流输送装置、导流装置、撑袋装置和定重装袋装置构成。通过多工位装袋实现了高效,通过辊式导流实现了低损伤。通过对该机关键部件的力学分析和导流过程的运动学分析,确定了影响马铃薯损伤和装袋效率的主要因素为导流仓门角度、输送速度和上料量。以导流仓门角度、输送速度和上料量为试验因素,以破皮率、伤薯率和单口装袋效率为试验指标,进行了二次回归正交旋转组合试验,通过 Design-Expert 8.0.6 软件对试验结果进行方差分析,通过响应面试验分析了试验交互因素对试验指标的影响规律。利用 Design-Expert 8.0.6 软件优化模块并结合实际工作情况确定各因素最佳取值,在此基础上进行了试验台验证试验,结果表明:当导流仓门角度为 45°、输送速度为 0.35 m/s、上料量为 27 t/h 时,破皮率为 1.8%、伤薯率为 1.4%、单口装袋效率为 12.4 t/h,在该参数组合下辊式导流马铃薯定重装袋机破皮率和伤薯率均较低,且装袋效率较高。

**关键词:** 马铃薯; 辊式导流; 装袋机; 定重装袋

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## Design and Test of Roller-guided Potato Fixed Weight Bagging Machine

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**Abstract:** Bagging is an important link from harvesting to transportation and storage of potatoes. To solve the problems of low efficiency and high damage rate of existing potato bagging machines, a new infusion, bag support and fixed weight bagging structure was designed, an efficient and low damage roller-type infusion potato fixed weight bagging machine was developed, and mechanical analysis of key components of the machine and kinematic analysis of key motion processes were conducted, and the main factors affecting the damage and bagging efficiency were identified as inflow bin door angle, conveying speed and loading volume. A quadratic regression orthogonal rotating combination test was conducted with the inflow bin door angle, conveying speed and loading volume as the test factors, and the breakage rate, injury rate and single-port bagging efficiency as the test indicators, and the test results were analyzed by ANOVA with Design-Expert 8.0.6 to determine the main order of the factors affecting the test indicators and to fit the test data. The test factors were analyzed by visually discerning the optimization region through response surface analysis, and the influence law of the test factors on the test indexes was analyzed. Using Design-Expert 8.0.6 optimization module and combining with the actual working situation to determine the optimal values of each factor, a test bench verification test was conducted on this basis, and the test results showed that when the inflow bin door angle was 45°, the conveying speed was 0.35 m/s, and the loading volume was 27 t/h, the breakage rate was 1.8%, the injury rate was 1.4%, and the single-port bagging efficiency was 12.4 t/h, this parameter under the roller type guide flow potato fixed weight bagging machine breakage rate and injury rate was lower, and the bagging efficiency was higher.

**Key words:** potato; roll diversion; bagging machine; fixed weight bagging

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农作物病虫害识别关键技术研究综述

程建祥 曹益飞 孙焕良 袁培森 王浩云

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# 马铃薯通风储藏库加湿系统设计与试验

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3. 山东省马铃薯生产装备智能化工程技术研究中心, 德州 253600)

**摘要:** 为解决现有马铃薯通风储藏库加湿系统选型参数标准模糊和加湿方式无法随库内环境参数变化进行自动调节等问题, 设计了一套马铃薯通风储藏库自动加湿系统。在现有马铃薯储藏库基础上, 考虑马铃薯生理特性, 该加湿系统选择 PLC S7-200 为主控制器, 并运用控制变量法进行试验设计, 采用 Origin 数据分析软件对各影响因素与入口风速和相对湿度之间的关系进行单因素试验分析, 研究加湿帘厚度、加湿泵功率和风机风速对储藏库加湿效果的影响。硬件选型试验表明, 该储藏库的最佳参数组合为湿帘厚度 45 cm、加湿泵功率 70 W、风机风速 16 m/s, 当风速达到 16 m/s 时能够达到完全穿透效果。加湿系统应用试验证明, 系统能够正常工作, 并且将库内相对湿度维持在 95% 左右, 储藏后马铃薯平均失重率为 3.70%, 满足马铃薯储藏的加湿需求, 且系统可根据库内环境参数的变化进行相应调整, 使马铃薯保持较充足的水分和较低的失重率, 从而保证储藏库内环境适合马铃薯储藏。

**关键词:** 马铃薯; 通风储藏库; 加湿系统; 相对湿度

中图分类号: S532; S229<sup>+</sup>.3

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## Design and Test of Humidification System for Potato Ventilated Storage

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3. Shandong Provincial Intelligent Engineering and Technology Research Center for Potato Production Equipments, Dezhou 253600, China)

**Abstract:** In order to solve the problems of fuzzy selection parameter standards of the humidification system of the existing potato ventilated storage and the inability of the humidification method to automatically adjust with the changes of the environmental parameters in the storage, a set of automatic humidification system for the potato storage was designed and developed. The humidification system was based on the existing potato storage, combined with the physiological characteristics of the potato, selected PLC S7-200 as the main controller for development, and the control variable method was used for experimental design. Through the data analysis software Origin, a single factor test analysis was carried out on the relationship between the various influencing factors and the inlet wind speed and relative humidity, and the influence of the thickness of the humidification curtain, the power of the humidification pump and the wind speed of the fan on the humidification effect of the storage was obtained. Through experimental research, it was concluded that the best collocation plan for the storage warehouse was that the thickness of the wet curtain was 45 cm, the power of the humidification pump was 70 W, the wind speed of the fan was 16 m/s, and the full penetration effect can be achieved when the wind speed reached 16 m/s. The application test of the humidification system proves that the system can work normally and can meet the humidification requirements of potato storage. It can be adjusted according to the changes of environmental parameters in the warehouse, so that the potato can maintain sufficient moisture and low weight loss rate, and guaranteed the storage in the warehouse. The environment was suitable for the storage of potatoes.

**Key words:** potato; ventilated storage; humidification system; relative humidity

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# Model-Driven Deep Learning Scheme for Adaptive Transmission in MIMO-SCFDE System

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**ABSTRACT** Adaptive transmission (AT) is considered as one of the critical technologies to enhance the effectiveness of communication systems. In this article, we propose a model-driven deep learning (DL) scheme for AT in multiple-input multiple-output single-carrier frequency-domain equalization (MIMO-SCFDE) systems, in which the adaptive modulation network (AMNet) and adaptive demodulation network (ADNet) are adopted to complete the modulation of the signal and the modulation recognition of the receiver. Under the target bit error rate (BER), the adaptive modulation (AM) scheme can adjust the modulation mode selection of different transmitting antennas adaptively according to the estimated channel information to improve the throughput. The features required by the AMNet are extracted from the received signal, and the labels are assigned according to the optimal modulation scheme got by analyzing the signal detection performance. Since the spectral correlation function has a powerful ability to suppress noise and the cyclic spectrum varies with the modulation mode, we take the preprocessed cyclic spectrogram as the input of ADNet to achieve the adaptive modulation recognition (AMR). Comparative experiments demonstrate that the proposed scheme gets better performance in terms of throughput and reliability in MIMO-SCFDE systems than the traditional scheme and the existing DL scheme.

**INDEX TERMS** Model-driven, deep learning, adaptive transmission, MIMO-SCFDE, adaptive modulation, adaptive demodulation.

## I. INTRODUCTION

Adaptive transmission (AT) refers to the technology that the transmitter utilizes the channel state information (CSI) to adjust the transmission strategy adaptively, including changing the transmission power, adjusting the modulation mode, or adjusting the channel coding scheme so that the system can improve the information transmission rate or reliability [1]. Traditional AT technology mostly enhances the performance of the communication system through sophisticated algorithms [2]. However, for 5G communications that require high efficiency and high density, the increase in computational complexity will inevitably reduce the effectiveness

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of communications. With the resurgence of artificial intelligence (AI) technology, deep learning (DL) as an advanced data processing algorithm has been widely used in image analysis and speech recognition [3]. The organic combination of DL and wireless communication will become a breakthrough in physical layer transmission [4].

The research on applying DL to the physical layer is mainly divided into two types: data-driven network and model-driven network [5]. The data-driven DL network regards the multiple function blocks of the wireless communication system as an unknown black box replaced by the DL model and then relies on a large number of labeled data to complete the input-output training [6]. In [7], the receiving module after removing the cyclic prefix (CP) in the orthogonal frequency division multiplexing (OFDM) system is regarded



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□ [A Novel Signal Detection Scheme Based on Adaptive Ensemble Deep Learning Algorithm in SC-FDE Systems](#)  
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# A Novel Signal Detection Scheme Based on Adaptive Ensemble Deep Learning Algorithm in SC-FDE Systems

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**ABSTRACT** Reliable signal detection plays an essential role in enhancing the quality of signal transmission in wireless communication systems. In this paper, we combine signal detection theory with a deep learning model and propose a novel signal detection scheme based on adaptive ensemble long short term memory (AE-LSTM) neural network to handle wireless single carrier frequency domain equalization (SC-FDE) systems in an end-to-end manner. The feature information used for offline training of the deep learning model is extracted from the received signal containing channel state information (CSI) after the multi-path channel and fast Fourier transform (FFT), and the labels are assigned according to the constellation map adopted at the transmitter. To improve the adaptability of the system, we utilize the received power under different delays as the adaptive factor to integrate the output of each sub-network. Then the original data generated by the channel model is recovered by using the trained model instead of channel estimation and frequency domain equalization. Comparative experiments on SC-FDE symbol detection demonstrate that the proposed scheme achieves better performance in terms of reliability than the traditional scheme and the similar deep learning scheme.

**INDEX TERMS** Deep learning, adaptive ensemble, signal detection, SC-FDE, channel estimation, frequency domain equalization.

## I. INTRODUCTION

With the development of mobile Internet, 5G technology has become a hot topic in the communication industry and academia [1]. Since the 5G mobile communication network has the characteristics of high dimensions, high capacity, and high density, how to use massive amounts of data to reduce the complexity of the system and improve the reliability of performance has become the critical point of the physical layer technology [2]. Single carrier frequency domain equalization (SC-FDE) is a new broadband wireless communication technology developed by combining the advantages of traditional single carrier transmission and orthogonal frequency division multiplexing (OFDM) technology, which uses the cyclic prefix (CP) and frequency

domain equalization to eliminate the effect of multi-path channels on the signal [3], [4]. However, due to the impact of inter-block interference (IBI) in channel estimation and frequency domain equalization, the system's reliability fluctuates with the change of the channel impulse response (CIR). Although the SC-FDE system's performance has been improved in various ways, it is far from meeting the requirements of 5G communication [5].

Experts from all over the world have done relevant research on signal detection in wireless communication systems. The authors of [6] design a method to mitigate interferences for SC-FDE with insufficient CP symbols, and uses an iterative interference cancellation method to remove the residual interferences. To ensure the integrity of information, [7] proposes a frequency-domain multipacket detection technique for SC-FDE schemes, which can achieve an efficient packet separation in the presence of successive collisions.

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## The effects of fungal lipase-treated milk lipids on bread making

Zhiguang Huang, Charles Stephen Brennan, Haotian Zheng, Maneesha S. Mohan, ... Jianfu Liu

Article 109455

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## Influence of the fermentation time and potato pulp addition on the technological properties and volatile compounds of wheat dough and steamed bread

Yanfei Cao, Haijing Zhang, Zhe Yang, Min Zhang, ... Hongjun Li

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## Microencapsulation as a tool to producing an extruded functional food

Carmen S. Favaro-Trindade, Bhavesh Patel, Marlucci P. Silva, Talita A. Comunian, ... Osvaldo H. Campanella

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## Effect of extrusion cooking on the physical-chemical properties of whole kiwicha (*Amaranthus caudatus* L) flour variety *centenario*: Process optimization

Jaime Basilio-Atencio, Luis Condezo-Hoyos, R. Repo-Carrasco-Valencia

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# Influence of the fermentation time and potato pulp addition on the technological properties and volatile compounds of wheat dough and steamed bread

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### Keywords:

Steamed bread  
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## ABSTRACT

This study aimed to assess the effect of fermentation time and potato pulp addition on the fermentation characteristics of dough and textural profiles of the steamed bread. Volatile compounds in steamed bread processing were also determined. Rheofermentometer analysis showed that the gas retention capability of dough decreased with the increase in potato pulp level, and the productive fermentation time might be shortened through the addition of high potato pulp levels (40%–50%) to dough. The resistance to extension of dough samples decreased with the increase in fermentation time and potato pulp level. When the fermentation time was 60–75 min, all steamed bread samples had high specific volumes and soft textures. Moreover, the volatile compounds in the fermented dough and steamed bread were enriched by the addition of potato pulp. These results indicated that fermentation time and potato pulp affected the technological properties and volatile compounds of wheat dough and steamed bread.

## 1. Introduction

Steamed bread is a traditional staple food in China that accounts for approximately 40% of wheat products (Zhu, Sakulnak, & Wang, 2016). The materials of steamed bread are wheat flour, yeast and water mixed to develop the dough, which is fermented, sheeted, shaped, proofed and then steamed. Dough fermentation is an important step in steamed bread production; it is affected by a number of factors, such as fermentation time and raw materials (Alvarez-Ramirez, Carrera-Tarela, Carrillo-Navas, Vernon-Carter, & Garcia-Diaz, 2019; Li, Li, Song, & Cui, 2019), influencing the technological characteristics of the dough (Buksa & Krystjjan, 2019).

Steamed breads have been fortified with various ingredients to increase nutritional value and product appeal. Researchers have attempted to add wheat germ flour (Sun, Zhang, Hu, Xing, & Zhuo, 2015), potato flour (Liu, Mu, Sun, Zhang, & Chen, 2016), inulin (Luo et al., 2017), black tea (Zhu et al., 2016) and sorghum (Wu et al., 2018) to produce wheat steamed breads. Among these ingredients, potato has relative high nutritional value which is largely attributed to their higher vitamin and mineral content compared with cereals (Zhou et al., 2019). Thus, new potato-based staple products, such as steamed bread, have become increasingly popular (Zhao, Mu, & Sun, 2019). However, the addition of potato flour causes processing challenges because potato

flour influences the rheological behaviour of the dough and the quality parameters of the products (Liu et al., 2016; Pu et al., 2017). Although the viscoelastic properties of wheat dough and the quality parameters of steamed bread have been analysed (Singh & Singh, 2013; Wang, Guo & Zhu, 2016), the technological properties during dough fermentation are poorly studied.

Similar to that of bread, the quality of steamed bread is determined by its colour, volume, texture and flavour (Pico, Bernal, & Gómez, 2015). Among these basic characteristics, flavour is one of the most important characteristics that determine whether it is accepted by consumers (Pico et al., 2015). The flavour of steamed bread is formed by a large number of volatile compounds, mainly containing alcohols, esters, aldehydes, ketones and acids (Liu et al., 2018). The flavour of steamed bread is influenced by many factors, not only depending on the materials but also on the fermentation and steaming conditions (Pico, Martínez, Bernal, & Gómez, 2017). Therefore, the volatile compounds in fermented dough and steamed bread have been investigated to comprehend their formation at different stages. However, the flavour evolution from fermented dough enriched with potato pulp to crumb has been rarely studied.

The traditional potato flour or starch applied in potato stable products are usually obtained through a series of processing steps, including cleaning and peeling, combined colour protection by

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## Stability of melamine-formaldehyde (MF) resin under different pH and ionic strength values

Lambros Farmakis, Athanasia Koliadima, Sotirios Vamvakas

e14471 | First Published: 15 April 2020

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## Effects of D-allulose as a sucrose substitute on the physicochemical, textural, and sensorial properties of pound cakes

Phyrim Lee, Hyeonbin Oh, Si Yeon Kim, Young-Soon Kim

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## Impact of potato pulp on the processing characteristics and gluten structures of wheat flour dough

Yanfei Cao, Min Zhang, Shuang Dong, Peng Guo, Hongjun Li

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## Effect of germination and high pressure treatments on brown rice flour rheological, pasting, textural, and structural properties

Hao Wang, Feifei Hu, Chunfang Wang, Hosahalli S. Ramaswamy, Yong Yu, Songming Zhu, Jian Wu

e14474 | First Published: 17 April 2020

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## Influence of PH on the properties of sodium alginate films with norbixin salt

Yuri Buratto de Farias, Renato Queiroz Assis, Diego Santiago Tupuna-Yerovi, Alessandro de Oliveira Rios

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# Impact of potato pulp on the processing characteristics and gluten structures of wheat flour dough

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**Abstract**

The processing characteristics and gluten structures of dough with potato pulp were investigated by Farinograph and Extensigraph tests, Starch Viscometer, Spectrophotometry, and Fourier transform infrared spectroscopy. The development time and water absorption of dough decreased with the increase in the potato pulp level. High potato pulp addition ( $\geq 30\%$ ) extensively modified the extensional properties of dough, affecting the processing characteristics of dough. The pasting properties showed that wheat flour with potato pulp had lower viscosity parameters. The gluten of dough with 30%–50% potato pulp showed higher content of the free SH and lower content of S–S compared with the control. In addition, the gluten of dough with 30%–50% potato pulp significantly ( $p < .05$ ) decreased the contents of  $\beta$ -sheet and  $\alpha$ -helix structures compared with the control. Results showed that potato pulp affected the processing characteristics and gluten structures of wheat dough.

**Practical applications**

The traditional potato flour or starch applied in potato stable products is usually obtained through a series of processing steps, including cleaning and peeling, combined color protection by atmospheric and high pressure, drying, and superfine grinding. These processing steps caused many problems like high energy consumption, high emission and high pollution, and brought damage to nutritional components like protein and dietary fiber. In comparison, applying potato pulp directly into dough making not only simplifies the processing steps, but also reduces energy consumption and cost and reserves more nutrients. In addition, developing nutritious staple potato-based food products, such as noodles, cakes, bread, and steamed bread, suitable for the dietary habits are important to promote potato consumption and improve nutritional qualities (enhancing the dietary fiber, total polyphenol content, and antioxidant activity).

## 1 | INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important vegetable crop with a global yield of 377 million tonnes in 2016 behind rice, wheat, and maize (Zhou et al., 2019). The high nutritional value of potatoes is largely attributed to their higher vitamin and mineral content compared with cereals and higher carbohydrate and fiber content

compared with vegetables (Zhang, Xu, Wu, Hu, & Dai, 2017). Potato protein has a balanced amino acid composition, which improves the deficiency of cereal proteins. Furthermore, potatoes contain polyphenolics and flavonoids with anticancer, antioxidant, and anti-hypertensive effects (Ezekiel, Singh, Sharma, & Kaur, 2013). Therefore, potato is a highly desirable vital foodstuff in a diet due to its beneficial effects on human health.





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# 定向排列纵横切分马铃薯种薯切块机设计与试验

王相友<sup>1</sup> 祝珊<sup>1</sup> 李学强<sup>2,3</sup> 李腾训<sup>1</sup> 王琳琳<sup>1</sup> 胡周勋<sup>2,3</sup>

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**摘要:** 针对马铃薯种薯需求量大以及人工切种工作量大、劳动强度高、切种效率较低等问题, 设计了一种定向排列纵横切分马铃薯种薯切块机, 可同时进行马铃薯种薯清土除杂、大小分选、种薯排列、切块、薯块杀菌消毒、薯种碎片清选和集薯输送等多种作业。该种薯切块机包括种薯分选装置、定向排列装置、纵切装置和横切装置, 采用纵刀和横刀组合切块工艺, 可有效提高种薯切块效率, 降低劳动强度。以中间电机Ⅱ转速、上下胶皮辊中心距和薯刀梳子安装角为试验因素, 以薯块合格率、薯块盲眼率和种薯损耗率为试验指标, 进行了响应曲面试验, 采用 Design-Expert 8.0.6 软件对试验数据进行分析, 得出最优参数组合为: 中间电机Ⅱ转速为 965.76 r/min, 上下胶皮辊中心距为 315 mm, 薯刀梳子安装角为 104.61°。最优参数组合条件下薯块合格率 94.86%, 薯块盲眼率 1.84%, 种薯损耗率 9.72%。在最优参数组合条件下进行了验证试验, 结果表明, 薯块合格率为 92.13%, 薯块盲眼率为 1.91%, 种薯损耗率为 10.21%。与预测值相比, 薯块合格率、薯块盲眼率及种薯损耗率的相对误差分别为 2.88%、3.80%、5.04%, 满足马铃薯种薯切块要求。

**关键词:** 马铃薯种薯; 定向排列; 纵横切分

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## Design and Experiment of Directional Arrangement Vertical and Horizontal Cutting of Seed Potato Cutter

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**Abstract:** In view of the large demand for seed potatoes, the large amount of manual cutting, high labor intensity and low cutting efficiency, on the basis of adapting to the planting pattern and agronomic requirements, a directional arrangement of longitudinal and transverse cutting seed potato cutter was developed, which can simultaneously complete the tasks of seed potato cleaning, impurity removal, size sorting, directional arrangement of seed potatoes, slicing, potato block sterilization, seed fragments cleaning and collecting and transporting. The seed potato cutting machine performed the cutting operation under the motor drive. The key components included the seed potato sorting device, directional aligning device, longitudinal slicing device and transverse slicing device. The seed potato cutting machine adopted a combination of a longitudinal knife and a transverse knife to cut the block process, which can effectively improve the cutting efficiency of the seed potato and reduce the labor intensity. Taking the intermediate motor II speed, the central distance between upper and lower rubber rollers and installation angle of potato knife comb as test factors, the response surface test was carried out with the qualified rate, blind rate and loss rate of seed potato as test indicators. The test data was analyzed by Design-Expert 8.0.6 software. To explore the correlation between seed cutting performance and various influencing factors and the interaction law, the optimal parameter combination was as follows: the intermediate motor II speed was 965.76 r/min, the center distance between upper and lower rubber rollers was 315 mm, the

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## 农产品加工工程

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# 马铃薯贮藏库调控系统设计及试验

王相友<sup>1</sup> 李少川<sup>1</sup> 王法明<sup>2</sup> 李学强<sup>2</sup> 李腾训<sup>1</sup> 王荣铭<sup>1</sup>

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**摘要:** 针对目前马铃薯贮藏方式、管理方式不当和贮藏效果不佳的问题, 根据马铃薯贮藏工艺条件, 设计了一套马铃薯贮藏环境调控系统。该调控系统利用温度传感器、湿度传感器和 CO<sub>2</sub> 浓度传感器对环境参数进行实时检测, 通过调节进出气窗、风机、压缩机组以及加湿装置, 对马铃薯贮藏环境的温度、相对湿度以及 CO<sub>2</sub> 体积分数等参数进行调控, 使贮藏环境中的温度、相对湿度以及 CO<sub>2</sub> 体积分数等参数满足马铃薯的贮藏要求。各测点的温度误差在 -0.3 ~ 0.3℃ 范围内, 各测点温度极差为 0.6℃, 检测温度与真实温度基本一致; 调控试验中, 库内温度处在系统设定的允许范围内, 库外温度对于库内温度影响较小, 相对湿度和 CO<sub>2</sub> 体积分数均可控制在合理范围内。该调控系统能够较好地改善马铃薯的贮藏环境。

**关键词:** 马铃薯; 贮藏库; 调控系统; 设计

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## Design and Experiment of Potato Storage Equipment Control System

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**Abstract:** Aiming to solve the problems of unsuitable storage and management and poor storage effect, a set of potato storage environment control system was designed according to the technological conditions of potato storage. The system used temperature sensor, humidity sensor and CO<sub>2</sub> concentration sensor to monitor the environmental parameters in real time. By adjusting the inlet air window and outlet air window, fan, compressors and humidification device, the environment temperature parameters in callus period, the temperature, humidity and CO<sub>2</sub> concentration in storage period were regulated. The purpose was to make the storage environment attain the requirements of potato storage. In the temperature accuracy test of each measuring point, the temperature error of each measuring point was within -0.3 ~ 0.3℃, and the temperature range of each measuring point was 0.6℃, the monitoring temperature was basically the same as the real temperature on the whole. In the experiment of regulation effect, the temperature of callus period and storage period was within the allowable range of the system set value, while the temperature outside the storage had little effect on the temperature inside the storage, and the humidity and CO<sub>2</sub> concentration could be controlled within a reasonable range. Therefore, it was very important to improve the storage environment of potato, accelerate the postharvest callus, prolong the storage period and ensure the quality of potato.

**Key words:** potato; storage house; regulation and control system; design

## 0 引言

马铃薯是世界第四大农作物, 并且具有粮食、蔬菜以及轻工业原料等多种用途。随着马铃薯主粮化战略的实施, 我国马铃薯种植面积和总产量均居世

界第一。因此, 科学贮藏对于马铃薯产业的健康发展具有重要意义<sup>[1-3]</sup>。

在马铃薯贮藏期间, 其自身的呼吸作用会使贮藏环境中的温度、湿度以及气体环境发生变化, 长期处于这种环境将会导致马铃薯的品质下降<sup>[4]</sup>。目前, 国内

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## Research Article

# A Cognitive Radio Spectrum Sensing Method for an OFDM Signal Based on Deep Learning and Cycle Spectrum

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In a cognitive radio network (CRN), spectrum sensing is an important prerequisite for improving the utilization of spectrum resources. In this paper, we propose a novel spectrum sensing method based on deep learning and cycle spectrum, which applies the advantage of the convolutional neural network (CNN) in an image to the spectrum sensing of an orthogonal frequency division multiplex (OFDM) signal. Firstly, we analyze the cyclic autocorrelation of an OFDM signal and the cyclic spectrum obtained by the time domain smoothing fast Fourier transformation (FFT) accumulation algorithm (FAM), and the cyclic spectrum is normalized to gray scale processing to form a cyclic autocorrelation gray scale image. Then, we learn the deep features of layer-by-layer extraction by the improved CNN classic LeNet-5 model. Finally, we input the test set to verify the trained CNN model. Simulation experiments show that this method can complete the spectrum sensing task by taking advantage of the cycle spectrum, which has better spectrum sensing performance for OFDM signals under a low signal-noise ratio (SNR) than traditional methods.

## 1. Introduction

The emergence of the fifth-generation mobile communication network (5G) [1] has greatly promoted the development of broadband wireless communication [2], and orthogonal frequency division multiplex (OFDM) is one of the popular physical transmission technologies for wireless communication [3, 4]. Many of its characteristics meet the requirements of cognitive radio (CR) [5–7]. Therefore, OFDM is the preferred technology for CR communication. As the core technology of the cognitive radio network (CRN), spectrum sensing can improve spectrum utilization and alleviate spectrum resources [8–10]. Traditional spectrum sensing is mainly done by mathematical methods of signal processing, including energy detection [11], matched filter detection [12], and cyclostationary feature detection [13]. [14] proposed a spectrum sensing method based on

correlation detection, the correlation of cyclic prefix (CP) was used in OFDM, and the sampled data was subjected to correlation operation. In [15], the signal and noise were estimated simultaneously by the time domain correlation function, and the estimated threshold was continuously adjusted by the estimated value to complete the spectrum sensing of an OFDM signal. In [16], the received autocorrelation function was estimated at each OFDM symbol of its symbol period, and then, the multivariate statistical theory was used to calculate the judgment amount and the decision threshold. Finally, the judgment amount and the decision threshold were compared to obtain the judgment result. In the face of complex wireless network communication environments, these methods cannot meet the needs of spectrum sensing. In [17], focusing on classifying different OFDM signals, authors proposed a two-step detection and identification method. However, this method is not combined with





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# Effect of wheat flour substitution with potato pulp on dough rheology, the quality of steamed bread and *in vitro* starch digestibility

Yanfei Cao, Fengjie Zhang, Peng Guo, Shuang Dong, Hongjun Li\*

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## ARTICLE INFO

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Dough rheology  
Starch-gluten network  
Steamed bread quality  
*In vitro* starch digestibility

## ABSTRACT

Wheat flour substituted with potato pulp was applied in steamed bread to improve nutrient value and reduce the energy consumption and the cost. The dough rheology, starch–gluten network, the quality and *in vitro* starch digestibility of steamed bread containing 0%–50% potato pulp were investigated. The dough sample with 10% potato pulp content exhibited the optimal elastic and viscous modulus values. Scanning electron microscopy (SEM) and sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) revealed that dough samples with potato pulp contents of more than 30% weakened starch–gluten interaction and exhibited discontinuous network structures. Steamed bread with 30%–50% potato pulp contents showed reduced specific volumes and increased hardness. The rapidly digestible starch contents and expected glycaemic indices of steamed bread enriched with potato pulp decreased from 46.98% to 31.40% and from 87.81% to 72.79%, respectively. In conclusion, wheat flour substituted with potato pulp can be used in the energy-efficient and cost-effective production of steamed bread with improved nutritional value.

## 1. Introduction

Steamed bread is a typical fermented and steamed wheat flour product. In China, steamed bread is a staple food and has been consumed for at least 2000 years. It is also widely consumed in other Asian countries and has gained considerable popularity in North America and some European countries (Wu et al., 2012). Compared with baked bread, steamed bread at relatively low temperature is considered healthy due to the less existing of Maillard reactions products such as acrylamide and furan (Hsieh, Weng, Yu, & Wang, 2017).

Simply consumption of steamed bread produced by pure wheat flour is not enough for human nutrition balance, for the less content of lysine, minerals and vitamins (Liu, Mu, Sun, Zhang, & Chen, 2016). Moreover, the high glycaemic indices of wheat products limits their consumption by individuals with diabetes and cardiovascular disease (Patel, Chandra, Alexander, Soble, & Williams, 2017; Riccardi, Rivellese, & Giacco, 2008). The nutritional quality of steamed bread may be improved through the partial substitution of wheat flour with whole flour or other functional components. Many researchers have focused on the addition of different ingredients, such as quinoa flour (Turkut, Cakmak, Kumcuoglu, & Tavman, 2016), fibres (Fendri et al., 2016) and rice flour (Pérez-Quirce, Lazaridou, Biliaderis, & Ronda, 2017) to wheat flour. The substitution of wheat flour with other kinds

of flour with low gluten content, however, alters dough rheological properties and product quality (Turkut et al., 2016). During dough preparation, gluten forms networks that provide the essential viscoelastic properties of dough and strengthen the final steamed bread product (Lagrain, Goderis, & Brijs, 2010).

The potato is an international staple crop that plays an important role in the human diet and is the fourth most important food crop in the world behind rice, wheat and maize (Wu, 2016). Fresh potatoes contain starch, proteins, minerals, organic acids and dietary fibres (Li et al., 2011; Liu, 2010). The proportion of the essential amino acid lysine of potato is higher than most cereal proteins, which improves the deficiency of cereal proteins (Bártov, Bárta, Brabcov, Zdráhal, & Horáckov, 2015). Potato is also rich in non-starch polysaccharide, vitamin and minerals, which are not sufficient in cereal grains (Liu et al., 2016; Zhang, Xu, Wu, Hu, & Dai, 2017). Moreover, they contain phytochemicals, such as polyphenols and flavonoids, with antibacterial and anticancer properties. RS3, or retrograde starch, was primarily formed during the chilling process of cooked potatoes, which provided health related benefits for obesity prevention, glycemic control and colonic health (Larder, Abergel, Kubow, & Donnelly, 2018). King and Slavin (2013) showed that blood sugar levels can be effectively controlled through RS intake. Therefore, the potato as wheat substitute can improve nutritive values of steamed bread and may represent a solution to

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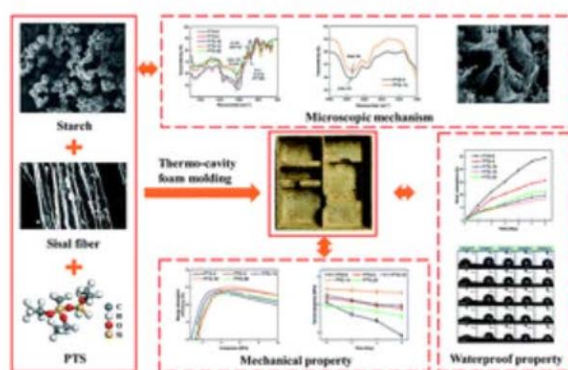




# Effect of poly-methyltriethoxysilane on the waterproof property of starch/fiber composites with open cell structures

Xu Sun, Xiu-jie Jia, Fang-yi Li, Jian-feng Li, Jian-yong Li, Chuan-wei Zhang, Shuai Chen, Jin-feng Cui, Kai-qiang Sun and Shan-guo Zhang

Novel starch/fiber composites with open cell structures were proposed through thermo-cavity molding.



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# Effect of poly-methyltriethoxysilane on the waterproof property of starch/fiber composites with open cell structures

Xu Sun,<sup>ab</sup> Xiu-jie Jia,<sup>ID</sup> \*<sup>ab</sup> Fang-yi Li,<sup>ID</sup> <sup>ab</sup> Jian-feng Li,<sup>ab</sup> Jian-yong Li,<sup>\*ab</sup> Chuan-wei Zhang,<sup>ab</sup> Shuai Chen,<sup>ab</sup> Jin-feng Cui,<sup>ab</sup> Kai-qiang Sun<sup>ab</sup> and Shan-guo Zhang<sup>ab</sup>

Novel starch/fiber composites with open cell structures were proposed through thermo-cavity molding. To overcome the disadvantage of the water sensitivity of the resulting composites, poly-methyltriethoxysilane (PTS) was added as a waterproofing agent. The results showed that the addition of PTS improved the waterproof property of the composites. The composites with 15 g PTS (PTS-15) exhibited an optimal waterproof property. The water contact angle and drop absorption of the PTS-15 composites improved by 59.9% and 223.5%, respectively, compared with the values for those without PTS. Moreover, the addition of PTS could effectively prevent the degradation of the mechanical properties of the composites after water absorption. The rate of tensile property degradation for the PTS-15 composites reached 5.3%, whereas that for the PTS-0 composites totaled 56.6%. The chemical bonds and micro-structure of the composites were investigated to reveal the inherent mechanism of property changes. Fourier transform infrared spectra revealed the formation of new hydrogen bonds between starch and PTS. Hydrophobic groups, including Si–O–Si, Si–C, and Si–OH, were found in the resulting composites, thereby explaining the waterproof property changes. Scanning electron microscopy images showed that the open cell structure of the composites initially became denser and then loosened with the increase in the PTS content, resulting in the initial enhancement and the subsequent weakening of their mechanical properties.

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## 1. Introduction

At present, with the rapid development of express packaging industries, the problems including environmental pollution and non-renewable resource consumption caused by plastic packing materials have become prevailing concerns among environmental science communities.<sup>1–3</sup> To solve these issues, scholars have focused on identifying biodegradable composites prepared using renewable natural polymers (*e.g.*, starch, fiber, lignin, polylactic acid (PLA), poly- $\beta$ -hydroxybutyrate (PHB), and chitosan).<sup>4,5</sup> In particular, plant fiber and starch, as the most abundant organic compounds found in nature, are ideal materials for the preparation of biomass composites. However, the natural starch-based composites feature poor mechanical properties given their high hydrophilicity and crystallinity.<sup>6</sup> Several strategies have been investigated to minimize or overcome these poor characteristics; these strategies include blending thermoplastic starch (TPS) with different biodegradable polymers such as polyvinyl alcohol

(PVA),<sup>7</sup> polycaprolactone,<sup>8</sup> polylactic acid,<sup>9</sup> cellulose fibers<sup>10</sup> or plant fibers.<sup>11</sup>

In addition, scholars have focused on the research of starch modification methods, including esterification,<sup>12</sup> etherification,<sup>13</sup> oxidation,<sup>6,14</sup> graft-copolymerization,<sup>15</sup> and plasticization.<sup>6,16</sup> Zhang<sup>17,18</sup> investigated a starch modification method combining oxidation and plasticization. This method can form additional hydrogen bonds between TPOS and the sisal fiber, thereby improving the mechanical properties of the composites but reducing their waterproof property. The effects of citric acid on the properties of glycerol-plasticized thermoplastic starch (GPTPS) were studied by Yu J. G.<sup>19</sup> Citric acid can also improve the elongation of GPTPS and ameliorate its water resistance at high relative humidity (RH). However, citric acid decreases the tensile stress. Cova A.<sup>20</sup> obtained modified cassava derivatives by modifying the native cassava starch (CS) with octenyl succinic anhydride (OSA). The results showed that OSA modification yielded a more hydrophobic material than native CS. Ma X.<sup>21</sup> prepared pea starch-based composites reinforced with citric acid-modified pea starch (CAPS) and citric acid-modified rice starch (CARS) by screw extrusion. The introduction of granular CAPS and CARS improved the storage modulus, glass transition temperature, tensile strength, and water vapor barrier properties of the composites but decreased their thermal stability. The

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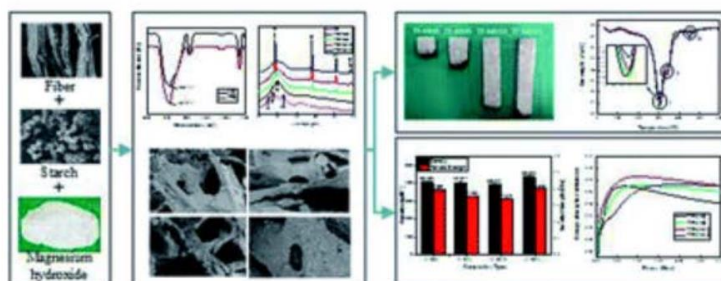




# Effects of magnesium hydroxide on the properties of starch/plant fiber composites with foam structure

Jin-Feng Cui, Fang-Yi Li, Jian-Yong Li, Jian-Feng Li, Chuan-Wei Zhang, Shuai Chen and Xu Sun

The process and the property of starch-based composite.



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# Effects of magnesium hydroxide on the properties of starch/plant fiber composites with foam structure

Jin-Feng Cui,<sup>ab</sup> Fang-Yi Li,<sup>ab</sup>  Jian-Yong Li,<sup>\*ab</sup> Jian-Feng Li,<sup>ab</sup> Chuan-Wei Zhang,<sup>ab</sup> Shuai Chen<sup>ab</sup> and Xu Sun<sup>ab</sup>

In this study, magnesium hydroxide (MH) flame-retarded starch/plant fiber composites containing various MH contents (0%, 5%, 15%, 15%) were prepared and named as TF-MH0, TF-MH5, TF-MH10, TF-MH15. Thermal degradation, flame retardancy, mechanical and microscopic characteristics were discussed. The reduction in the maximum thermal degradation rate revealed that the addition of MH provided improvement in the thermal stability of the composite. The horizontal burning test and the limiting oxygen index analysis suggested enhancement in flame retardancy with increasing MH content. Moreover, the density of composites initially decreased and then increased as the MH content increased. The tensile strength was positively correlated with the density, whereas the cushioning performance was negatively correlated with the density. Microscopic analysis showed that there was an interfacial interaction between MH and thermoplastic starch, which not only improves the thermal stability, but also promotes bubble nucleation as a nucleating agent. The cells of TF-MH10 were uniform and dense, thus TF-MH10 had the best buffering performance. Furthermore, the cell structure of TF-MH15 was short in diameter, small in number, and large in skeleton thickness; therefore, TF-MH15 had the highest tensile strength.

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## 1. Introduction

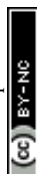
With the rapid development of the logistics industry, the use of petroleum-based cushioning packaging materials has gradually increased. However, the use of conventional petroleum based matrix can lead to environmental pollution and resource consumption.<sup>1</sup> Considering the requirements of green environmental protection and sustainable development, replacement of petroleum derived polymers with bio-based ones has been one of the most important trends in the polymer field.<sup>2,3</sup> Many biodegradable polymers, such as polylactic acid, polycaprolactone and other synthetic polymers, are available in the market, but with low cost-effectiveness.<sup>4</sup> Meanwhile, starch, plant fiber, and other renewable natural polymer materials are widely found in nature. For example, sisal fiber is a hard fiber with the largest amount and the widest range in the world. It has the characteristics of toughness, wear resistance, salt and alkali resistance and corrosion resistance that has been widely used in various industries such as automobiles. Previous studies have found that sisal fibers can improve better the

mechanical properties of composite compared to pulp fibers, straw fibers and wood fibers.<sup>5</sup> Because they have excellent mechanical properties, are inexpensive and environmentally friendly, starch/plant fiber composites with foam structures have been widely investigated.<sup>6,7</sup> The current research focused on the modification of starch and plant fibers to improve the compatibility and mechanical properties of composites. For example, native starch (NS) was added with a small molecule plasticizer, such as a polyol (glycerin and ethylene glycol) or an amide (formamide and acetamide), to destroy the hydrogen bond between the starch molecules to achieve plasticization, thereby improving the processing performance. The compatibility of plant fiber with starch can be improved by alkali treatment and silane coupling agent treatment.<sup>8–12</sup> Starch/plant fiber composites are flammable materials; thus, their applications are limited. However, the thermal stability and flame retardancy of starch/plant fiber composites have not received considerable attention from researchers.<sup>13</sup>

In recent years, the flame retardancy of composites has become more increasingly important, and flame retardants have been developed. According to different components, a flame retardant is divided into inorganic salt flame retardants, organic flame retardants, and mixed flame retardants. Halogenated flame retardants in organic flame retardants were the most effective and widely used flame retardants. However, their combustion releases toxic gases; therefore, the use of halogen-

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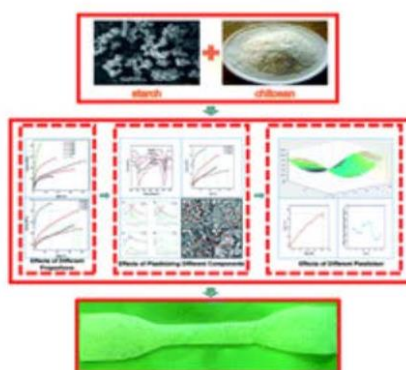
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# Optimisation of compatibility for improving elongation at break of chitosan/starch films

Kai-qiang Sun, Fang-yi Li, Jian-yong Li, Jian-feng Li, Chuan-wei Zhang, Shuai Chen, Xu Sun and Jin-feng Cui

Three methods were used to improve the elongation at break of chitosan/starch films to obtain the optimal compatibility.



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## Optimisation of compatibility for improving elongation at break of chitosan/starch films

Kai-qiang Sun,<sup>ab</sup> Fang-yi Li,<sup>ID</sup> \*<sup>ab</sup> Jian-yong Li,<sup>\*ab</sup> Jian-feng Li,<sup>ab</sup> Chuan-wei Zhang,<sup>ab</sup> Shuai Chen,<sup>ab</sup> Xu Sun<sup>ab</sup> and Jin-feng Cui<sup>ab</sup>

When chitosan/starch films were used as agricultural mulch films, the problem of rupture often occurred. In order to improve the elongation at break, chitosan/starch blend films were prepared by casting with different formulations (different ratios of chitosan to starch, different plasticizing components and different plasticizer ratios) in this research. The elongation at break of the film reached up to 104.1% when chitosan was plasticized with 10% glycerol and 0.94% ethylene glycol alone and then mixed according to a 1 : 0.6 chitosan–starch ratio. The fact that plasticizing starch, plasticizing chitosan or co-plasticizing starch and chitosan made a big difference to the mechanical properties of the films was discovered for the first time. The films with different plasticizing components were characterized by their mechanical properties, crystal structures and surface morphologies. Mechanical properties of the films were related to their crystallinity. The higher the crystallinity, the higher the elongation at break. Plasticizing starch alone facilitated the formation of hydrogen bonds and massive structures. Plasticizing chitosan alone was beneficial to the formation of network structures of the films and exhibited anti-plasticization at low plasticizer concentration.

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### 1. Introduction

Plastic waste poses a serious threat to the environment and human health.<sup>1</sup> Finding fully degradable natural polymer materials to replace plastics is currently a hot topic.<sup>2</sup> Agricultural mulch films are widely used in crop protection, as they can retain heat and moisture, improve the utilisation of solar energy, and protect plant roots. Most of these films remain in the form of debris in the soil, thereby causing heavy metal contamination of the soil and impeding soil permeability.<sup>3</sup> Therefore, the development and utilization of degradable films has become a trend. Among the existing degradable materials, natural biopolymers (*i.e.* starch) have huge advantages compared to synthetic biodegradable polymers as they are renewable, widely available, degradable and are fully compostable and free of toxic residues.<sup>4</sup>

However, starch films are limited in application due to their poor mechanical properties and poor water resistance.<sup>5,6</sup> To overcome these shortcomings, researchers have studied a number of methods, including: (1) physical modification: ultrasonic treatment of starch films to increase its elongation at break.<sup>7</sup> (2) Chemical modification: plastic modification,<sup>8,9</sup> cross-linking modification,<sup>10,11</sup> *etc.* to improve mechanical properties;

(3) blending modification: mixing sugar palm nanocrystalline cellulose<sup>12–14</sup> to improve the waterproofness and degradability,<sup>15,16</sup> adding chitosan<sup>17–19</sup> to improve the mechanical properties and waterproofness. Among all the improvements, chitosan has good antibacterial properties<sup>20</sup> and biocompatibility.<sup>21,22</sup> The prepared chitosan/starch films as agricultural mulch films can serve as fertilisers to nourish crops after full degradation and keep seeds away from harmful bacteria. Therefore, it is a good choice to replace agricultural plastic films. However, when the chitosan/starch films are used as an agricultural mulch film, the problem of film rupture often occurred. Hence, the elongation at break of such films must be increased. The mechanical properties of chitosan and starch at different ratios and with concentration gradients of 0.5 were compared in the study by Xu *et al.* The results showed that the tensile strength and elongation of the films increase first and then decrease as starch content increases. The maximum elongation at break of the film can reach 60%.<sup>23</sup> Therefore, by changing the ratio of chitosan to starch, the elongation at break of the films can be increased. However, the exact ratio of chitosan to starch at the highest elongation at break has not been explored. In addition, it has been widely proved that plasticizing modification can improve the mechanical properties of the films.<sup>9,10,24,25</sup> The results of Natta laohakunjit *et al.* showed that glycerol, sorbitol and ethylene glycol had different effects on the mechanical properties of starch films when used as plasticizers.<sup>9</sup> It was found that glycerol molecules were probably bound to the acetamide group of chitosan by H-bonds, which

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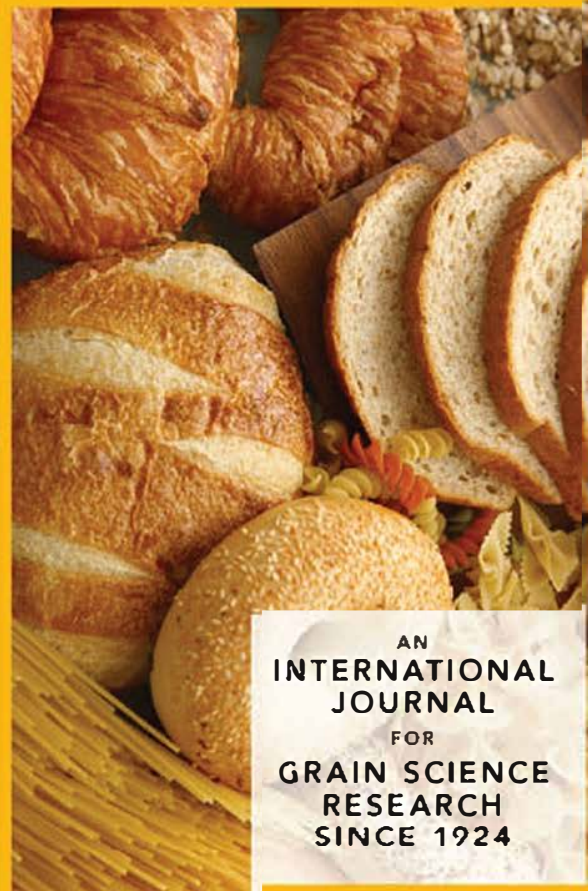
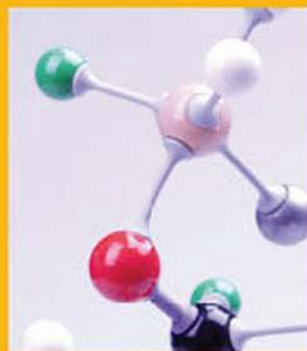




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## RESEARCH ARTICLE

# Influence of potato pulp on gluten network structure in wheat dough and steamed bread

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**Abstract**

**Background and objectives:** Steamed bread is the traditional fermented wheat product in China and has popularity in other Asian, European, and some North American countries. Wheat flour replaced by potato pulp can be an effective way to improve nutritive values of steamed bread and promote potato consumption. The aim of this study was to investigate the influences of potato pulp on disulfide bond (S–S) contents, protein secondary structures, starch crystallinity, and microstructures of dough and steamed bread. Spectrophotometry, Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), and confocal laser scanning microscopy (CLSM) were used for analyses.

**Findings:** The dough and steamed bread samples added with 10% potato pulp had higher S–S contents than the other tested samples. Compared with the control, the free sulfhydryl contents in the dough (3.2  $\mu\text{mol/g}$ ) and steamed bread (2.7  $\mu\text{mol/g}$ ) added with 30% potato pulp significantly increased, whereas those of the S–S decreased to 10.0 and 10.9  $\mu\text{mol/g}$ , respectively. The contents of  $\beta$ -sheet and  $\alpha$ -helix in the dough and steamed bread containing 10% potato pulp were higher than those in samples without the potato pulp. The relative crystallinity of starch in the dough significantly decreased with increasing potato pulp level ( $p < .05$ ). The CLSM and SEM images showed that potato pulp significantly affected the microstructure. Sample with 10% potato pulp possessed improved gluten network structures. However, samples with high potato pulp contents (>20%) possessed more gas cells and a loose gluten network structure.

**Conclusions:** The results showed that the addition of potato pulp affected gluten network structural characteristics in wheat flour dough and steamed bread, but appropriate level of potato pulp could be produced for gluten network enhancement.

**Significance and novelty:** The study would contribute to better understanding of the effect of potato pulp on the structural characterization of gluten network in steamed bread making and provide theoretical basis for in-depth application to wheat-based products.

**KEYWORDS**

crystallinity, disulfide bond, microstructure, potato pulp, protein secondary structure

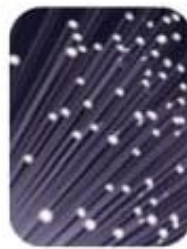




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## **Effects of Mashed Potatoes on Dough Properties and Quality of Steamed Bread**

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**Abstract:** Effect of mashed potato on the rheological properties of dough and optimization of mashed potato on fermentation technology were investigated. The results showed that the dough with 20% mashed potato had the best flour properties and tensile properties possessing 1.6 min travel time of dough, 2.2 min stability time of dough, 207 FU weakening degree, 41.7% water absorption rate, and 23 flour quality index was. The optimum dough parameters determined by single factor experiment and specific volume were 20% mashed potatoes addition, 50 min fermentation time and 32 °C. The effects of mashed potato on fermentation technology including sensory evaluation, specific volume, color difference and glue stickiness of steamed bread were discussed by quadratic orthogonal rotary combination design with the three factors and five levels. Response surface analysis (RSA) was used to analyze the data of these experiments. The optimum range of fermentation parameters were obtained, the addition of mashed potatoes was 20%-22%; the fermentation time was 38 min-50 min; and the fermentation temperature was 29-32 °C. The optimum fermentation parameters were obtained by validation experiments, the addition of mashed potato was 20%, the fermentation time was 50 min, and the fermentation temperature was 32 °C. Under these conditions, the specific volume was 2.35 ml/g, the sensory evaluation was 77, the whiteness was 75.7, and the stickiness was 9.53 J.

**Keywords:** Steamed bread, Dough rheological properties, Tensile properties, Fermentation parameters

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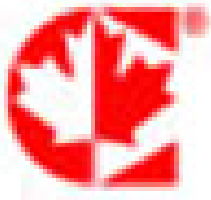
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### **I. Introduction**

Potato, an annual herbal crop of Solanaceae, is food and vegetable crops, which has high nutritional value and medicinal value[1]. There are many nutrients in fresh potatoes with 9-20% starch content, 1.5-2.3% protein content, 0.1-1.1% fat content, 0.6-0.8% crude fiber content[2]. Nutritional components of potatoes per 100 g includes 66-113 J calorie, 11-60 mg calcium, 15-68 mg phosphorus, 0.4-4.8 mg iron, 0.03-0.07 mg thiamine, 0.03-0.11 mg riboflavin, 0.4-1.1 mg nicotinic acid[3]. Besides, carotene and ascorbic acid, an important ingredient to human body, are rich in them. From the nutritional point of view, potatoes can provide a lot of energy to the human body, which is not provided by rice and flour.

Steamed bread is a kind of pasta with Chinese traditional characteristics. It is made by fermentation of flour and steaming[4]. There are many kinds of steamed bread, such as miscellaneous grain steamed bread, truffle and brown sugar steamed bread. As one of the main foods in our daily life, steamed bread made from wheat flour plays an indispensable role in China[5]. Accompanying the more attention of healthy diet and the attraction of coarse food grain, there is the prosperous of potato steamed bread with whole flour. Steamed mashed-potato bread has a unique advantage that cannot be achieved by potato whole flour steamed bread[6, 7]. It has higher safety, similar taste with white steamed bread, the fragrance of potatoes and costs relatively low. In this study, mashed potatoes were used as raw materials, and the orthogonal method was used to optimize the transportation of steamed mashed-potato bread. This research breaks through the traditional food production methods in the production technology and affords theoretical basis on the application of fresh potatoes. Mashed potatoes were used to make steamed bread, which enriched the types of steamed bread, provided a favorable means for the industrial production of new staple foods, and made it possible to increase economic benefits.

In this study, the main factors (the addition amount of mashed potato, fermentation time, fermentation temperature) in the fermentation process of steamed mashed-potato bread were tested by single factor test. The specific volume, color difference, glue and sensory evaluation of steamed mashed-potato bread were used as the evaluation indexes to study the better technology of steamed mashed-potato bread. On this basis, three factors, five levels and two times were carried out on steamed mashed-potato bread. The fermentation process of












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# Effect of Whole Purple Potato Flour on Dough Properties and Quality of Steamed Bread

Tianyu Zhang<sup>1,2</sup>, Fengjie Zhang<sup>1,2</sup>, Yanfei Cao<sup>1,2</sup>, Haijing Zhang<sup>1</sup>, Zhe Yang<sup>1</sup> & Hongjun Li<sup>1,2</sup>

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## Abstract

WPPF was added into the wheat flour (WF) flour with different addition amount (0%~50%) to study the influence of whole purple potato flour (WPPF) on dough properties and quality of steamed bread. Result revealed that the WPPF addition significantly influenced the dough properties and quality of steamed bread. The water absorption, the maximum height of the gas release, total volume of CO<sub>2</sub> release and the hardness of steamed bread significantly increased with the increase of WPPF addition amount, while decreased the dough stability, the maximum height of dough, the gas holding capacity and the specific volume. Moreover, peak viscosity, final viscosity and setback value had a remarkable decrease when 10% WPPF added, but increased following the addition of WPPF. Considering the sensory evaluation, the steamed bread with 20% WPPF is acceptable. Appropriate addition amount of WPPF improves the nutrition value and variety of steamed bread and did not effect on the quality of the quality of dough and steamed bread.

**Keywords:** whole purple potato flour, pasting properties, fermentation properties, texture properties, sensory evaluation

## 1. Introduction

Purple potato is a cross-breed potato variety native to South America and introduced to China in recent years(Gan, Xin, & Yun, 2017).Purple potato has a high nutritional value due to the large amount of starch, dietary fiber, amino acids, minerals and vitamins. Each 100 grams of fresh purple potato contains about 11.0 mg of calcium, 1.2 mg of iron, 343.0 mg of potassium, 22.9 g of magnesium, 16.0 mg of vitamin C and 40 mganthocyanins(Qiu, Wang, Song, Deng, & Zhao, 2018), which can effectively compensate for the deficiencies of traditional staple foods(Gan et al., 2017).

Compared with other major crops potato has stronger adaptability to barren drought, severe climate and has higher production per units, it's part for human consumption up to 85% (Lutaladio, Castaldi, & Lutaladio, 2009).In 2015, the Ministry of Agriculture of China proposed a strategy of potato staple food, and promoted the potato into a staple food such as steamed bread, noodles and synthetic rice. The potato will become another staple food other than rice, wheat and corn. Comparing with the consumption model of international China's potato is mainly used for fresh food, starch raw materials, and feed raw materials and so on. Increasing the consumption of potato in China can improve the fulfillment of the nutritional needs of the residents and promote the sustainable development of agriculture(Wang, Liu, & Zhao, 2016).

Lack of gluten in the respective products leads to weak dough structure and deterioration of crumb quality, therefore, potato food products are made from a mixture of potato flour and wheat flour, both to solve the problem of whole potato powder poor processing performance, and can remedy the nutritional limitations of potato flour.

The addition of whole purple potato flour changed the proportions of starches, protein and other components. Their presence influences water absorption, pasting properties and farinograph properties of the dough as well as texture and staling of the steamed bread, which allows the manufacture of products with strictly designed and controllable properties(Zhu, 2014).

In this research, the quality characteristics of steamed bread with high proportion of purple potato powder were



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# 低位铺放双重缓冲马铃薯收获机设计与试验

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5. 山东希成农业机械科技有限公司, 德州 253600)

**摘要:** 针对现有马铃薯收获机分离效果不理想、铺放环节防损减损能力弱、伤薯率和破皮率较高等问题, 结合国内北方地区马铃薯种植农艺, 采用“振动输送分离+双重缓冲减速+低位铺放减损”的薯-土-杂分离工艺, 设计了一种低位铺放双重缓冲减损马铃薯收获机, 主要由挖掘装置、仿形松土限深装置、低位铺放输送分离装置、2级振动装置、切土切蔓装置、双重缓冲帘、平土压实装置等部分组成。在阐述总体结构及工作原理基础上, 建立薯块运动模型, 确定关键部件参数。薯土分离阶段分为振动输送分离段和低位铺放缓冲分离段, 以在满足高效分离的同时降低破皮率; 优化改进后的仿形松土限深轮, 作用在薯垄内部薯块上的挤压力相对减小, 即达到薯土松离效果的同时降低伤薯率; 平土压实装置, 可有效避免薯块被挖掘分离后被再次掩埋, 利于捡拾且提高明薯率。台架试验利用碰撞检测技术, 分析低位铺放环节的碰撞冲击特征, 以揭示缓冲帘减损机理。试验结果表明, 在收获速度为 0.88、1.16 m/s 时, 纯作业时间生产率分别为 0.41、0.54 hm<sup>2</sup>/h, 伤薯率分别为 1.03% 和 0.84%, 破皮率分别为 1.52% 和 0.95%, 各项性能指标均满足相关标准的要求。

**关键词:** 马铃薯; 收获机; 低位铺放; 双重缓冲

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## Design and Experiment of Potato Harvester Using Double Cushions for Low Laying Separation Technology

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**Abstract:** To reduce the losses of bruising and damage, an appropriate available potato-soil separation technology is essential during the potato harvesting process. Combined with the agronomic techniques of potato cultivation in the north of China, a potato harvester with double cushions at low position laying stage was designed, which was developed with the potato-soil-impurity separation technology of vibration separation, double cushions, and low position laying. The harvester was mainly composed of excavating device, soil loosening and depth limiting device, low position laying and separation device, 2-level vibration device, soil cutting and seedlings cutting device, double cushions, soil compacting and flattening device and other parts. The kinetic models were established at the low position laying stage, and structural parameters of primary components were determined. The potato-soil separation device was divided into vibration separation stages and low position laying separation stage with double cushions, to improve the harvesting efficiency and reduce the harvesting losses. The loosening and depth limiting device was improved to reduce the bruising and damage. Simultaneously, the soil compacting device

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# 多回流式变量喷药控制系统设计与试验

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**摘要:** 针对目前大型宽幅喷药机在喷药过程中施药方式不合理、控制方式单一等问题, 在3WP-1200型喷杆式宽幅(22 m)喷药机基础上, 设计了一种多回流式变量喷药控制系统。该控制系统可根据喷药机行驶速度来调节比例控制阀, 通过改变回流口的开口度来改变喷药流量, 实现变量喷药。该控制系统分5路控制所有喷头, 每一路可单独控制开断, 一路或几路断开的同时可打开相对应的回流口, 使系统在不改变流量的情况下, 其余喷头喷药量不变; 多回流式的控制方法使系统压力更稳定, 控制精度更高。同时设计了该系统的硬件和软件, 并对该控制系统进行了液位标定与喷药精度试验。液位标定试验中, 对不同液位对应的药液容积进行了标定, 其标定模型决定系数 $R^2$ 为0.994; 流量控制精度试验中, 单个喷头的目标流量与实际流量相差不大, 其相对误差不大于4.1%; 喷药量控制试验中, 喷药流量可随速度变化而变化, 但其设定喷药量与实际喷药量相差不大, 相对误差在6%以内, 实现了变量喷药, 且控制精度较高。

**关键词:** 宽幅喷药机; 变量喷药; 多回流式; 控制系统

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## Design and Experiment of Multi-reflux Variable Spraying Control System

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**Abstract:** In order to solve the problems of unreasonable pesticide application methods and relatively simple control methods in the spraying process of large-scale wide-width spraying machine, a multi-reflux variable spraying control system was designed based on the 3WP-1200 spraying rod spraying machine with 22 m spraying width. The control system could adjust the proportional control valve according to the running speed of the sprayer, which realized the variable spraying by changing the spray flow rate caused by the opening of return port. The control system was divided into five paths to control all sprinklers, and each path could be controlled separately. When one or more routes were disconnected, the corresponding return port could be opened, so that the spraying quantity of the other sprinklers would not change without changing the flow rate of the system. At the same time, its multi-reflux control method made the system pressure more stable and control precision higher. Moreover, the hardware and software of the system were designed, and the liquid level calibration and spray accuracy test of the control system were carried out. In the liquid level calibration test, the liquid volume corresponding to different liquid levels was calibrated, and the determination coefficient  $R^2$  of the calibration model was 0.994. In the flow control accuracy test, the target flow rate of a single sprinkler had little difference from the actual flow rate, and the relative error was not more than 4.1%. In the spraying control test, the spraying flux could vary with the speed, but the actual spraying flux was almost the same as that of the set spraying flux, and the relative error was within 6%. These experimental results showed that the system could achieve variable spraying with high control accuracy.

**Key words:** wide-width sprayer; variable rate spraying; multi-reflux; control system

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# 基于振动排序的马铃薯微型种薯播种机设计与试验

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**摘要:** 为提升中国马铃薯微型种薯(简称微型薯)机械化播种水平,根据微型薯物理特性及农艺特点,设计了一种基于振动排序的马铃薯微型种薯播种机,该机可一次完成开沟、播种、覆土、起垄等作业。基于受迫振动原理,通过对微型薯单列排序输送投种、振动回种等过程的分析,确定了播种装置关键结构参数和工作参数。采用调节板高频低幅往复运动,动态微量调节落种口尺寸,避免薯种在种箱内的结拱;利用离散元仿真模拟,明晰振动板较合理的振动频率及相应的驱动连接轴转速。开沟装置、播种装置、覆土起垄装置前后依次布置,先后完成开沟、种薯覆土和起垄工序。田间试验表明,当作业速度为5 km/h时,种薯播种重播指数为4.6%,漏播指数为5.6%,合格指数为89.8%,种植深度合格率为96.5%,各项指标均符合国家和行业标准要求。

**关键词:** 马铃薯; 播种机; 振动排序; 覆土起垄; 田间试验

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## Design and Experiment of Vibration-arranging Based Seeder for Potato Micro-seed

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**Abstract:** Aiming at enhancing the mechanization level of potato micro-seed planting, a vibration-arranging based seeder for potato micro-seed was designed. The seeder consisted of seeding device, seed dropping adjustment mechanism, ditching device, and soil and ridging device, which can complete several working procedures in a single pass, such as ditching, seeding, soil covering and ridging. Based on the principle of forced vibration, potato micro-seeds were arranged and seeded in single row, and some seeds failed to arrange in single row were reseeded by vibration plate. The key structural and working parameters of seeding device were confirmed according to the physical characteristics of potato micro-seed and agronomy requirements. An adjusting plate with reciprocating motion of high frequency and low amplitude was applied to micro-change the size of seed-dropping mouth in dynamic conditions. By this way, the stored seeds forming arch in seed box would be avoided. Furthermore, discrete element simulation was used to clarify the reasonable vibration frequency and revolving speed of adjusting plate and driving shaft, respectively. Ditching device, soil covering and ridging device were arranged from front to back, so as to sequentially complete ditching, soil covering and ridging. Key parameters of the ditching opener and double-disc were determined by theoretical analysis. As indicated in the field experiment, at the working speed of 5 km/h, the multiple-seeding index, miss-seeding index, qualified-seeding index and qualified-seeding depth rate were 4.6%, 5.6%, 89.8% and 96.5%, respectively. Results showed that performance indexes of the seeder all met the relevant work quality evaluation specification requirements. The research can provide reference for the development of mechanical planting of potato micro-seed.

**Key words:** potato; seeder; vibration-arranging; soil covering and ridging; field experiment

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## 马铃薯微型种薯振动排序播种装置播种性能优化

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**摘要:** 为推动马铃薯微型种薯(简称微型薯)播种机械化的发展, 在现有研究的基础上, 提出基于受迫振动原理的单一排序机械化播种技术, 设计马铃薯微型种薯振动排序播种装置。在对播种装置工作原理进行阐述的基础上, 对投种过程进行运动学和动力学分析, 阐明了振动排序播种装置播种特性, 并明晰了影响播种性能的主要因素及各因素的试验取值范围。以偏心轮偏心距、驱动轴转速和种床带速度为试验因素, 以重播率、漏播率和播种合格率为评价指标, 对 3 个不同级别的微型薯为研究对象开展二次回归正交组合试验, 建立各个级别下微型薯的各指标与因素间的回归数学模型, 分析相关因素对播种性能参数的影响, 获得合理的参数组合, 并进行验证试验, 结果表明: 3 个不同级别的微型薯在较优的试验组合下, 重播率和漏播率均小于 5%, 播种合格率在 90% 以上。由此表明, 该播种装置满足马铃薯播种机播种性能要求。该研究为微型薯等大颗粒种子相关播种装置的研究、设计和优化以及播种性能的提升提供参考。

**关键词:** 机械化; 优化; 农作物; 马铃薯; 播种装置; 受迫振动; 播种性能; 验证

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### 0 引言

以微型薯为种薯所种出的马铃薯具有产量高、品质好、商品率高等优点, 为提升微型薯的种植面积和机械化水平, 应推动其播种机械化的发展<sup>[1-4]</sup>。现有微型薯机械化播种技术研究主要集中在气力式和输送带式投种两个方面。其中, 气力式投种方面, Mcleod 等<sup>[5]</sup>研究开发了一种气力式微型薯精量播种装置, 通过负压吸种和携种, 正压排种, 且在播种装置上设置喷枪, 将喷嘴上吸附的多余种子剔除, 以降低重播率; 美国 Crary 公司生产的 Lockwood 600 系列播种机<sup>[6]</sup>, 采用负压吸种方式播种微型薯, 并利用电子监控系统控制种子播量; 赖庆辉等<sup>[7-8]</sup>针对微型薯不易充种问题, 设计了一种可振动供种的气吸圆盘式微型薯排种器, 并进行了充种性能模拟和排种性能试验以获取较优的参数组合; 吕金庆等<sup>[9-10]</sup>研制出一种多种臂气吸取种式马铃薯排种器, 并开展正压吹

种零速投种性能优化试验。输送带式投种方面, Meijer 等<sup>[11]</sup>设计一种单人操作单行半自动马铃薯播种机, 采用输送带式排种器, 并开展了相关播种性能试验; 德国 Grimme 公司制造的 GB330 型带式马铃薯播种机<sup>[12]</sup>, 取种方式采用水平差速传送带, 可实现高速取种; 何玉静<sup>[13]</sup>开发研制一种带式马铃薯排种机构, 并开展播种性能试验研究。综上所述, 以上两种播种方式为微型薯机械化播种提供了技术支持。然而, 对于气力式播种装置而言, 因微型薯为大颗粒, 对播种装置的气密性和配套动力均提出较高要求<sup>[14]</sup>; 而带式马铃薯播种装置虽具有对薯种外形体积要求不高, 可高速取种等优点, 但该类播种装置结构复杂, 操作繁琐, 对作业环境适应性较差且价格较为昂贵<sup>[15]</sup>。

近年来, 因基于受迫振动原理对谷物进行分选、输送和播种具有作业稳定、谷物损伤小、作业质量高等优点, 国内外学者已开展相关研究。Kim 等<sup>[16]</sup>为提高谷物(水稻、小麦等)分选机的分选性能, 通过有限元分析和模态分析, 研究了分选机的振动特性; 王应彪等<sup>[17]</sup>根据振动送料原理, 提出一种实现玉米种子定向排列输送的方法, 对种子定向过程进行了动力学分析; 邢洁洁等<sup>[18]</sup>通过理论分析、EDEM 仿真和实际试验对电磁振动料斗内成堆玉米种子分散于排序输送机理进行了研究, 为后续玉米种子定向包装及播种提供了参考。

综上, 本文提出一种基于受迫振动原理对微型薯进

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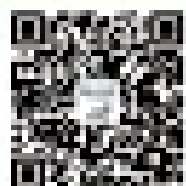
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**摘要:** 针对现有马铃薯收获机薯土分离效果不理想、伤薯率和破皮率较高等问题, 该文采用“2级高频低幅振动分离+薯秧分离及侧输出+低位铺放”的薯土分离工艺, 研制了一种缓冲筛式薯杂分离马铃薯收获机, 该机具主要由挖掘装置、松土限深装置、切土切蔓装置、分离筛、振动调整装置、薯秧分离装置、秧蔓侧输出装置、低位铺放装置以及压实整平装置等部分组成。结合分离筛末端与缓冲筛衔接处的薯杂分离状况, 分析了缓冲筛倾角变化对薯块和秧蔓的影响规律, 优选出较佳的缓冲筛倾角为36°。试验结果表明, 在收获速度为0.88和1.16 m/s时, 生产率分别为0.41和0.54 hm<sup>2</sup>/h, 伤薯率分别为1.47%和1.12%, 破皮率分别为1.89%和1.07%, 各项性能指标均满足相关标准的规定。随着收获速度的增加, 薯块碰撞加速度峰值和碰撞次数均减小, 可有效降低伤薯率和破皮率, 但明薯率有所降低; 反之, 碰撞加速度峰值明显增大, 明薯率提高的同时伤薯率和破皮率也明显增大。薯块位于分离筛上对应于薯垄边缘位置时, 容易产生较大的碰撞加速度峰值(>150g)。研究结果可为进一步探讨薯土分离减损控制方法及薯土分离工艺的优化改进提供参考。

**关键词:** 农业机械; 收获; 马铃薯; 振动分离; 收获品质

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### 0 引言

在国家粮食种植业结构调整和马铃薯主粮化战略的大背景下, 当前中国马铃薯种植面积和总产量均居世界前列, 马铃薯已成为国内第4大粮食作物<sup>[1-3]</sup>。国内北方马铃薯主产区主要集中在内蒙古、河北、黑龙江、甘肃和陕西等地, 有覆膜垄作和不覆膜垄作种植形式之分<sup>[4-6]</sup>。就收获方式和收获机结构形式而言, 不同的薯土分离结构形式直接影响着机具总体设计布局、生产效率、分离效果和收获品质等<sup>[7-8]</sup>。目前, 马铃薯收获机普遍采用的薯土分离振动装置按其结构形式不同分为一级振动分离、两级振动分离、振动与波浪两级分离以及摆动分离等<sup>[9-11]</sup>。薯土分离振动装置结构形式的选取必须与种植农艺紧密结合, 还要综合考虑收获地块的土壤类型、土壤含水率以及收获后马铃薯的不同用途等因素<sup>[12-15]</sup>。

在机械化收获作业时, 伴随着薯土分散分离、土块破碎分离、薯秧分离和集薯输送等过程, 使得薯杂混合物在分离筛等关键部件上的运动复杂多变, 薯土分离关键部件的结构形式、布置方式以及薯块在分离筛末端的铺放形式等均是影响马铃薯收获品质的关键因素。而振动装置的振动胶轮个数、振动幅度、振动轴转速、分离筛的张紧程度以及振动装置的布置方式直接影响着施加于分离筛上振动强度的强弱, 当然也影响着薯杂混合物的分散与分离<sup>[16]</sup>。综上所述, 影响薯土分离效率和收获品质的因素是多方面的, 现有机械化收获技术的振动碎土分离与收获品质的关系、铺放形式对收获品质的影响以及薯土分离工艺对收获效果的影响、薯块碰撞冲击损伤的精确评估等方面尚存不足<sup>[17-20]</sup>, 薯土分离环节的减损防损技术仍然是当前马铃薯收获机设计和改进的关键点<sup>[21-22]</sup>, 薯农迫切需要一种分离效果与减损防损相互兼顾的马铃薯收获机应用于实际生产。

本文在前期马铃薯收获试验的基础上<sup>[23]</sup>, 对铺放环节进行优化改进, 基于高频低幅振动分离技术和低位铺放减损技术研制了一种缓冲筛式薯杂分离马铃薯收获机, 在阐述总体设计和工作原理的基础上, 介绍了关键部件的设计计算与参数选取, 分析了薯土分离阶段的薯杂混合物运动特征以及分离筛和缓冲筛衔接处的薯块运动特征, 并利用碰撞检测装置获取了不同收获速度和缓

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# 基于多段分离工艺的马铃薯联合收获机设计与试验

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**摘要:** 针对马铃薯分段收获人工捡拾工作量大、劳动强度高、收获效率低等问题, 在适应种植模式和农艺要求的基础上, 设计了一种基于多段分离工艺的马铃薯联合收获机, 该机可同时完成双垄双行马铃薯的挖掘、薯土分离、清土除杂和集薯输送等任务。收获机在拖拉机的牵引作用下进行收获作业, 其关键零部件包括松土限深调控装置、切土切薯装置、挖掘装置、摆抖式薯土分离装置、过渡分离装置、清土除杂装置和集薯输送装置等。该收获机采用多段分离工艺, 可有效提高薯土分离效率, 显著降低含杂率, 降低劳动强度。田间试验表明: 作业速度分别为 3.17 km/h 和 4.16 km/h 时, 样机的损失率分别为 1.64% 和 1.59%, 伤薯率分别为 1.72% 和 1.48%, 破皮率分别为 2.31% 和 1.92%, 生产率分别为 0.41 hm<sup>2</sup>/h 和 0.54 hm<sup>2</sup>/h, 各项性能指标均达到了作业标准。基于碰撞检测技术获取了收获过程中薯块的动态碰撞信息, 在对碰撞特征和薯土混合物运动特点进行分析的基础上, 明确了联合收获机易产生较大碰撞加速度的关键位置为: 分离筛 I 与分离筛 II 交接处及集薯输送装置的落料端, 降低分离筛 I 和分离筛 II 之间的高度差, 改善集薯装置末端的缓冲效果, 是降低伤薯率和破皮率的有效措施。

**关键词:** 马铃薯; 联合收获机; 多段分离; 碰撞检测

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## Design and Experiment of Potato Combined Harvester Based on Multi-stage Separation Technology

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**Abstract:** The main technical problem of potato mechanical partition harvest is the large workload for farmers to pick up, high labor intensity and low harvest efficiency. A potato combined harvester based on multi-stage separation technology was developed on the basis of planting patterns and agronomic requirements. It could implement digging, potato-soil separation, soil cleaning and potato gathering simultaneously under the condition of double ridge and double row. The harvester was worked by the tractor's traction, the key parts of the harvester included depth control device of loosing soil, device of cutting soil and seedings, device of digging, shaking device of potato-soil separation, device of transition separation, device of removing soil and impurities and collecting device. The harvester adopted multi-stage separation technology, which could effectively improve the separation efficiency of potato-soil, reduce impurity content and labor intensity significantly. Field tests showed that loss rates were 1.64% and 1.59%, damage rates were 1.72% and 1.48%, and bruising rates were 2.31% and 1.92% and the productivity were 0.41 hm<sup>2</sup>/h and 0.54 hm<sup>2</sup>/h when the harvesting speeds were 3.17 km/h and

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# Intelligent Building Fire Control System Based on Internet of Things

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**Abstract:**Nowadays, the Internet of Things technology is very mature and widely used in fire control. Aiming at the needs of modern building intelligence, an intelligent building fire control system based on Internet of Things technology was designed. The system consists of two parts: the upper computer and the lower computer. It combines various external sensors to realize the fire linkage function. The MCGS configuration touch screen for PLC is applied to the fire control system, it is used as the host, and the STM32F103RBT6 microcontroller is used as the slave to realize the master-slave control function. The ASP.NET MVC framework is used to design the host computer cloud platform to remotely monitor and control the real-time status of the lower computer, and visualize the fire status of the entire building.

**Key Words:** Internet of things technology; Intelligent building; MCGS; ASP.NET MVC

## 1 INTRODUCTION

Internet of Things technology is a new technology after the emergence of the Internet. However, with the development of technology, people's understanding of the concept of "smart building" is more and more profound. Because people need more intelligent devices that are convenient for their lives to ensure the safety of life and property, so the research and design of intelligent control systems is of great significance[1-3]. Traditional intelligent devices are relatively independent individuals. They are not connected with other devices. Even if they are connected together, the functions implemented are not comprehensive enough. The accumulation of too many devices causes waste of resources. Intelligent building fire control system remote monitoring through uniting all the single devices and using the Internet of Things technology to display the fire protection status

of the entire building on a computer, facilitating people's lives[4-5]. Firstly, this paper puts forward the overall design scheme of the system, then introduces the Modbus communication protocol in detail and how to use the Modbus communication protocol to achieve the fusion of MCGS configuration touch screen and STM32 single-chip microcomputer. The hardware circuit is designed according to the system framework. Finally, the objectivity function is realized through the cloud platform based on the ASP.NET MVC framework.

## 2 DESIGN OF THE OVERALL SYSTEM

The intelligent building construction fire control system is mainly composed of intelligent fire control box (lower position machine), remote monitoring cloud platform (host computer), external detection and control module[6-7]. The overall framework of the system is shown in Fig 1:

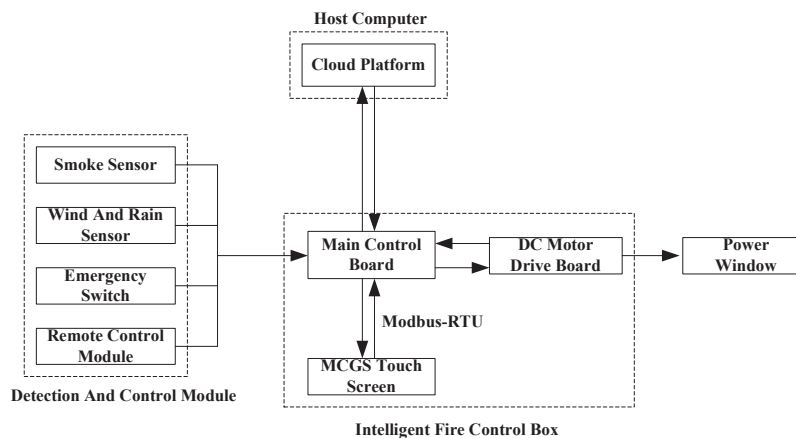


Fig. 1. System overall framework

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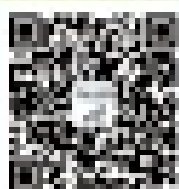
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## 振动与波浪二级分离马铃薯收获机改进

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**摘要:** 针对当前马铃薯机械化收获环节存在的破皮率和伤薯率较高等问题, 通过设置振动分离段和波浪分离段、基于振动与波浪二级分离改进了一种马铃薯收获机, 并分析了振动与波浪二级分离条件下的分离筛及薯块运动特征。单因素试验表明, 收获速度为 0.726 m/s 时, 单位时间内挖掘的薯土混合物较少, 易导致薯块疲劳累积损伤, 当收获速度为 1.167 m/s 时分离筛的分离负担加大, 土壤和杂质分离效率降低, 导致明薯率下降; 分离筛运行速度从 1.52 提高至 2.80 m/s 时, 破皮率和伤薯率先降低后增大的趋势, 但明薯率自 99.8% 下降至 96.4%; 振动强度由无振动增加到强烈振动时, 明薯率提高 3.3%, 但破皮率和伤薯率均有较大幅度的增加; 峰谷高差自 40~40 mm 增大到 200~200 mm 时, 明薯率由 97.2% 升高至 99.8%, 但其破皮率和伤薯率均有所升高。正交试验表明: 破皮率和伤薯率受收获速度和振动强度的影响规律基本一致; 收获速度和振动强度对破皮率和伤薯率的影响较显著 ( $P<0.05$ ), 振动强度和峰谷高差对明薯率的影响较显著 ( $P<0.05$ )。该文为马铃薯收获机的研发优化以及薯土分离效率和收获品质的综合控制提供了技术参考。

**关键词:** 振动; 机械化; 收获; 马铃薯; 混合分离; 破皮率; 伤薯率; 运动特征

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### 0 引言

马铃薯种植广泛, 是典型的根茎类作物, 粮蔬兼用, 还具有一定的能源价值<sup>[1-3]</sup>。机械化生产环节中马铃薯 70% 的损伤来自收获环节, 主要是由静载、剪切、挤压、振动和冲击载荷等作用产生的多次碰撞、反复摩擦以及不同方向的压力综合作用所致<sup>[4-5]</sup>, 其损伤力学特性一般需通过黏弹性进行分析与表征<sup>[6-7]</sup>。收获环节造成的破皮损伤严重影响了马铃薯的外观品质, 并导致储藏环节薯块水分易向外迁移、易感染病菌而腐烂, 给薯农造成较大的经济损失<sup>[8-9]</sup>。因此, 马铃薯机械化收获应解决的主要技术难题是破皮和伤薯率的综合控制, 即实现薯-土、薯-秧、薯-石(杂)高效分离, 并且减少动态损伤及切线擦伤等形式的损失<sup>[10-13]</sup>。

薯土分离装置是马铃薯收获机的核心部件, 不仅要完成大量收获物料的输运, 还要保证土壤、秧蔓及碎石

等杂质的高效分离<sup>[14-15]</sup>。在保证分离效率和收获品质的前提下, 要尽可能避免薯块“跳跃”、“回流”, 以减小因碰撞所产生的动态损伤、多次摩擦导致的疲劳累积损伤和切线擦伤。常见收获分离工艺有两级振动分离、斜置平输送、前置振动两级分离、后置振动两级分离以及拨辊推送等形式<sup>[16-20]</sup>, 选用何种分离工艺, 对马铃薯的分离效率和收获品质有着一定的影响。

研究薯块在分离筛上的运动规律, 探讨土壤、秧蔓等杂质的动态特性, 有助于探讨最优收获品质、较高分离效率条件下作业参数及薯土分离参数, 有利于指导马铃薯收获机的研发改进。本文阐述了基于振动与波浪二级分离的马铃薯收获机的基本结构及特点, 探讨了薯块在分离筛筛面上的运动特性, 并结合分离筛的运动特点分析了薯块在振动分离段和波浪分离段的运动特征, 在此基础上进行了田间单因素试验和正交试验, 得到了较佳薯土分离参数。试验数据对明晰薯土分离参数对收获品质的影响规律具有一定的参考价值。

### 1 基于振动与波浪二级分离的马铃薯收获机

#### 1.1 结构改进及薯土分离技术特点

##### 1.1.1 总体结构

基于振动与波浪二级分离的马铃薯收获机主要由土豆限深装置、切土装置、薯土分离装置、挖掘装置、导流防护装置、波浪可调整装置和集薯装置等组成(如图 1 所示)。

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# 基于离散元的微型马铃薯仿真参数标定

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**摘要:** 为系统全面地研究微型马铃薯种子离散元仿真物性参数, 根据其物料特征创建微型薯模型, 以此为基础建立微型薯离散元参数获取模型。利用试验测定及仿真模拟相结合的方法对微型薯颗粒离散元参数进行标定和校准, 即以先后建立碰撞恢复系数测定模型、微型薯-钢板摩擦因数测定模型、微型薯颗粒间摩擦因数测定模型的方法, 在 EDEM 中建立仿真试验模型并以所标定的相应离散元仿真参数为自变量, 以仿真模型所测定的因素为评价指标, 通过在仿真模型中改变自变量获取相应的评价指标值, 建立曲线拟合方程, 将真实试验模型中对各因素所测定的值作为仿真目标值代入拟合方程中得到微型薯离散元仿真参数并进行了仿真试验验证。求得微型薯种子离散元仿真参数: 微型薯-钢板碰撞恢复系数为 0.523, 微型薯颗粒间碰撞恢复系数为 0.478, 微型薯-钢板静摩擦因数为 0.644, 微型薯-钢板滚动摩擦因数为 0.022 1, 微型薯颗粒间静摩擦因数为 0.325, 微型薯颗粒间滚动摩擦因数为 0.030 0。对标定后的微型薯离散元物性参数进行仿真验证试验, 结果表明标定后的微型薯仿真颗粒堆积角以及种子分布情况与真实试验条件相吻合, 为微型薯相关播种机具设计和优化提供了理论依据。

**关键词:** 微型马铃薯; 离散元; 仿真参数; 标定

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## Calibration of Simulation Parameters for Potato Minituber Based on EDEM

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**Abstract:** In order to study the discrete element simulation physical parameters of potato minituber, the combination methods of experiment and simulation were used to calibrate contacting parameters of particle discrete simulation. The simulation experimental model was built in EDEM by using coefficient measurement model of restitution, particle-steel friction coefficient measurement model and particle-particle coefficient friction measurement model. The corresponding contacting parameters of particle discrete element was used as independent variable, the data which was measured by simulation model was used as evaluation index, and then curve fitting equation was built by changing the independent variables to obtain the corresponding evaluation index value in the simulation model. Finally, the factors measured in the real test model were substituted into curve fitting equation as the simulation target values to obtain the discrete element simulation contact parameters of potato minituber. The simulation experiment was verified through repeated simulation experiments. The particle discrete element simulation target parameters were obtained as the particle-steel coefficient of restitution was 0.523, the particle-particle coefficient of restitution was 0.478, the particle-steel coefficient of static friction was 0.644, the particle-steel coefficient of rolling friction was 0.022 1, the particle-particle coefficient of static friction was 0.325 and the particle-particle coefficient of rolling friction was 0.030 0. The calibrated physical parameters of the potato minituber were simulated by EDEM. The result showed that the calibrated particle stacking

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# 基于多元非线性回归分析的马铃薯加工品质特性预测

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**摘要:** 为快速准确检测马铃薯加工品质,对希森3号及希森6号马铃薯的加工品质指标干物质和还原糖含量在马铃薯内部的分布规律进行研究。通过试验得出,两种马铃薯干物质含量在马铃薯中呈与马铃薯形状相似的椭球分布,在中心部位有最小值。采用拟牛顿算法和通用全局优化算法,结合对试验数据进行多元非线性回归分析,得出希森3号和希森6号马铃薯干物质含量关于检测点坐标值 $x$ 、 $y$ 和 $z$ 的回归模型,决定系数分别为0.9099和0.9123,均能有效预测马铃薯干物质含量。马铃薯还原糖含量在马铃薯中心位置含量最高,由中心向表皮还原糖含量逐渐降低,在马铃薯茎部的还原糖含量低于马铃薯顶部关于中心对称位置的还原糖含量。两种马铃薯还原糖含量的多元非线性回归模型,决定系数分别为0.8336和0.8246,可预测马铃薯内部各点还原糖含量。通过对试验数据归纳分析得出,马铃薯靠近表皮位置干物质含量高,还原糖含量低,适合加工薯片薯条。

**关键词:** 马铃薯; 加工品质; 干物质; 还原糖; 多元非线性回归分析

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## Potato Processing Quality Characteristics Prediction Based on Multivariate Nonlinear Regression Analysis

XU Yingchao WANG Xiangyou YIN Xiang YUE Rencai HU Zhouxun SUN Jingbin

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**Abstract:** Aiming to accurately detect potato processing quality, the distribution of processing quality index dry matter and reducing sugar in potato were investigated. It was concluded that potato dry matter had the ellipsoid distribution in potato and the minimum value was in the center part. The experimental data was analyzed by using quasi-Newton algorithm combined with universal global optimization method, and the regression model of dry matter content of Xisen 3 and Xisen 6 potato about testing point coordinates  $x$ ,  $y$ , and  $z$  was received. The determination coefficients of regression models about dry matter content of Xisen 3 and Xisen 6 potato were 0.9099 and 0.9123, respectively, and regression models can effectively predict the potato dry matter content. The content of reducing sugar in the center of potato was the highest, and the reducing sugar content from the center to the epidermis was decreasing. The reducing sugar content in the stem of potato was lower than that on the top of potato. The determination coefficients of multivariate nonlinear regression models about two kinds of potato reducing sugar content were 0.8336 and 0.8246, respectively. The regression models could predict the contents of reducing sugar in potato. According to the analysis of experimental data, the potato close to the epidermis was higher in dry matter and lower in reducing sugar, which was suitable for processing potato chips and French fries. The average content of dry matter of Xisen 6 potato is more than 20%, and the average content of reducing sugar is less than 0.1%, which is suitable for processing. This research can help processors for effective utilization of potato for various types of processing products viz., chips, French fries and flour, and provide a theoretical basis for NIR nondestructive detection of potato processing quality.

**Key words:** potato; processing quality; dry matter; reducing sugar; multivariate nonlinear regression analysis

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# 马铃薯干物质空间分布状态可视化研究

许英超 王相友 印祥 胡周勋 岳仁才

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**摘要:** 采用可见-近红外高光谱检测系统对马铃薯干物质进行快速检测,并最终实现其分布状态的可视化。采用9种光谱预处理方法对采集的马铃薯高光谱数据进行分析对比,得到标准正态变量(SNV)结合Savitzky-Golay平滑(SG)和一阶导数(FD)的预处理方法效果最好。经过光谱预处理后,采用正自适应加权算法-连续投影法(CARS-SPA)对光谱进行特征变量提取,获得22个变量。对所选变量不同的建模方法进行了比较,以偏最小二乘回归(PLSR)模型预测效果最优,预测集决定系数为0.849,均方根误差为0.878%,相对分析误差为2.312,优于全波段模型。将SNV-SG-FD-CARS-SPA-PLSR模型与高光谱图像结合,得到马铃薯干物质主要分布在内髓与维管束环之间、在内髓位置干物质含量最低、由内髓向外干物质逐渐增加的空间分布。内髓位置干物质质量分数最低,为12.16%,外层最高可达24.62%。结果表明:可见-近红外高光谱技术可准确、快速地实现马铃薯干物质的检测和空间分布的可视化。

**关键词:** 马铃薯; 干物质; 空间分布; 可视化; 高光谱

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## Visualization Spatial Assessment of Potato Dry Matter

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**Abstract:** In order to visualize the spatial distribution of potato dry matter, the internal dry matter content of potato was studied by using visible/near-infrared hyperspectral imaging (HSI) and a detection model of dry matter of potato was established. The reflectance spectra of sliced potatoes which were extracted from the regions of interest of HSI were performed with different pretreatments. The standard normal variable (SNV) combined with Savitzky-Golay smoothing (SG) and the first derivative (SNV-SG-FD) was the optimal pretreatment. Based on optimal pretreatment, competitive adaptive reweighted sampling (CARS) combined with successive projections algorithm (SPA) was used to select variables of the spectrum and obtained 22 variables. Three regression models based on principal component regression (PCR), support vector regression (SVMR) and partial least squares regression (PLSR) were established. The best performance was achieved by PLSR model, its determination coefficient ( $R_p^2$ ), root mean square error for prediction and relative percent difference were 0.849, 0.878% and 2.312, respectively. The PLSR model based on 22 variables was superior to the full-spectrum model. An imaging processing algorithm was developed to transfer each pixel in potato dry matter content with the SNV-SG-FD-CARS-SPA-PLSR model. The imaging showed the distribution of dry matter within the potatoes. It showed that the potato dry matter was mainly distributed between the inner pith and vascular bundle and the inner pith had the lowest dry matter content. It was gradually increased from the inner pulp to the outer. Dry matter content was 12.16% in inner pith and the outer layer reached up to 24.62%. The results show that the visible near infrared hyperspectral imaging is a useful tool for rapidly and effectively visualizing detecting spatial distribution of potato dry matter.

**Key words:** potato; dry matter; spatial distribution; visualization; hyperspectra

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# Effects of sampling depth on near infrared spectroscopy model of potato dry matter

Yingchao Xu, Xiangyou Wang<sup>\*</sup>, Xiang Yin, Jingbin Sun, Zhouxun Hu, Rencai Yue

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**Abstract:** To improve the detection accuracy of the near infrared spectroscopy model of potato dry matter, near infrared spectroscopy models of the peeled and unpeeled potatoes were investigated. Potato slices with 5-13 mm sampling depths were obtained by Fourier transform infrared spectrometer with fiber optic. The optimal spectral data under each condition were extracted after different pretreatments. Then, effective wavelengths were selected via genetic algorithm (GA) and partial least squares regression (PLSR), and least square-support vector machine (LS-SVM) was applied to construct models that predicted the dry matter content in potato. The results showed that prediction models established with GA selected effective wavelengths were better than full-spectrum models. The LS-SVM model built by using near infrared spectroscopy with GA for unpeeled potato with 7 mm sampling depth can nondestructively determine the dry matter content of potato, and the prediction correlation coefficient and relative percent deviation were 0.920 and 1.465, respectively. The PLSR model achieved the best performance for peeled potato with 11 mm sampling depth, and the prediction correlation coefficient and relative percent deviation were 0.930 and 1.818, respectively. This research provides a basis for online inspection and further development of portable equipment of potato dry matter content.

**Keywords:** near infrared spectroscopy; genetic algorithm; potato; dry matter; sampling depth

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## 1. Introduction

As the fourth-largest grain crop in the world, potato boasts both high yield and wide plantation. In 2016, the planting area for potato was 85.26 million mu, and the total output reached 92.01 million tons in China (Yang, Guo, & Sun, 2017). The potato is also an important industrial raw material that plays a central role in people's lives; and the high-quality modern lifestyle has led to higher stress on the potato processing industry stress to increase the quality of potato preprocessing. The content of dry matter provides an important index for potato (Rady & Guyer, 2015a). Traditionally, the proportion method (Helgerud et al., 2015) has been adopted to measure the dry matter content, but it takes a long measurement cycle, which makes it unsuitable for

the rapid testing that is required in production. Therefore, realizing both rapid and nondestructive testing of the dry matter content in potato, while increasing the testing precision are of great significance for the development of the potato processing industry.

Research shows that near infrared spectroscopy (NIR) has gradually become a research hotspot of nondestructive testing in recent years due to its advantages of convenience, speed, efficiency, and non-destruction of samples (Balabin & Smirnov, 2011). Quantitative model needs to be built to test the content of the components of fruits and vegetables with NIR (Magwaza et al., 2012; Pu, Feng, & Sun, 2015). Sampling depth has a major influence on the testing precision of the quantitative mode. This is because the content of the components within fruits and vegetables is unevenly distributed (Mo et al., 2017; Zhu et al., 2016), while NIR is poor in penetration; therefore, only surface information can be obtained (Wu et al., 2014). Hence, only when the depth of spectroscopy for obtaining information and the

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# 马铃薯精密播种机智能控制系统设计

孙传祝<sup>1,2</sup>, 王法明<sup>1,2</sup>, 李学强<sup>2,3\*</sup>, 苏国梁<sup>2,3</sup>,  
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**摘要:** 针对现有马铃薯播种机播种株距控制精度不高、易产生重种漏种等问题, 研发了一种由主控制模块、检测模块、株距控制模块和振动强度控制模块等 7 个模块组成的马铃薯精密播种机智能控制系统, 采用液压马达控制薯种输送带运转, 步进电机控制薯种输送带的振动强度, 实现了播种株距和重种漏种率的自动控制。试验结果表明, 播种速度相同时, 实际播种株距相对于设定播种株距的平均偏差分别为 2.65%、3.37%、3.67%、5.75%和 4.09%, 播种速度越高实际播种株距的稳定性越差; 薯种输送带振动强度越强, 重种率越低, 漏种率越高, 各因素对重种漏种率影响的主次顺序为: 薯种输送带振动强度 > 播种速度 > 薯种质量, 且薯种输送带振动强度对重种率、薯种输送带振动强度和播种速度对漏种率有显著影响; 较佳的播种作业参数为: 薯种输送带振动强度为 II 级 (即轻微振动时)、播种速度为 1.16 m/s 及薯种质量为 35 g。经 2~3 个周期即可调整到允许范围内, 且稳定性好。因此, 完全能够满足种植户的实际播种作业要求, 为智能控制马铃薯精密播种装备的后续研发提供参考。

**关键词:** 农作物; 设计; 振动; 精密播种; 智能控制; 播种株距; 重种率; 漏种率

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## 0 引言

马铃薯粮菜兼用, 营养丰富, 种植范围广泛<sup>[1-3]</sup>。2015年初, 国家正式启动“马铃薯主粮化”战略, 到 2020 年国内马铃薯种植面积将达到  $6.7 \times 10^6$  hm<sup>2</sup>, 且 50% 以上的马铃薯将会作为主粮消费。但是, 中国只是马铃薯生产大国而不是强国, 其机械化水平明显滞后于小麦、玉米和水稻等主要粮食作物<sup>[4-6]</sup>, 无法满足产业化需要。

目前, 现有马铃薯播种机常用的排种装置是碗勺式, 但这种排种器易产生重种和漏种<sup>[7]</sup>。因此, 吕金庆等<sup>[8]</sup>研制的舀勺式马铃薯排种器, 当主动轮转速为 42 r/min, 倾角为 0°, 清种强度为 0.75 时, 排种合格指数为 92.6%, 重播指数为 4.5%, 漏播指数为 2.9%; 牛康等<sup>[9]</sup>设计的双层种箱式排种装置, 空种率小于 10%, 重种率小于 20%, 与单层种箱式排种装置相比, 空种率降低 50%, 重种率降低 24.5%; 孙伟等<sup>[10]</sup>设计了由定位和测薯模块组成的漏

播检测系统以及由固态继电器和电磁铁组成的速动补薯装置, 可将漏种率控制在 8% 以下, 补种成功率在 85% 以上; 张锡志等<sup>[11]</sup>研制的与大型宽幅精密播种机相配套的智能监测仪, 采用模拟原理对传感器信号进行采集; 龚丽农等<sup>[12]</sup>设计了具有自动补种功能的排种系统, 通过单片机控制电磁阀的动作实现补种, 能够实现精确补种。Buitenwerf 等<sup>[13]</sup>根据马铃薯从薯种碗中的释放时间建立了数学模型, 台架试验表明, 马铃薯薯种形状和薯种碗类型对播种精度影响很大; Leemans 等<sup>[14]</sup>研制的控制系统不仅能对播种状况进行监测, 还可引导播种作业; Mcleod 等<sup>[15]</sup>设计的试验装置可将单粒薯种传送到特定位置, 且不仅可播种马铃薯, 还可用于其他小种子作物的播种。另外, 还有专家学者在马铃薯播种机结构优化等方面做了大量研究<sup>[16-28]</sup>。

综上所述, 目前关于马铃薯播种机方面的研究主要集中在提高播种精度和结构优化等方面, 而对于马铃薯播种机智能控制方面的研究较少。本文研制了一种马铃薯精密播种机智能控制系统, 以期解决播种株距控制精度不高、易产生重种漏种等问题, 提高其播种精度和播种效率。

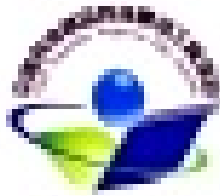
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中国农业机械学会主办

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# 拨辊推送式马铃薯清洗分选机设计与试验

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3. 山东理工大学机械工程学院, 淄博 255000)

**摘要:** 针对现有马铃薯清洗分选机的薯土分离效果差、伤薯率较高、工作效率低等问题, 设计了一种拨辊推送式马铃薯清洗分选机。对该机器的工作机理进行了阐述, 确定了清洗装置、分选装置的结构参数, 分析了马铃薯在清洗分选过程中的力学特性。选取机组的转速、上料量、机组提升角度作为试验因素, 伤薯率、分选清洁率为试验性能指标进行正交试验, 并对试验结果进行显著性分析。结果表明, 各因素对伤薯率影响的主次因素顺序为: 机组提升角度、机组转速和上料量; 对分选清洁率的影响主次因素顺序为: 上料量、机组转速和机组提升角度。按照以马铃薯的伤薯率较低, 兼顾分选清洁率较高的原则, 确定较优组合, 即机组转速为 145 r/min, 上料量为 20 t/h, 机组提升角度为 12°, 并对该参数组合进行了验证试验, 结果表明, 在该条件下机器伤薯率为 0.773%, 分选清洁率为 95.42%, 符合基本作业要求。

**关键词:** 马铃薯; 清洗分选机; 拨辊推送式; 力学分析; 正交试验

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## Design and Experiment of Potato Cleaning and Sorting Machine

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**Abstract:** In order to solve the problems of poor separation effect, high damage rate and low working efficiency of the existing potato cleaning and sorting machine, a poking roller shoving type potato cleaning and sorting machine was designed. The working mechanism of the potato cleaning machine was described, and the structural parameters of the cleaning device and the sorting device were determined. And the mechanical properties of potato during cleaning and sorting process were analyzed. The orthogonal test was carried out with the unit speed, feeding amount and unit lifting angle as experimental factors, the damaged rate and sorting cleaning rate as experimental indexes. The test results were analyzed by using the data processing software, and it showed that the primary and secondary factors influencing the damaged rate were as follow: unit lifting angle, rotating speed and feeding amount; and the factors affecting the sorting cleaning rate were as follow: feeding amount, unit speed and unit lifting angle. According to the principle of low damage rate and good cleaning rate, the optimum experimental parameters combination were as follow: the unit speed of 145 r/min, the feeding account of 20 t/h, and the unit lifting angle of 12°. And verifying test results were as follows as follow: the damage rate of potato was 0.773% and the sorting cleaning rate was 95.42%, which met the requirement of potato cleaner. The research provided a reference for further reducing the damage rate and optimizing the parameter of potato sorting machine.

**Key words:** potato; sorting machine; shifting roller; mechanical analysis; orthogonal test

### 引言

伴随着我国农业产业的结构调整以及马铃薯主

粮化战略的部署, 马铃薯的种植面积逐年增加, 当前马铃薯的总产量已经稳居世界前列<sup>[1-4]</sup>。但是, 我国并不是马铃薯的加工和贸易出口强国, 很重要的

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# 大蒜种子分级机研究现状及展望\*

李超<sup>1</sup>, 冯芮<sup>1</sup>, 徐洪岑<sup>1</sup>, 孙倩<sup>1</sup>, 宋井玲<sup>1</sup>, 金诚谦<sup>1, 2</sup>

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**摘要:**大蒜种子形状复杂、大小差异较大给大蒜种植机的开发设计带来困难,对种子进行分级不但可使大蒜出苗整齐,便于播种和管理,也有利于大蒜种植机械的研发和提高大蒜机械化种植质量。针对目前专用的大蒜种子分级机较少、对其分级技术的研究不够深入的问题,阐述农业物料分级技术以及大蒜种子机械化分级技术的研究现状,分析国内外现有机械式大蒜种子分级机和图像识别大蒜种子分级方法的工作原理及特点,并对其性能进行分析比较。针对现有大蒜种子分级机械存在的窜级、无法充分发挥各级效率、筛孔堵塞和蒜皮飞落等问题,提出合理选用筛面材料或设置导向凸棱、依据大蒜尺寸分布设计筛面长度、增设清筛装置和蒜皮、尘土收集装置等建议,展望大蒜种子分级机应向破瓣、分选、分级复合作业和智能化发展,旨在为大蒜种子分级机的进一步发展提供参考,推动大蒜生产机械化进程。

**关键词:**大蒜;种子分级机;滚筒;分级筛;分级技术

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Li Chao, Feng Rui, Xu Hongcen, Sun Qian, Song Jingling, Jin Chengqian. Research status and prospect of garlic seed classifier [J]. Journal of Chinese Agricultural Mechanization, 2021, 42(6): 91-96

## 0 引言

大蒜属鳞茎植物,是我国主要经济作物。近年来,我国大蒜种植和加工产业发展迅速,主要生产区有山东、江苏、河南、四川、陕西等。目前我国大蒜生产机械化处于起步阶段,仍以手工为主,作业效率低,强度大<sup>[1-4]</sup>。随着大蒜种植业的发展,对大蒜生产机械化的要求日益增强,大蒜种植机械化是大蒜生产机械化的重要环节,由于大蒜种子形状复杂、大小差异较大给大蒜种植机的开发设计带来了困难。大蒜种子分级不但可使大蒜出苗整齐,便于播种和管理,也是提升大蒜种植机性能和效率的有效途径,但目前专用的大蒜种子分级机较少,对其分级技术的研究也不够深入。因此,本文从分析农业物料分级技术入手,对大蒜种子的机械化分级技术现状进行分析,旨在能够推动我国大蒜产业机械化的发展,特别是大蒜种子分级机的研发和应用。

## 1 国内外现有农业物料分级技术

农业物料主要是依据物料的特性进行分级,包括

物料的基本物理特征(如尺寸、颜色、形状等)、物理特性(如硬度、密度等)、振动特性(低频振动、声波振动、超声波等)、光学特性等。

1) 机械式分级技术。机械式分级技术是根据物料的基本物理特征进行分级的,如形状、尺寸等,特点是分级效率高,对作业环境要求低,但容易对物料造成损伤。

2) 计算机视觉检测技术。计算机视觉检测分级技术是将计算机图像检测技术与分级装置相结合,通过摄像头提取图像信息,采集卡将提取到的图像信息转化成为数字信息,计算机利用模糊技术和神经网络对反馈的数字信息进行识别判断,建立相应的指标关系,实现检测和分级<sup>[5-6]</sup>。

3) 重量检测分级技术<sup>[7]</sup>。重量检测分级技术是将物料在线称重进行检测分级,传送装置上设置有重量检测系统,将检测到的信息转化为数字信息,传输终端进行判断,再结合分级装置完成分级。

4) 光电技术。综合利用现代光学、电子学和生物学等新技术对物料外观形态、内部品质等方面进行检测,并进行自动分级剔除。如近红外光谱技术、高光谱

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# 蒜种种植方位对大蒜生长发育及产量的影响<sup>\*</sup>

徐洪岑<sup>1</sup>, 李超<sup>1</sup>, 冯芮<sup>1</sup>, 宋井玲<sup>1</sup>, 朱俊科<sup>1</sup>, 金诚谦<sup>1, 2</sup>

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**摘要:**为研究蒜种种植方位对大蒜生长发育及产量的影响,为大蒜机械化种植装备的研发应用及其直立种植性能指标的确定提供依据,以杂交红蒜为试验对象,对蒜种种植方位进行单因素田间完全随机区组试验研究。结果表明:芽尖向上 30°以上种植的大蒜在蒜薹长度和蒜头产量与水平种植差异不显著,但出苗早,出苗齐整,植株高大,建议芽尖向上 30°以上作为衡量大蒜种植机械直立种植指标。芽尖向下种植的大蒜出苗晚,出苗不齐整,与水平种植相比,出苗率低 4%,蒜薹长度短 6.9%~15.2%,蒜头产量减产 8.4%~15.1%,蒜头的横径较小,大小不一致,形状不规则,直立种植时应尽量避免芽尖向下种植。

**关键词:**大蒜;种植方位角;产量;出苗率

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徐洪岑, 李超, 冯芮, 宋井玲, 朱俊科, 金诚谦. 蒜种种植方位对大蒜生长发育及产量的影响[J]. 中国农机化学报, 2021, 42(2): 74-78

Xu Hongcen, Li Chao, Feng Rui, Song Jingling, Zhu Junke, Jin Chengqian. Effect of garlic planting position on garlic growth and yield [J]. Journal of Chinese Agricultural Mechanization, 2021, 42(2): 74-78

## 0 引言

我国是世界上最大的大蒜生产国和出口国,出口量占全球大蒜贸易量的 80%<sup>[1]</sup>。因大蒜种子外形不规则,且在种植过程中有芽尖向上直立栽种的农艺要求,大蒜种植机械化较难实现。长期以来国内大蒜的种植主要依靠人工进行栽种,劳动强度大,生产效率低,生产成本低<sup>[2]</sup>。

欧美等发达国家地广人稀,为实现规模化种植,多采用机械单粒播种,不追求鳞芽朝上。以中国、日本、韩国为代表的亚洲国家,人多地少,是大蒜的芽尖朝上直立种植机械研究的主要地区。大蒜直立种植机械通常由单粒取种、蒜种定向和直立栽植三部分组成。蒜种的定向问题是世界难题<sup>[3-6]</sup>,至今仍未很好解决,国内外成熟的、实用化的大蒜种植机械很少。

为探索蒜种种植方向对大蒜生长发育的影响,推动大蒜种植机械的研发及应用。农业农村部南京农业机械化研究所金诚谦等<sup>[7]</sup>和济宁市农业科学研究所的高圆圆等<sup>[8]</sup>进行了蒜种鳞芽朝上、朝下、随机三种朝向种植的田间试验研究,结果表明大蒜的鳞芽种植朝向

对大蒜植株、蒜薹以及鳞茎等主要农艺性状均有影响。山东农业大学的刘静<sup>[9]</sup>进行了蒜鳞芽向上 90°、倾斜 45°、平放 0°、倒置 45°和倒置 90°种植的盆栽试验,结果表明,倒置种植严重阻碍植株、蒜薹和鳞茎的生长。山东省农业科学研究所的颜冬等<sup>[10]</sup>进行蒜种直立 90°、左倾 45°、前倾 45°、平放 0°和倒立 90°种植的田间区组试验,结果表明倒立 90°不适用于大蒜栽培,机播中应尽量避免。目前为止,多数研究观察的样本量有限,也没能从试验设计上尽量消除样本生长环境与田间管理存在的差异,研究的种植方向较少,难以给直立种植性能指标确定提供足够依据。本文拟深入研究种植方位对大蒜的生长发育及产量影响,为大蒜种植机械的研发和推广应用及其直立种植性能指标的确定提供依据。

## 1 材料与方法

### 1.1 试验材料及地点

试验蒜种为“杂交红蒜”,根据农艺要求,选用生长发育良好,种皮色泽一致、饱满、无病、无损伤的蒜种<sup>[11]</sup>。其平均长度为 32.1 mm,宽度为 19.2 mm,厚度为 16.4 mm,质量为 5.4 g。

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# 蒜薹机械化收获技术现状分析\*

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**摘要:**蒜薹收获是大蒜生产的重要环节,收获时既要保证蒜薹质量又不能伤害植株影响其继续生长,实现机械化收获比较困难,蒜薹收获仍以人工为主,为研发能达到推广应用要求的蒜薹收获机,对蒜薹收获机械化技术现状进行分析。从大蒜的收获模式和蒜薹收获的方法对蒜薹、蒜头产量的影响出发,综合分析现有蒜薹收获机械的类型、关键部件和工作原理,通过现有蒜薹收获机械性能比较分析,针对现有蒜薹收获机械普遍存在对蒜薹假茎破坏、影响蒜头后期生长的问题,提出采用夹薹原理机械化收获蒜薹,蒜薹长且对假茎损伤小,蒜薹收获机械化应向智能化方向发展才能提高收获部件工作的准确性、减少对植株和蒜薹的损害乃至无损。为我国蒜薹收获机械进一步发展提供借鉴和参考,推动大蒜生产机械化的发展进程。

**关键词:**蒜薹;大蒜;夹薹法;蒜薹收获机械

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Feng Rui, Li Chao, Xu Hongcen, Yang Qinghua, Song Jingling, Jin Chengqian. Analysis of the status of garlic bolt mechanized harvesting technology [J]. Journal of Chinese Agricultural Mechanization, 2021, 42(2): 37-44

## 0 引言

大蒜是我国的重要经济作物和出口创汇产品,种植面积约占世界总种植面积的 1/3,产量约为世界产量的 75%。蒜薹作为大蒜的花茎,也是人们喜欢吃的蔬菜之一<sup>[1-3]</sup>。从全国范围来看,近几年来,蒜薹产量一直在稳步增长。2018 年全国主产区共收贮蒜薹 80 849 万 kg<sup>[4-5]</sup>,蒜薹的产量和收获方法与收获时长有着极大的关系,因此为了调节劳力紧张程度和保证蒜薹提早或延晚上市,在长期生产实践中,蒜农对于如何抽好蒜薹,积累了丰富的经验,但还停留在人工采摘阶段,劳动强度大,效率低。采收蒜薹时温度为重要的影响因素,晴天中午或者午后采摘蒜薹,此时蒜薹有些萎蔫,叶鞘与蒜薹容易分离,并且叶片有韧性不易折断,可减少损伤<sup>[6]</sup>。有不少农户由于不会科学采摘蒜薹,造成蒜薹质量差、产量低,蒜头个子小、减产多<sup>[7]</sup>。蒜薹收获时既要保证蒜薹质量又不能伤害植株影响其继续生长,实现机械化收获比较困难,目前蒜薹收获仍以人工为主,严重制约蒜薹及大蒜产业的进一步发展,适

合大蒜生产的农艺技术和相应的机械化收获技术亟待解决。近年来,劳动力不断进入城市,农村劳动人员数量越来越少,雇佣劳动力的成本也越来越高。为了增强我国蒜薹收获的机械化水平、缓解蒜薹收获劳动力短缺的问题,研究适合我国大蒜种植模式的蒜薹收获机械迫在眉睫。本文分析了蒜薹收获机械的研究现状,提出了存在的问题以及今后的发展方向,旨在为蒜薹收获机械的研发提供借鉴和参考,推动大蒜生产机械化的发展进程。

## 1 大蒜收获模式

蒜薹收获机械的性能要求与大蒜收获模式有关,蒜农通常根据自身的需求和自然条件选择合适的大蒜品种和相应的收获模式,以实现经济利益最大化<sup>[7]</sup>。

1) 以收大蒜头为主。收获时主要收获蒜头,蒜薹产量较低,采薹时应尽量保持假茎完好,以利蒜头生长。

2) 以收蒜薹为主。专门的薹用大蒜品种<sup>[8]</sup>,主要目的是采收蒜薹,可剖开或用针划开假茎提出蒜薹,这

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# 胶辊式和锥盘式破瓣技术比较分析\*

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**摘要:**大蒜制种和深加工都需先对大蒜进行破瓣,目前大蒜机械化破瓣技术主要有胶辊式和锥盘式破瓣技术,为提高大蒜机械化破瓣效率、降低破损率,本文对胶辊式和锥盘式破瓣技术的性能以及破瓣后蒜瓣的状态进行了对比分析。胶辊式大蒜破瓣装置对大蒜破瓣率为 91.6%,破损率为 1.6%。锥盘式大蒜破瓣装置对大蒜的破瓣率为 95.3%,破损率为 3.3%。结果表明,锥盘式大蒜破瓣装置比胶辊式大蒜破瓣装置的破瓣率高,但胶辊式大蒜破瓣技术易于实现多级破瓣,通过添加多级胶辊可以有效的提高破瓣率;利用胶辊式大蒜破瓣装置进行破瓣后的大蒜,蒜皮保存较为完整,对牙尖部位的损伤较小,蒜瓣适合大蒜种植;利用锥盘式大蒜破瓣装置破瓣后的大蒜,蒜瓣脱皮现象较多,且蒜瓣的损伤主要以牙尖部位损伤和蒜瓣缺失为主,蒜瓣更适合应用于深加工。分析结果为大蒜机械化技术的应用和机具开发设计提供参考依据。

**关键词:**大蒜;锥盘;胶辊;大蒜破瓣;大蒜破瓣机

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## 0 引言

大蒜风味独特,是生活中不可或缺的食用佐料。除其食用价值外,大蒜还在保健医疗方面发挥着灭菌、消毒等多种作用<sup>[1-3]</sup>。我国大蒜种植面积和总产量稳居世界前列,同时我国也是世界上生产、出口和消费大蒜最多的国家之一<sup>[4-5]</sup>。现阶段,我国的大蒜大部分采用人工进行破瓣,劳动强度大、效率低、耗时耗力,据 Dakshinamurthy 报道,通过人工对大蒜进行破瓣,效率大约为 2~3 kg/h,随着大蒜种植业和蒜种深加工产业的发展,对大蒜的机械化蒜瓣需求不断增加。

目前大蒜机械化破瓣技术主要有胶辊式和锥盘式破瓣技术,为提高大蒜机械化破瓣效率、降低破损率,本文对胶辊式和锥盘式破瓣技术的性能和破瓣后蒜瓣的状态进行了对比分析,为大蒜机械化技术的应用和机具开发设计提供参考依据。

## 1 胶辊式和锥盘式破瓣原理对比分析

机械破瓣一般是给大蒜施加作用力以克服蒜瓣之

间的结合力,使各蒜瓣之间分离,将蒜头破成蒜瓣的过程。由于当前国内外大蒜破瓣机械的研究较少,以及缺乏相应的大蒜破瓣原理文献。通过查阅杏仁、核桃、花生等农产品的破壳原理和破壳方式<sup>[6]</sup>,可以借鉴以下几种原理对大蒜破瓣进行分析。

1) 撞击法。撞击法是物料高速运动时突然受阻而受到冲击力,使外壳破碎而实现脱壳。典型设备为由高速回转甩料盘及固定在甩料盘周围的粗糙壁板组成脱壳机。撞击脱壳法适用于仁壳间结合力小,仁壳间间隙较大且外壳较脆的物料。该原理适合葵花籽、松子等体积较小的物料进行破壳。

2) 碾搓法。物料在固定磨片和运动着的磨片间受到强烈的碾搓作用,使物料的外壳被撕裂而实现脱壳。其典型的设备为由一个固定圆盘和一个转动圆盘组成的圆盘剥壳机<sup>[7]</sup>。

3) 挤压法。挤压法脱壳是靠一对直径相同转动方向相反,转速相等的圆柱辊,调整到适当间隙,使物料通过间隙时受到辊的挤压而破瓣(壳)<sup>[8]</sup>。要使物料在两挤压辊间被挤压破壳,物料首先必须被夹住,因此辊子之间的间隙对挤压法破瓣有着重要的影响。花

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# 马铃薯联合收获机摇摆架及挖掘结构的设计

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**摘要:** 随着国内马铃薯收获机械化水平的不断提升,在借鉴了国内外先进技术的基础上,结合马铃薯在国内收获地形差别较大的实际情况,设计了一款能够适应多种收获地形的仿形挖掘机构—摇摆架。该结构既能够在平坦的收获地形实现高效收获,又可在薯垄具有一定高度差的地块收获时实现双垄不同挖掘深度的独立调节,提高了收获机适应不同收获地形的能力,解决了因收获地面不平而造成的伤薯问题。模块化的辅助机构设计,增强了收获机满足不同马铃薯种植农艺要求的能力。通过液压缸控制挖掘铲的收放,提高了收获精度,降低了劳动强度。该结构的设计对马铃薯收获机的改进提供了参考。

**关键词:** 马铃薯收获机; 摇摆架; 模块化; 独立调节

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## 0 引言

马铃薯是世界上公认的第四大粮食作物,在我国种植面积广<sup>[1-2]</sup>。在整个马铃薯生产过程中,收获是非常重要的一个环节,而目前马铃薯收获装备无法满足产业化需求,机械化水平远低于其他主要粮食作物。国内研发的马铃薯收获设备种类繁多,但结构往往比较简单,适用范围局限在地势较为平坦的平原地带,对于地势相对有起伏的地域适应能力不强,生产效率相对较低,严重制约着马铃薯产业的发展<sup>[3-4]</sup>。

马铃薯收获的第1个工序就是挖掘,因此挖掘部件的设计与优化决定了马铃薯收获机的收获性能。随着马铃薯产业机械化水平的不断提升,对挖掘各部件的设计提出了更高的要求。我国是世界上马铃薯种植面积最大的国家,种植地域的广泛分布造成了收获情况的复杂多变。对于地势较为平坦的平原地区,马铃薯收获机械目前形成了较为统一的收获机构;但对于收获具有一定倾斜度的地块时,现有的马铃薯收获机大多采用增加挖掘深度的方式进行收获。由于深度挖掘造成收获效率低下,增加动力的消耗,过多的上土量为后期的清选带来困难;如果挖掘过浅,将会增加伤薯率和漏薯率。

目前,一些针对收获地面倾斜而设计的收获机械显得较为专门化和小众化,适用范围受到地域的局限,且收获质量参差不齐,机械化程度不高,远远满足不了市场的需求。因此,设计一款既能够在平坦收获的情况下达到高效收获的目的,又能在地势高低起伏变化相对较大的地区实现挖掘收获的马铃薯收获机构,对于提高马铃薯收获的工作效率、减轻农民的劳动强度具有重要意义。

## 1 结构与工作原理

### 1.1 整体结构

基于马铃薯联合收获机设计的摇摆挖掘限深机构主要由摇摆架、液压系统、挖掘铲、仿形碎土辊、切土圆盘、限位传感器和控制系统等组成,可在仿形限深的过程中根据收获地形情况的不同实现双垄不同挖掘深度的独立调节,保证双垄的挖掘深度一致,达到适应更为复杂的收获条件和高效收获的目的。整体结构如图1所示。

### 1.2 工作原理

该结构是基于马铃薯联合收获机设计的,采用拖拉机牵引的方式进行工作。在挖掘过程中,仿形碎土辊行走在薯垄上,初步破碎薯垄上板结的土块,降低挖掘铲的挖掘阻力;挖掘铲切入薯垄土层,两侧的切土圆盘对掘起的薯垄进行剪切与地面分离;随着牵引前行,将掘起的薯垄通过铲体斜面滑行,并输送到挖掘装置后面的输送分离筛;在滑行输送的过程中,初步破碎的土壤会经过单垄三小铲的滑草间隙散落,减少后续分离清选装置的工作负担。

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# 滑切去顶式甜菜打缨机的设计与试验

李少川<sup>1</sup>，胡周勋<sup>1</sup>，王琳琳<sup>2</sup>，岳仁才<sup>1</sup>，祝珊<sup>1</sup>，李学强<sup>2</sup>，王相友<sup>1</sup>

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**摘要:** 甜菜的打缨切顶是甜菜收获过程的重要组成部分,直接影响甜菜的收获质量,且切顶准确性的提高对于甜菜收获质量及收获效率有较大的促进作用。我国现有机型存在切顶效果不佳、打秧效果不好,以及作业效果比较单一等问题。针对上述问题,设计了一款新型的甜菜打缨机,在保证甜菜打缨切顶质量的同时,又可以调整刀组之间的距离,提高了该机型的适应能力。该机打秧刀采用两种材质的刀配合作业,使打秧效果更好,且降低对甜菜的损害率;后部安装仿形切顶机构,改变传统的仿形方式,采用平行四杆仿形机构和滑切去顶的方式,使切顶效果更佳。该机型的设计为解决存在的问题提供了比较合适的方案,为进一步的研究奠定了基础。

**关键词:** 甜菜; 打缨机; 平行四杆机构

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## 0 引言

甜菜在我国是仅次于甘蔗的第二大制糖原料,具有很高的经济价值,但目前甜菜的机械化水平在我国相对落后,无法满足市场对于甜菜的大量需求。甜菜在我国一般采用分段式的收获方式,包括切顶去叶、挖掘收获及筛选集箱,而切顶去叶阶段是整个收获过程的重要组成部分,影响后续的收获过程和质量,但现在仍采用传统的人工去顶,劳动强度大、效率低,不能保证良好的作业效果<sup>[1-5]</sup>。

国外由于机械化程度较高、技术先进,在甜菜机械方面研究起步较早,各方面已经相当的成熟。例如,德国格力莫公司的 FT-300 前置打叶机能够实现甜菜的精确切顶,保证了甜菜的收获质量。由于国外以大田作业为主,多数采用联合收获的方式,实现了自动化控制。国内机械化水平较低,制约了甜菜机械全程化的发展,一些专家学者经过不断地努力,取得了一定成效。王合等为了提高甜菜的收获水平,研制的 4Q-2 型甜菜切顶去叶机,在一定程度上提高了工作效率<sup>[6]</sup>。福海县推广使用的 4TG-2 型甜菜割叶机,工作部件为单独仿形,能够适应多种地块,且割

叶、切顶一次性完成,提高了工作效率<sup>[7]</sup>。何磊等设计了一种集仿形、切顶及切缨为一体的甜菜切顶机,经过田间试验确定最优参数组合,大大提高切顶合格率<sup>[8]</sup>,但在甜菜分段收获过程中仍存在着切顶作业切削损失大、效率低及效果不理想等问题。针对上述问题,设计了一种新型的甜菜打缨机,对其整体进行优化,使其结构紧凑合理。通过对打秧刀的设计,使打秧质量提升;采用平行四杆仿形机构增强切顶能力的同时,使切顶效果更佳,且打秧和仿形切的工作性能及适应性方面有较大提高。

## 1 整机结构以及主要技术参数

### 1.1 整机结构

甜菜打缨机整机由机架总成、护罩、牵引装置、传动系统、液压系统、刀轴总成、地轮总成,以及切顶机构总成等组成,如图 1 所示。

工作原理:该甜菜打缨机采用牵引式的方式与拖拉机相连,能够适应较复杂环境。工作时,动力由拖拉机通过万向节式传动轴输送到该打缨机变速箱,动力经变速箱输出轴传递到皮带,由皮带驱动刀轴总成旋转,为了获得更好的动力传输效果,采用两侧传动的形式。机具在前进过程中:第 1 组钢制刀轴打碎甜菜叶片,在离心力作用下将其抛洒至地面;第 2 组和第 3 组橡胶刀,负责清除顶端剩余甜菜叶;3 组打秧刀工作时,旋转方向两两相反,保证清除各个角度的剩余甜菜叶片。机具末端装有切顶刀具用来完成甜菜的切顶作业,通过液压提升机构减少损耗和损伤,通

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# 食品研究与开发<sup>®</sup>

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# 甘薯泥对面团流变特性及馒头品质的影响

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**摘要** 利用粉质仪、拉伸仪、质构仪和色差计研究甘薯泥对面团流变特性及馒头品质的影响。结果表明 随着甘薯泥添加量的增加, 面团吸水率、面团形成时间、稳定时间及粉质指数逐渐降低, 软化度增加, 面团的拉伸曲线面积、拉伸阻力、拉伸比增大, 延伸度降低, 且醒发时间越长, 其变化趋势越大。与白面馒头相比, 甘薯泥的加入使馒头的比容、感官评分降低, 胶黏性增大, 馒头的亮度下降, 色泽变暗, 馒头具有浓郁的甘薯香味。

**关键词** 甘薯泥; 面团; 流变特性; 馒头; 感官评价

## The Effects of Mashed Sweet Potato on Rheological Quality of Dough and Quality of Steamed Bread

ZHANG Feng-jie<sup>1,2</sup>, ZHANG Tian-yu<sup>1,2</sup>, CAO Yan-fei<sup>1,2</sup>, YANG Zhe<sup>1,2</sup>, ZHANG Hai-jing<sup>1,2</sup>, LI Hong-jun<sup>1,2,\*</sup>

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2. School of Agricultural Engineering and Food Science, Shandong University of Technology, Zibo 255049, Shandong, China)

**Abstract** : The effects of mashed sweet potato on the rheological properties of dough and the quality of steamed bread were investigated by means of a farinograph, an extensograph, a texture analyzer and a color-difference meter. The results showed that the water absorption rate, dough development time, stability time and farinograph quality number of flour decreased with the increase of mashed sweet potato content, and degree of softening increased. With the mashed sweet potato adding, the area stretch curve, tensile resistance and stretching ratio of dough were increased, and the extensibility decreased, and the longer the waking time, the greater the change trend. Compared with the steamed bread with white flour, the addition of mashed sweet potato reduced the specific volume and sensory score of the steamed bread, increased its stickiness, reduced the brightness and darkened the color of the steamed bread, and the steamed bread had a strong sweet potato flavor.

**Key words** : mashed sweet potato; dough; rheological quality; steamed bread; sensory evaluation

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甘薯又名地瓜、番薯等, 肉多为黄白色, 但也有紫色。甘薯的营养价值丰富, 除了富含淀粉和可溶性糖

外, 还含有蛋白质、脂肪酸、多种维生素以及钙、磷、铁等无机盐。甘薯作为 13 种最佳蔬菜的冠军, 还是一种理想的减肥食品<sup>[1]</sup>, 而且, 甘薯具有抗癌、预防肺气肿、增强免疫等功能。

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我国甘薯资源丰富, 甘薯产业具有很大的发展潜力。随着科学技术的飞速发展和人民生活水平的迅速提高, 国内外对于甘薯的开发利用日渐增多。张颖等<sup>[2]</sup>将甘薯全粉添加到面条中, 得出了最优的工艺条件;

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# 粮油 食品 科技

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国家粮食和物资储备局科学研究院主办

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# 响应面法优化甘薯泥馒头加工工艺

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2. 山东理工大学 农业工程与食品科学学院, 山东 淄博 255049)

**摘要:** 以 20%甘薯泥和小麦粉为原料, 研究压面次数、醒发时间、醒发温度对甘薯泥馒头品质的影响规律。在单因素实验基础上, 选取感官评价为考察指标, 利用响应面分析法对甘薯泥馒头加工工艺进行优化。结果表明, 甘薯泥馒头的最佳工艺为: 压面次数 14 次, 醒发时间 18 min, 醒发温度 33 ℃。所制作的甘薯泥馒头品质较好, 具有特殊的甘薯香味。

**关键词:** 甘薯泥; 响应面法; 馒头品质; 工艺优化

中图分类号: TS213.2 文献标识码: A 文章编号: 1007-7561(2020)01-0040-06

## Optimization of processing technology of sweet potato puree steamed bread by response surface method

ZHANG Feng-jie<sup>1,2</sup>, ZHANG Tian-yu<sup>1,2</sup>, CAO Yan-fei<sup>1,2</sup>, YANG Zhe<sup>1,2</sup>, ZHANG Hai-jing<sup>1,2</sup>, LI Hong-jun<sup>1,2</sup>

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**Abstract:** With 20% sweet potato puree and wheat flour as raw materials, the effects of knead times, fermentation time and fermentation temperature on the quality of sweet potato puree steamed bread were studied. On the basis of single factor test, sensory evaluation was selected as the evaluation index, and response surface analysis was used to optimize the processing technology of sweet potato puree steamed bread. The results showed that the optimum technological formula of sweet potato puree steamed bread was as follows: 14 times of kneading, 18 min of fermentation and 33 ℃ of fermentation temperature. With special sweet potato flavor, the quality of sweet potato puree steamed bread is better under this condition.

**Key words:** sweet potato puree; response surface method; steamed bread quality; process optimization

甘薯, 作为我国仅次于水稻、小麦、玉米的主要粮食作物<sup>[1]</sup>, 是我国淀粉工业的主要原料。甘薯具有很高的营养价值, 其中必需氨基酸含量相对较高, 特别是米面中较缺的赖氨酸。从营养角度看, 甘薯营养比较平衡<sup>[2]</sup>, 比大米、小麦粉具有更多的优点。因此, 将甘薯与大米、小麦粉等谷

物类食品搭配食用, 可以使蛋白质的组成更全面<sup>[3]</sup>。

近年来, 国外很多发达国家将甘薯视为“健康食品”及“太空食品”, 掀起了一股食用甘薯的热潮<sup>[4-6]</sup>。在我国, 甘薯主要以加工淀粉<sup>[7]</sup>和制作薯片<sup>[8]</sup>为主, 以甘薯为原料的主食产品研究报道较少。马名扬等<sup>[9]</sup>向小麦粉中加入一定比例的甘薯全粉制作馒头, 研究了甘薯全粉添加量对面团流变学特性及馒头品质的影响; 梁建兰等<sup>[10]</sup>将甘薯配粉馒头与普通馒头挥发性物质进行了比较, 发现甘薯配粉馒头中的香气物质比普通馒头多十多种。

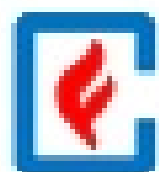
实验将甘薯制成泥后添加到小麦粉中制作甘

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# 消防科学与技术 9

## Fire Science and Technology 2021.9

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广告

### 红色旋风



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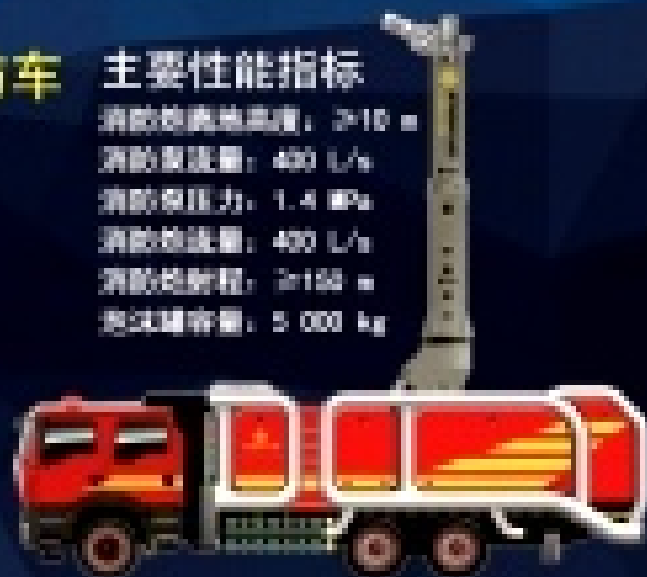
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3. 可减少大场火灾车辆和人员数量，集中供液，远距离喷射，安全地降温控火，能降低火灾救援人员伤亡和财产损失。

#### 主要性能指标

消防炮喷射高度：≥10 m  
 消防泵流量：400 L/s  
 消防泵压力：1.4 MPa  
 消防炮流量：400 L/s  
 消防炮射程：≥150 m  
 泡沫罐容量：5 000 kg



#### ●超重型泡沫消防车



#### 主要性能指标：

消防泵流量：400 L/s  
 消防泵压力：1.4 MPa  
 消防炮流量：400 L/s  
 消防炮射程：≥150 m  
 泡沫罐容量：5 000 kg

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# 基于自适应集成神经网络的火灾预测方法

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**摘 要:**针对传统火灾预测方法存在误报和漏报的问题,提出了一种基于自适应集成神经网络的火灾预测方法。首先,在信息层采用速率检测算法将不同类型传感器检测到的奇异数据输入到网络模型中。其次,在特征层采用长短期记忆网络(LSTM)和径向基前馈神经网络(RBF-BPNN)构建集成网络学习不同输入参数下的火灾特征,最后,在决策层设计模糊逻辑控制系统推理输出火灾报警等级。实验结果表明,该方法具有更高的预测精度。

**关键词:**自适应集成神经网络;速率检测算法;模糊逻辑控制系统;火灾预测

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在各类灾害中,火灾是威胁公共安全和社会发展的主要灾害之一。近几年,火灾发生数量逐年增加,一种高效、稳定的火灾预测方法对减少火灾造成的人员伤亡以及财产损失具有重要意义。传统的火灾预测方法是通过单一特征信息的阈值来判断是否有火灾发生,但由于火灾发生的地点和原因不同,火灾呈现出不同的特点,而且环境和人为干扰因素都可能导致火灾的误报和漏报。虽然神经网络模型用于火灾监测已经有所研究并且相比于传统方法具有更好的性能,但仍存在判断准确率低和稳定性差的问题。因此,一种更加智能化的火灾早期监测方法是解决上述问题的关键。

针对火灾预测问题,国内外专家学者做过相关研究,例如,加权 Logistic 回归模型、灰色系统理论、小波分析和机器学习算法等。火灾信息具有连续时间序列的特征,使用上述方法并不能达到理想的预测精度。为此,赵月爱等根据长短时记忆网络(LSTM)可以对时间序列数据长期记忆的能力,提出一种基于 TensorFlow 智能学习框架的 LSTM 神经网络电气火灾预测算法;于秀丽等综合考虑多种类型的火灾特征参量,将径向基函数(RBF)神经网络与反向传播(BP)神经网络算法融合进行火灾特征层算法设计,提出采用 RBF-BP 组合网络对火灾特征参量进行融合计算。为了实现火灾的分级报警,李卫高等建立了一种神经网络与模糊逻辑相组合的火灾探测分级报警模型,进一步提高了火灾报警精度。以上研究通过将深度学习技术引入到火灾预测中进一步提高了火灾预测的精度,但由

于上述方法采用单一的神经网络模型,预测性能在不同的环境下稳定性较差。因此,进一步提高火灾监测系统的自适应性,降低火灾探测系统的误报率仍然是火灾预测的重点研究方向。

相比于单一的神经网络模型,集成神经网络具有可靠性高以及泛化性能强的特点。因此,笔者在分析火灾特征参数的基础上改进现有的集成神经网络模型,并提出了一种基于自适应集成神经网络的火灾预测方法。该方法通过不同类型的火灾传感器监测环境中的多种特征信息,并将提取的特征参数以不同组合作为 LSTM 和 RBF-BPNN 子网络的输入特征,构建集成神经网络。同时,集成网络采用自适应加权平均算法对子网络的输出进行综合分析来提高模型的自适应性。

## 1 系统结构

基于深度学习的火灾预测方法性能的关键在于火灾预测模型的设计。根据火灾发生时的环境信息参数以及神经网络结构对火灾预测性能的影响,设计了基于自适应集成神经网络的火灾预测系统,其系统结构如图 1 所示。

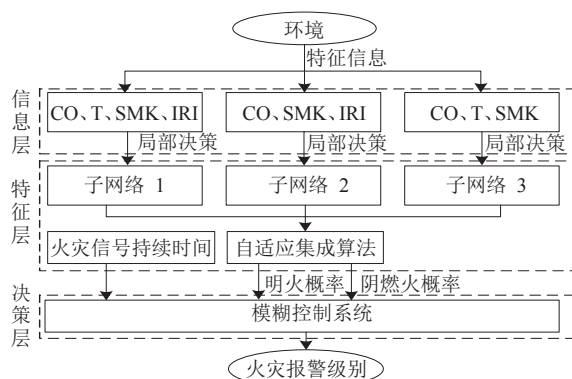


图 1 火灾预测系统结构

火灾预测模型的结构分为信息层、特征层和决策层,依次完成对火灾信息的预处理、特征提取和决策输出功能。在信息层中,火灾环境的温度(T)、一氧化碳浓度(CO)、烟雾浓度(SMK)和红外辐射强度(IRI)的火灾数据由传感器采集,并通过去噪和归一化方法对数据进行预处理。为了降低后续模块信息处理的负担,在局部决策过程中,采用速率检测算法检测 4 个特征信号是否超过报警阈值。算法的实现包括 3 个步骤。

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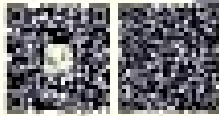
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## 基于深度学习的信号调制自动识别

### Automatic Recognition of Signal Modulation Based on Deep Learning

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**摘要:** 深度学习(DL)在很多领域都显示出强大的生命力,但它很少涉及无线通信。本文提出了一种基于深度卷积神经网络的信号调制自动识别方法,以解决无线通信中的常见问题。该算法通过深度学习的深度卷积神经网络自动提取图像的各种特征细节,以在各种信噪比条件下实现信号调制类型准确识别。该方法使用图像处理 GPU 构建 VGGNet,在深度学习架构 Tensorflow 下自动识别 MPSK 和 MQAM 中的 10 种调制信号。仿真结果表明,当信噪比为 5dB 时,各种信号的最小识别精度为 96.7%。与其他方法相比,该方法更好。

**关键词:** 深度学习(DL);神经网络;调制;无线通信

**Abstract:** Deep learning(DL) shows great vitality in all areas, but it rarely involves wireless communication. This paper proposes an automatic signal modulation recognition method based on deep convolutional neural network to solve common problems in wireless communication. The algorithm automatically extracts various feature details of images through deep learning deep convolutional neural networks, rather than the huge engineering of manual design features to achieve accurate identification of signals and noise under various signal-to-noise ratio conditions. The method uses the image processing GPU to construct VGGNet, and automatically recognizes 10 kinds of modulated signals in MPSK and MQAM under the deep learning architecture Tensorflow. The simulation results show that when the signal-to-noise ratio is 5dB, the minimum recognition accuracy of various signals is 96.7%. This method is better than other methods.

**Key words:** Deep learning(DL); neural network; modulation; wireless communication

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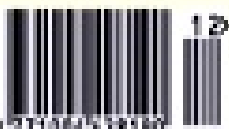
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## 工业水箱液位智能控制系统设计

### Design of Intelligent Control System for Liquid Level of Industrial Water Tank

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**摘要:** 针对现代工业生产中工业水箱液位反映实时性弱、可视性差以及经济性不理想等问题,本文设计了一种由工控触摸屏和 STM32F103 系列单片机组成的工业水箱液位智能控制系统。该系统主要由触摸屏组态画面设计和多种硬件电路设计组成,实现了数据可视化和快速的数据接收和指令执行功能,在满足人性化要求的同时也提高了工业生产的经济效益。

**关键词:** 水箱液位;工控触摸屏;STM32F103

**Abstract:** In view of the problems such as weak real-time performance, poor visibility and unsatisfactory economic efficiency reflected by the liquid level of industrial water tank in modern industrial production, this study designs an intelligent control system of industrial water tank liquid level composed of industrial touch screen and STM32F103 series single-chip microcomputer. The system is mainly composed of touch screen configuration picture design and a variety of hardware circuit design. Data visualization and rapid data reception and instruction execution functions have been achieved. It not only meets the humanized requirements, but also improves the economic benefits of industrial production.

**Key words:** water tank level; industrial touch screen; STM32f103

随着单片机技术以及通信技术的发展,以前的通过人工方式管理工业水箱的方法已不能满足日益提高的工业生产的需求,现代工业生产中虽然出现了许多由 PLC 或单片机组成的水位控制系统,但大多数都存在数

据传送不及时,无可视画面操作的问题,这样不仅降低了工业生产率,而且有可能因为数据响应不及时对工业生产造成毁灭性的后果。

针对该类问题,本设计采用核心为以

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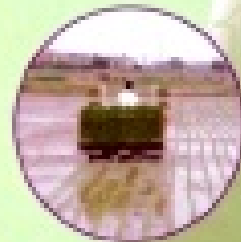
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## 2CMW-4B 微型马铃薯播种机的设计与试验

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**摘要:** 随着我国马铃薯主粮化的发展,对马铃薯的需求进一步增加,而脱毒微型原种的种植是提高马铃薯产量的有效措施。因此,微型原种的种植面积将不断扩大,微型马铃薯播种机的研制势在必行。针对目前我国微型马铃薯种植机械化水平低、机械作业播种质量较差、多数需要人工辅助作业等一系列问题,设计了一款基于振动排序技术的微型马铃薯播种机。该播种机采用履带式的播种机构,具有较高播种质量和作业效率。对样机进行田间试验,结果表明:该机作业效率和播种精度较高,工作性能稳定,播种间距合格率为92.0%,重种率为5.7%,漏种率为3.9%,其各项性能指标都优于相关马铃薯播种要求,对推动我国马铃薯全程机械化的发展进程具有重要意义。

**关键词:** 播种机; 微型马铃薯; 振动排序; 高效播种

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### 0 引言

马铃薯粮菜兼用,具有很高的营养价值,其种植面积广,是仅次于水稻、玉米和小麦的4大农作物之一<sup>[1-3]</sup>。

近年来,随着我国马铃薯主粮化,种植面积进一步扩大,种植潜力也将进一步被挖掘。但是,我国马铃薯种植水平不高,平均单产量相比发达国家仍存在很大的差距,主要因素是我国脱毒种薯种植面积大约是总种植面积的1/4,而发达国家种植面积超过90%。脱毒种薯因无病毒感染、品质好等优点,可使马铃薯每亩产量提高到原来的1.3~1.5倍,高的甚至达到3~4倍<sup>[4]</sup>。然而,国内培育的脱毒种薯比较少,且随着脱毒种薯的种植面积的不断增加,也将导致脱毒种薯的供不应求<sup>[5]</sup>。因此,加大微型原种的种植来保证一级脱毒种薯的供应需求,扩大脱毒种薯的种植面积,对提高我国马铃薯生产水平和产量具有重要意义。

现阶段,我国的马铃薯播种机多以薯块播种为主,而微型薯比较小且是整薯种植,因此国内绝大部分播种机不适合微型薯的种植。在国内,微型种薯播

种机不多,机械化程度不高,在播种时仍存在人工取种半自动化种植,且很多地区还采用人工种植,难以保证株距一致、播深统一的农艺要求,耗费大量人力,作业效率不高,远不能达到马铃薯机械化发展的要求<sup>[6]</sup>。

因此,为满足我国微型马铃薯种大面积机械化播种作业需求,设计了一款基于振动排序技术的2CMW-4B型四行微型马铃薯播种机,可实现开沟、施肥、播种及覆土镇压等多项作业,同时具有较高的播种精度和作业效率。

### 1 整机结构与工作原理

#### 1.1 整机结构

2CMW-4B型四行微型马铃薯播种机主要由机架、传动装置、覆土装置、液压系统、施肥装置、排种装置、开沟器,以及划线器等组成,可一次性完成开沟、施肥、喷药、播种及覆土等作业,解决了人工效率低和生产成本高等问题。其播种机整机结构如图1所示。

#### 1.2 工作原理

工作时,拖拉机通过三点悬挂方式牵引微型马铃薯播种机前进,播种机动力来自地轮,随着拖拉机前行地轮转动,将动力通过链轮、链条传递给播种装置和施肥装置。

在播种过程中,播种传送带由播种主动链轮带动而转动,微型薯种经过输送带上的抖动板进入待传送区域;然后,在传送带和摆动片的作用下进行排序并

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# 高添加量紫马铃薯全粉馒头的研制

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**摘要:**以紫马铃薯全粉和小麦粉为原料制作馒头,研究不同紫马铃薯全粉添加量对馒头品质的影响。试验结果表明,随着紫马铃薯全粉添加量的增加,馒头的紫色会逐渐加深,并具有较好的薯香味,添加量超过30%时,馒头的比容下降明显,黏性增大,硬度和咀嚼性变大,内部结构变差,馒头的整体品质逐渐下降。在高于30%紫马铃薯全粉添加量的馒头中加入谷朊粉改善馒头品质,制作高添加量紫马铃薯全粉馒头,当紫马铃薯全粉添加量比例为30%、40%、50%时,谷朊粉添加量分别为8%、14%、17%时,馒头的硬度、比容和感官评价都能达到传统小麦粉馒头水平,所制备的馒头品质最佳。

**关键词:**紫马铃薯全粉;高添加量;质构特性;感官评价;谷朊粉

## Development of High Additive Amount of Purple Potato Whole Flour Steamed Bread

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**Abstract:** Steamed bread was made from purple potato whole flour (PPWF)-wheat flour blend, and the effects of different PPWF on the quality of steamed bread were studied. Results showed that the purple color of steamed bread gradually deepened with the increase of PPWF proportion, and the steamed bread had a better aroma of potato. When PPWF proportion more than 30%, the specific volume of steamed bread decreased significantly, with increased viscosity, hardness and chewiness, internal structure became worse, and the quality of steamed bread gradually declined. Added gluten into steamed bread with the additive amount of PPWF proportion more than 30% to improve the quality of steamed bread. When the proportion of PPWF was 30%, 40% and 50%, the additive amount of PPWF was 8%, 14% and 17% respectively, the hardness, specific volume and sensory evaluation of steamed bread reached the level of traditional wheat flour steamed bread, the better quality PPWF steamed bread can be made.

**Key words:** purple potato whole flour; high additive amount; texture properties; sensory evaluation; vital wheat gluten

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# 不同改良剂对高马铃薯全粉含量 面团流变学特性的影响

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2. 乐陵希森马铃薯产业集团有限公司, 山东德州 253600)

**摘要:**为改善高马铃薯全粉含量面团的品质特性,以普通面粉和马铃薯全粉为原料,研究了3种不同改良剂对含50%马铃薯全粉面团流变学特性的影响。结果表明,随谷朊粉、蛋清粉、海藻酸钠添加量的增加,面团的抗拉力呈先增大后减小的趋势。当谷朊粉、蛋清粉、海藻酸钠添加比例分别为4.5%、7%、0.6%时,面团抗拉力最大;流变学实验表明,添加改良剂的面团弹性模量和粘性模量均随着频率的不断增加而增大,且弹性模量均大于粘性模量。与对照组相比,添加改良剂能明显增加混合体系的粘弹性。添加改良剂后面团的损耗角正切值 $\tan\delta$ 均小于1,表明改良剂的添加增强了面团的固体性质,使面团的机械强度增大。

**关键词:**马铃薯全粉, 谷朊粉, 蛋清粉, 海藻酸钠

## Effect of Different Modifiers on Rheological Properties of High Contents Potato Whole Flour

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**Abstract:** To improve the quality characteristics of high potato flour dough, wheat flour and potato flour were used as the raw materials and the effects of adding three different modifiers on the rheological properties of the dough containing 50% of total potato whole flour were studied in this study. The results showed that with the increasing contents of wheat gluten, egg white powder and sodium alginate, the tensile stress of dough first increased and then decreased. Respectively, the tensile stress reached the maximum when the adding proportion was 4.5%, 7% and 0.6%. The rheological test revealed that both the elasticity modulus and viscosity modulus of dough after adding the modifier increased with the frequency increasing, and the elastic modulus of all samples was higher than the viscous modulus. Compared with the controls, the viscoelasticity of mixed system increased obviously after adding modifiers. In addition, the  $\tan\delta$  value of the group after addition of the modifier was less than 1, which indicated the solid properties and mechanical strength of the dough were increased by adding modifier.

**Key words:** potato whole flour; wheat gluten; egg white powder; sodium alginate

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马铃薯作为世界第四大粮食作物<sup>[1]</sup>,具有粮食和蔬菜的双重特点。研究表明,马铃薯中含有多种营养成分,其中赖氨酸和色氨酸含量较高,而这两者可以补足小麦粉中氨基酸的缺陷,故将马铃薯全粉和小麦粉配合可以使小麦粉中蛋白质的功效提升<sup>[2]</sup>。目前随着国家马铃薯主食化发展战略的推进,国内外市场对于马铃薯全粉的需求呈逐渐上升趋势<sup>[3]</sup>。

但是,由于马铃薯全粉中淀粉成分主要为支链淀粉,不含面筋蛋白,无法形成具有粘弹性的网络结构<sup>[4]</sup>,降低了面团相应的加工特性,当用高含量马铃薯全粉制作馒头时,存在成型难、口感差等问题<sup>[5]</sup>,这制约着高含量马铃薯全粉馒头的推广。

在马铃薯全粉馒头的制作过程中,可以通过添加改良剂的方法提高面团的粘弹性。任立焕等<sup>[6]</sup>研

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# 小麦麸皮粉对马铃薯淀粉及全粉特性的影响

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2. 乐陵希森马铃薯产业集团有限公司; 乐陵 253619)

**摘要:** 将60~80目的小麦麸皮粉添加到马铃薯淀粉和马铃薯全粉中, 研究其对马铃薯淀粉及全粉特性的影响。结果表明: 小麦麸皮粉的加入, 使马铃薯淀粉和马铃薯全粉的透光率和膨胀度都降低。色度方面, 小麦麸皮粉的添加增大了马铃薯淀粉体系的 $L^*$ 值、 $a^*$ 值和 $b^*$ 值, 使马铃薯全粉体系的 $a^*$ 值和 $b^*$ 值增大,  $L^*$ 值减小。小麦麸皮粉的添加对马铃薯淀粉的冻融稳定性无明显影响, 但能在一定程度上改善马铃薯全粉的冻融稳定性。马铃薯全粉体系的凝沉性均明显高于马铃薯淀粉体系, 小麦麸皮粉的添加影响不明显, 而添加小麦麸皮粉能够使马铃薯淀粉体系的凝沉性明显增强。通过扫描电子显微镜观察可以看出, 小麦麸皮粉与马铃薯淀粉和马铃薯全粉均能较好地融合在一起。

**关键词:** 小麦麸皮; 马铃薯淀粉; 马铃薯全粉; 扫描电子显微镜

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## Effects of wheat bran on properties of potato starch and potato powder

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**Abstract:** The aim of this study was to add wheat bran to potato starch and potato powder respectively, and to explore the effect of wheat bran on potato starch and whole powder. The results showed that the light transmittance and swelling power decreased with the addition of wheat bran. In terms of chromaticity, the wheat bran increased the  $L^*$ ,  $a^*$  and  $b^*$  values of the potato starch system, and the  $a^*$  and  $b^*$  values of the potato flour system increased while the  $L^*$  value decreased. The freeze-thaw stability of potato powder could be improved with the addition of wheat bran, while there was no significant difference between that of potato starch system. The agglomeration of potato starch was enhanced with the addition of wheat bran, while there was no significant difference between that of potato powder system. Moreover, wheat bran could be well mixed with potato starch and potato powder evenly by observation from scanning

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# 响应面法优化马铃薯生浆馒头的发酵工艺

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**摘要** :以普通面粉和马铃薯生浆为原料,利用响应面法对马铃薯生浆添加量、加水量、酵母添加量、发酵时间、发酵温度5个因素进行优化。通过五因素五水平二次旋转正交组合试验设计,利用SAS9.1软件对马铃薯生浆馒头感官评分数据进行处理分析,可以得到最佳工艺条件组合:马铃薯生浆添加量为21%,加水量68%,酵母添加量0.9%,发酵时间52 min、发酵温度35℃,在此条件下的马铃薯生浆馒头的感官评分是89分。

**关键词** :马铃薯;馒头;发酵工艺;响应面法;感官品质

## Optimization of Fermentation Process for Potato Pulp Steamed Bread by Response Surface

### Methodology

CAO Yan-fei<sup>1</sup>, ZHANG Feng-jie<sup>1</sup>, ZHANG Tian-yu<sup>1</sup>, CHEN Shan-feng<sup>1,2</sup>, LI Hong-jun<sup>1,2,\*</sup>

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**Abstract** :Steamed bread was produced by ordinary flour and potato pulp as raw materials. The response surface method was used to optimize the five factors of potato pulp addition, water addition, yeast addition, fermentation time and fermentation temperature. Quadratic orthogonal rotating combination design of five factors and five levels was employed to optimize parameters of fermentation making and obtained by SAS 9.1. Optimal condition was as following, potato pulp added amount was 21%, water amount was 68%, yeast added amount was 0.9%, fermentation time was 52 min, fermentation temperature was 35℃, and steamed bread sensory score was 89 with this condition.

**Key words** :potato; steamed bread; fermentation process; response surface methodology; sensory quality

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CAO Yanfei, ZHANG Fengjie, ZHANG Tianyu, et al. Optimization of Fermentation Process for Potato Pulp Steamed Bread by Response Surface Methodology[J]. Food Research and Development, 2019, 40(8): 32-39

我国马铃薯种植面积广阔,产量高,环境适应性较好,且消费市场广阔<sup>[1]</sup>。马铃薯具有丰富的营养物质和实用的医药价值。马铃薯中含人体必需的8种氨基酸,其中赖氨酸是谷物中的限制氨基酸,与小麦粉配合可以使蛋白的功效提升<sup>[2]</sup>;马铃薯含有小麦和大米中所

没有的胡萝卜素,有利于补充人体的维生素,减少与年龄有关的黄斑变性风险<sup>[3]</sup>;马铃薯含有丰富的膳食纤维,有助于肠道蠕动,可以预防便秘、防治癌症等<sup>[4]</sup>。

世界上有许多国家将马铃薯泥(粉)与面粉混合共同制成各种面制主食,而我国也在2015年推出马铃薯主粮化战略,通过产品研制和生产工艺创新,开发出符合我国居民饮食习惯的产品<sup>[5]</sup>。不少学者和科研院已经展开对马铃薯主粮产品的研究。冷进松等<sup>[6]</sup>探讨影响马铃薯粉蒸烤馒头加工的主要因素,经过Minitab联用

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### 粮食与油脂篇

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# 甘薯生浆对面团特性及馒头品质的影响

任妍妍<sup>1</sup>, 张凤婕<sup>1</sup>, 张天语<sup>1</sup>, 曹燕飞<sup>1</sup>, 李宏军<sup>1, 2</sup>, 陈善峰<sup>1\*</sup>

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2. 乐陵希森马铃薯产业集团有限公司, 乐陵 253600)

**摘要:** 通过考察甘薯生浆添加量对面团流变特性及馒头品质的影响, 以拓展甘薯在传统主食中的应用范围, 并为今后的甘薯馒头实际生产提供理论支持。在面粉中添加不同比例(0%~50%)的甘薯生浆, 测定甘薯生浆面团的粉质特性、拉伸特性、动态流变学特性以及甘薯生浆馒头的质构特性、色差, 并对馒头制品的感官品质进行评价。结果表明: 随着甘薯生浆添加量的增加, 面团的粉质特性和拉伸能力逐渐下降; 面团的动态流变学特性储能模量 $G'$ 与损耗模量 $G''$ 和损耗角正切值 $\tan\delta$ 均随着甘薯生浆的增加而减小。同时, 添加甘薯生浆使馒头的比容、硬度增加而弹性、回复性减小。加入少量的甘薯生浆, 可以改善面团的粉质特性和拉伸特性, 且甘薯生浆的最适添加量为30%, 此时馒头的质构特性及感官评价最好。

**关键词:** 甘薯生浆; 面团; 流变特性; 馒头; 品质

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## Effect of fresh sweet potato pulp on dough characteristics and quality of steamed bread

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**Abstract:** This work was to investigate the effect of the amount of sweet potato pulp added on the rheological properties of dough and the quality of steamed bread, so as to expand the application scope of sweet potato in traditional staple food and provide some theoretical support for future practical production. In this study, the fresh sweet potato pulp were added into the wheat flour at the levels of 0%~50% to determine of the sweet potato bread dough's flour properties, tensile properties and dynamic rheological properties, as well as texture, color difference and sensory evaluation of the steamed bread. The results suggested that the flour and stretching capacity of the dough decreased with the increase of the amount of sweet potato pulp. The dynamic rheological properties of dough  $G'$ , loss  $G''$  and tangent of loss angle both decrease with the increase of sweet potato pulp. In addition, adding sweet potato pulp can increase

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# 食品科技

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# 50%马铃薯全粉馒头的品质改良

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**摘要:** 为了改善高含量马铃薯全粉馒头制作时存在的成型难、发酵难、口感差等问题, 提高高含量马铃薯全粉馒头品质, 以普通面粉和马铃薯全粉为原料, 在单因素试验的基础上利用响应面分析法对3种食品添加剂的配方进行优化, 得到了含50%马铃薯全粉馒头的最佳配方。结果表明, 添加剂的最佳配方为谷朊粉添加量4.5%, 蛋清粉添加量7%, 海藻酸钠添加量0.6%, 在此条件下的马铃薯全粉馒头的感官评分为92.62。研究为开发马铃薯主食产品提供一定的数据参考。

**关键词:** 马铃薯全粉; 谷朊粉; 蛋清粉; 海藻酸钠; 品质改良

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## Quality improvement of 50% potato whole flour steamed bread

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**Abstract:** In order to improve the high content of potato whole flour steamed bread production problems, such as difficult to form and ferment, poor taste, enhance the quality of potato whole flour steamed bread with high content, wheat flour and potato flour were used as raw materials, and based on the single factor experiment, three kinds of food additive formulation optimization was optimized by response surface analysis to obtain the best recipe for steamed bread with 50% potato flour. The results showed that the optimal formula was wheat gluten 4.5%, egg white powder 7%, sodium alginate 0.6%, and 92.62 sensory score of the potato whole flour steamed bread was obtained. The study could provide a certain data reference for developing potato staple food products.

**Key words:** potato whole flour; wheat gluten; egg white powder; sodium alginate; quality improvement

马铃薯又称土豆、洋芋、地蛋<sup>[1]</sup>, 属于茄科, 它的块茎可以食用。马铃薯中含有人体容易吸收的蛋白质<sup>[2]</sup>, 营养价值极高, 而且与鸡蛋中所含

的蛋白质近似相同<sup>[3]</sup>。此外, 马铃薯中还含有人生长发育必需的钙、铁、锌等矿物元素<sup>[4]</sup>, 且热量和脂肪含量较低, 深受减肥和健身人士的喜爱<sup>[5]</sup>。马

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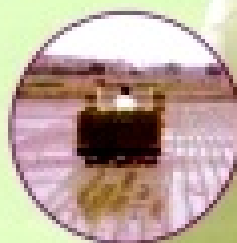
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黑龙江省农业机械工程科学研究院 主办  
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# 马铃薯播种机具研究进展

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**摘要:** 随着马铃薯主粮化战略的逐步推进和马铃薯种植面积不断增加, 实现马铃薯播种机械化对于促进农业可持续发展、保证粮食安全和现代服务农业具有重要意义。为此, 分析了近年来我国马铃薯机械化种植概况, 根据马铃薯播种机主要结构类型将其分为勺式、气力式、带式、转盘式及针刺式等几种类型, 并对各类型播种机的工作原理、作业特点进行了分析和阐述。在此基础上, 指出了现有国内马铃薯播种机存在的一些问题, 进一步提出了该领域未来研究重点与发展方向, 以为马铃薯机械化播种的研究提供参考依据。

**关键词:** 马铃薯; 播种机; 马铃薯主粮化; 研究现状

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## 0 引言

马铃薯是一种产量高、营养丰富、加工用途广且生长期短的粮食作物, 在世界范围内种植广泛, 是世界四大主要粮食作物之一, 对保障世界粮食安全具有重要意义<sup>[1]</sup>。我国马铃薯种植已有300多年的历史, 具有种植面积大、分布范围广等特点, 目前已成为世界第一大马铃薯生产国。据联合国粮农组织统计, 2014年我国马铃薯总产量和种植面积分别占世界的19%和29%<sup>[2]</sup>。2015年初, 国家提出马铃薯主粮化发展战略, 将其列为继小麦、水稻、玉米之后的第四大主粮作物<sup>[3]</sup>。2016年2月, 农业部正式发布《关于推进马铃薯产业开发的指导意见》, 意味着我国马铃薯产业发展进入快车道<sup>[4]</sup>, 而发展马铃薯种植机械化对于促进马铃薯产业的发展起着至关重要的作用。

播种是马铃薯生产过程中关键环节之一, 播种质量直接影响马铃薯收获、产量和品质<sup>[5-6]</sup>。我国虽然是马铃薯生产大国, 但迄今为止国内很多地区依然采用人工或半机械化播种作业, 劳动强度大、生产效率低、作业质量差、生产成本低, 严重制约着国内马铃薯产业的发展。20世纪初, 欧美一些国家开始对马铃薯播种技术与机具展开相关研究; 20世纪40-60年代,

美国、加拿大等发达国家已基本实现马铃薯播种机械化; 20世纪50年代末至60年代初, 国内开始对马铃薯播种机械开始研究<sup>[7-8]</sup>, 但同国外先进机具相比, 在机具性能稳定性、作业质量和播种精度等方面与发达国家尚存在一定差距<sup>[9]</sup>。因此, 了解和掌握马铃薯播种机及其关键部件主要类型和特点, 探讨存在的主要问题, 对于我国马铃薯机械化播种机具的研究和推广具有重要意义。

## 1 马铃薯机械化种植面积分析

图1为2008-2014年我国马铃薯种植面积变化图<sup>[10]</sup>。由图1可以看出: 2008-2014年全国马铃薯播种面积、马铃薯机耕面积及机播面积均呈逐年增加的趋势, 2014年马铃薯播种面积为5573.30km<sup>2</sup>, 比2008年增长了19.51%, 年平均增长率在3%以上。其中2008-2009年播种面积增长率达到8.95%, 增长幅度较大。马铃薯机耕面积方面: 2014年为3039.55km<sup>2</sup>, 比2008年增长了77.39%, 年平均增长率10.02%, 增长速度较快。其中2008-2011年年均增长速度接近15%。马铃薯机播方面: 2014年为1320.09km<sup>2</sup>, 较2008年增长了17.66%, 增长速度很快。其中2008-2009年及2010-2011年机械播种面积增长率均在32%以上。整体来看, 随着马铃薯耕作及播种机械化水平的提升, 马铃薯播种面积呈逐年增长的趋势, 但国内马铃薯种植机械化水平依然很低。其中, 机械化耕作面积不足马铃薯播种面积的1/2, 机械化播种面积不足马铃薯播种面积的1/5。马铃薯种植大部分靠人工进行作业, 对我国马铃薯产业的发展起到制约作用, 推进马铃薯播种机械化势在必行。

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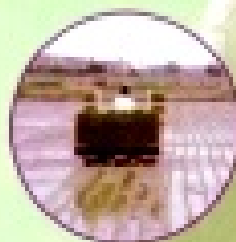
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# 5XF - 60 型马铃薯清洗机智能控制系统的研制

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**摘 要:** 针对马铃薯清洗机存在的上料流量输送不稳定及清洗辊轴间距调节不便的问题, 研制了一套马铃薯智能清洗控制系统。该系统应用变频调速技术控制主输送线上料速度, 保证上料清洗量的恒定, 提高了清洗后期的工作效率; 通过测距传感器采集上料输送带与中心轴间距信息的反馈, 利用步进电机控制输送带的张紧度, 从而避免输送带的跑偏问题, 提高马铃薯清洗机上料输送效率; 通过可编程控制器 PLC 控制液压缸的伸缩量, 完成相邻辊轴间距的调节, 实现马铃薯大小规格的统一。田间试验表明: 清洗效率明显提高, 劳动强度显著降低, 保证了马铃薯的清洗质量。

**关键词:** 马铃薯; 清洗; 智能; 张紧度; 辊轴间距

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## 0 引言

马铃薯是世界上仅次于小麦、水稻和玉米之后的第四大粮食作物<sup>[1-3]</sup>, 中国也是世界上马铃薯总产最多和消费最大的国家。尽管我国马铃薯的播种面积和产量很多, 然而在马铃薯机械化程度上相对落后, 因此实现马铃薯全程机械化迫在眉睫。

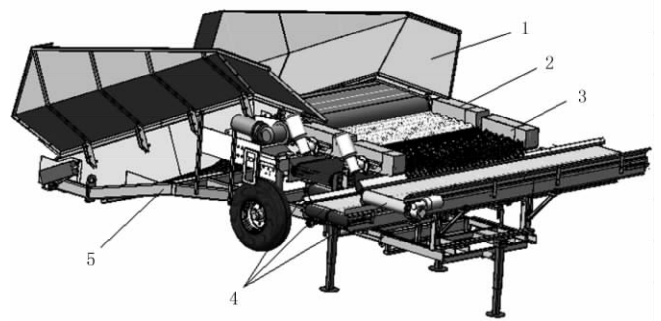
马铃薯农机产品主要分为马铃薯播种机械、中期管理机械和后期收获及其马铃薯仓储机械。目前, 马铃薯从前期播种到收获阶段的机械发展较为成熟, 但仓储设备比较匮乏<sup>[4-6]</sup>。马铃薯收获后需要根据客户的需求进行大小分级, 以达到客户的最大利润, 但在我国大部分地区, 尤其是在马铃薯种植面积比较大的内蒙古地区, 仍靠人工来清洗, 不仅效率低、劳动强度大, 清洗效果也不佳。马铃薯清洗装备能够方便马铃薯的大量分选工作, 代替了人工靠肉眼进行清洗的繁重工作, 减少了劳动力且大大提高了清洗质量<sup>[7-10]</sup>。

本文通过对马铃薯智能清洗控制系统的研制, 解决了马铃薯清洗机的上料流量输送不稳定及清洗辊轴间距调节不便的问题。其根据主输送线上料速度改变上料流量的稳定性, 经传感器采集上料输送带松弛距离信息自动调整输送带的张紧度, 通过相邻辊轴

间距的调节, 实现清洗状态的可视性, 提高马铃薯清洗机的效率, 降低薯块破皮率, 为马铃薯清洗装备的进一步智能化研究提供了参考, 对马铃薯清洗装备的设计优化有着重要的意义<sup>[11]</sup>。

## 1 整机结构及工作原理

马铃薯清洗机主要由主输送线上料装置、一级清洗装置、二级清洗装置、薯块输送线装置及泥土杂物输送线装置等组成, 如图 1 所示。



1. 主输送线上料装置 2. 一级清洗装置 3. 二级清洗装置  
4. 薯块输送线装置 5. 主机托架

图 1 马铃薯清洗机模型

Fig. 1 The model of potato cleaning machinery

工作过程中, 马铃薯通过装卸车倒入主输送线装置, 主输送线装置由液压系统控制其输送角度, 变频电机可以根据输送马铃薯的载荷量而调整其输送速度, 从而有效地提高了马铃薯的输送效率。马铃薯由主输送线装置输送到一级清洗装置, 小薯块与碎土杂质通过分选轴间隙落到下面的输送带上, 被输送到下一级输送带, 分选装置的分选轴间隙大小由液压系统

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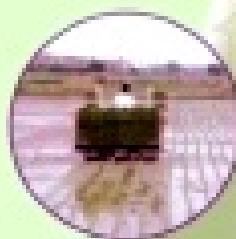
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# 基于高效低损目标的马铃薯收获机改进设计

孙传祝<sup>1a,2</sup>, 魏忠彩<sup>2,3</sup>, 苏国梁<sup>2,4</sup>, 杨平<sup>5</sup>, 李学强<sup>2,4</sup>, 王法明<sup>2,4</sup>, 王相友<sup>1b,2</sup>

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**摘要:** 针对现有马铃薯收获机收获效率低、伤薯率和破皮率高等问题,以高效、低损为目标,采用垄上压力自动调整、切土驱动、挖掘深度自动调整、振动强度参数可调和波浪式薯土分离等技术对现有马铃薯收获机进行了改进设计。改进后的马铃薯收获机收获作业过程中,压土轮始终处于浮动状态,既能松离薯土,又可避免压溃薯垄而导致伤薯;有效保证切土盘始终处于正常转动状态,彻底解决现有收获机作业过程中切土盘的时断时续转动问题;始终保证两侧的挖掘深度一致,有效解决因地表倾斜而导致的伤薯及能耗较高问题;马铃薯及土块、秧蔓混合物经过波峰与波谷之间的“翻滚”而实现碎土,提高了筛分效率,且可根据需要自动调整振动强度。本研究为马铃薯收获机的后续研究奠定了坚实基础。

**关键词:** 马铃薯; 收获机; 高效; 低损

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## 0 引言

马铃薯粮菜兼用,营养丰富,产品附加值高,国内种植面积居世界首位<sup>[1-2]</sup>。但是,目前马铃薯收获装备无法满足产业化需求,其机械化收获水平远低于小麦、玉米和水稻等主要粮食作物。农业部启动“马铃薯主粮化”战略之后,对马铃薯收获装备提出了更高要求。

但是,现有设备的收获效率低、伤薯率和破皮率高,较差的薯土分离效果和较高的伤薯率是制约马铃薯收获机高效、可靠工作的技术瓶颈<sup>[3-4]</sup>。据统计,马铃薯总损伤量的70%来自于收获环节,收获过程中机具的前进速度和土壤的含水率均影响着马铃薯块茎的损伤。国内对马铃薯收获机械的技术要求是:明薯率 $\geq 95\%$ ,伤薯率 $\leq 5\%$ ,损失率 $\leq 5\%$ <sup>[5-6]</sup>。

目前,国内主要采用分段式收获,杆条式分离筛是目前国内外马铃薯收获机具中广泛采用的结构形式<sup>[7]</sup>。收获作业后马铃薯被散置于地面,然后再进行人工捡拾,作业效率较低,劳动强度大<sup>[8-9]</sup>。马铃薯

收获机从挖掘、薯土分离到薯秧分离各个环节输送距离较长,薯块翻滚次数较多,碰撞、摩擦甚至挤压导致伤薯率较高。杆条式分离装置一般通过设置抖动轮的方式来抖落泥土,加大振动幅度可提高分离效率,但伤薯率则随着振动幅度的加大而趋于严重。因此,薯土分离效果与抖动装置对马铃薯的损伤相互矛盾、难以兼顾<sup>[10]</sup>。另外,杆条式分离装置收获作业一段时间后,杆条上会附着一定厚度的泥土,有学者专门设计了橡胶圆辊式清土装置,泥土清理效果较好<sup>[11]</sup>。

在马铃薯收获与捡拾装备研究方面,一些学者做了相关研究<sup>[5,12-13]</sup>。目前,如何合理调控垄上压力,提高薯土分离效果,合理控制薯土挖掘量,进一步提高收净率和明薯率,最大限度地降低伤薯率和破皮率,是设计和改进马铃薯收获机械的关键所在<sup>[14]</sup>。本文针对现有马铃薯收获机存在的问题,从垄上压力调整、切土调整、挖掘调整和薯土分离调整等高效低损关键技术入手进行改进,以期保证良好的薯土分离效果,且损失率低、破皮率低、含杂少。

## 1 总体结构及工作原理

### 1.1 总体结构

马铃薯收获机主要由机架、垄上压力调整装置、切土调整装置、挖掘调整装置及薯土分离装置等组成,如图1所示。沿着马铃薯收获机的前进方向,机架从前到后设有前、中、后3条横梁。垄上压土调整装置安装于机架的前横梁与中横梁之间的下方,其圆

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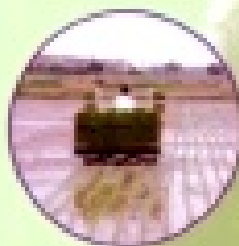
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## 2CMX-4B型马铃薯种植机施肥箱改进设计

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**摘要:** 针对现有马铃薯播种机施肥箱存在的流肥盒进料口处堵肥、出料口处的卡肥、肥箱底部的积肥及施肥不精确问题,对2CMX-4B型播种机施肥箱进行优化改进。采用蛟龙螺旋推肥作业方式,代替六方传动轴拨肥作业方式,彻底解决了流肥盒出料口处的卡肥问题,保证了肥料顺利排出;在肥箱体增设了搅拌装置,不仅能够将粘成团的大块肥料搅拌碎,又能将肥箱底部的肥料顺利推进流肥盒,避免了流肥盒进料口处的堵肥问题与肥箱底部的积肥问题;采用更换链轮调节传动比的方式代替原来靠调节流肥盒开口量的大小来控制施肥量的粗制方式,实现了肥量的精确控制。试验结果表明:改进后的马铃薯播种机各项指标均符合国家标准要求,施肥效果有着明显的改善,不仅提高了作业质量,而且有效节约了化肥用量,降低了用户种植成本。

**关键词:** 马铃薯播种机; 肥箱; 蛟龙; 肥量调整

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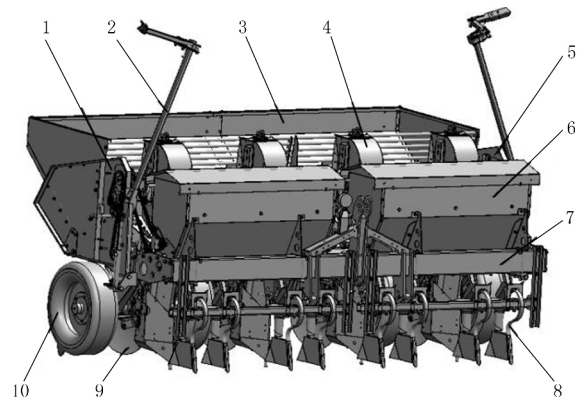
### 0 引言

随着我国马铃薯主粮化战略的推进,马铃薯相关机械产品也得到了快速发展,从前期播种阶段到后期收获阶段基本实现了机械化。其中,马铃薯播种作业是马铃薯生产中的重要环节,作业质量的优劣直接影响着马铃薯的产量,是保证其有良好收成的基础。播种前施肥的目的在于补充土壤中营养物质不足,满足马铃薯生长发育过程中对营养元素的需要,对马铃薯的良好生长都有着重要意义。因此,对马铃薯播种施肥机的研究是不可或缺的一部分<sup>[1-3]</sup>。

目前,马铃薯种植施肥尽管实现了机械化,在播种方面已经基本实现了智能控制,但在施肥过程中却存在诸多问题(如肥箱内部结构过于简单、施肥效果不理想、流肥盒进料口处堵肥和出料口处的卡肥、肥箱底部的积肥问题、施肥不精确等),大大降低了作业效率,直接影响了后期马铃薯生产质量。因此,对马铃薯种植施肥箱的研究改善有着十分重要的意义<sup>[4-7]</sup>。针对上述问题,本文以2CMX-4B型悬挂式播种施肥机为基础对施肥箱进行了进一步的完善,并进行了田间试验。

### 1 整机模型及工作原理

改进后的马铃薯播种施肥整机模型由肥量调整装置、划线器、薯料箱、播种单元、株距调整装置、肥箱、牵引大架、弹性开沟器、覆土盘和地轮组成,如图1所示。



1. 肥量调整装置 2. 划线器 3. 薯料箱  
4. 播种单元 5. 株距调整装置 6. 肥箱  
7. 牵引大架 8. 弹性开沟器 9. 覆土盘 10. 地轮

图1 马铃薯种植施肥机模型

Fig. 1 The model of Potato planting and fertilizing machine

该机牵引大架与拖拉机采用三点悬挂方式连接,在拖拉机的驱动下前行作业。工作时,地轮转动通过链轮传动至株距调整装置来驱动4个播种单元执行播种作业;薯料箱采用倾斜结构,保证薯种顺利进入播种单元;肥量调整装置同样依靠地轮来驱动工作,控制肥箱排出的肥料流量,然后将肥料输送到弹性开沟器已开好的沟槽中;弹性开沟器由4对构成,且每两个之间的间隙是可调的,便于用户根据实际需求进

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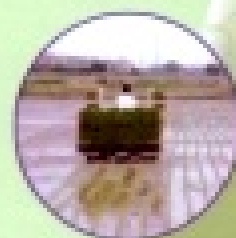
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# 3ZMP - 360 型马铃薯中耕起垄施肥机的改进设计

程鹏飞<sup>1</sup> , 王琳琳<sup>2</sup> , 李学强<sup>2</sup> , 于文强<sup>1</sup>

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摘要: 针对现有马铃薯中耕起垄施肥机存在的地轮传动不连续、粗制施肥及仿垄成形不够理想等问题,对 3ZMP - 360 中耕起垄施肥机驱动装置、肥箱调节装置和成形器进行了改进设计。采用驱动棘轮代替地轮传动,彻底解决了地轮空转、滑行导致肥箱不工作的问题;采用更换链轮调节传动比的方式设计的肥量调整装置,代替了原来靠调节施肥盒开口量的大小来控制施肥量的粗制方式,改进后的调整装置可根据不同土壤和不同品种的需求进行相应施肥,并且能够精确控制施肥量;采用弧面成形器代替原来平面成形器,垄形得到了改善,既保持了所需垄高,又能增加薯垄培土量,更有利薯种的生长发育。试验结果表明:改进后的马铃薯中耕起垄施肥机各项指标均符合国家标准要求,不仅提高了后期马铃薯生产量,而且有效地节约了化肥用量,降低了种植成本。

关键词: 施肥机; 施肥量; 垄形; 成形器; 驱动装置

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## 0 引言

随着我国马铃薯主粮化战略的推进,马铃薯机械产品也得到了快速发展,从前期播种到后期收获阶段基本实现了机械化。马铃薯的中耕、施肥是种植过程中重要的作业环节,中耕的主要作用是疏松土壤、增强透气性、提高地温、加速有机质的分解及提高土壤有效养分,以及防除杂草、害虫和调节水分、防旱保墒等。施肥的目的在于补充土壤中营养物质不足,满足马铃薯生长发育过程中对营养元素的需要<sup>[1]</sup>。

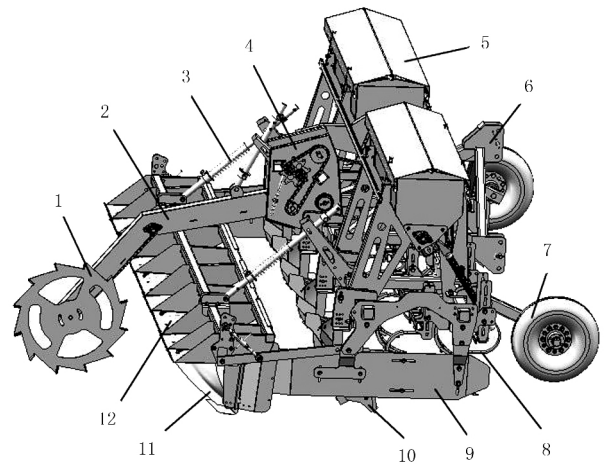
目前,马铃薯中耕起垄施肥尽管实现了机械化,但现有机型仍存在一些问題:大多采用行走地轮来驱动肥箱执行施肥,传动方式过于简单,不能解决地轮打滑导致的施肥卡滞与积肥问题;大多采用传统的施肥方式<sup>[2]</sup>,通过手动调节施肥盒开口大小,来粗制控制施肥量,不能按实际客观需求来合理施肥,施肥效果不理想;采用平面成形器,起垄效果不佳,直接影响了后期马铃薯的产量。

针对上述问题,本文对 3ZMP - 360 四垄中耕起垄施肥机驱动装置、肥箱调节装置和成形器进行了改进设计,增加了肥量调整装置和棘轮驱动方式,对成形

器结构做了进一步的完善,并进行了田间试验。

## 1 整机模型及工作原理

改进后的中耕起垄施肥机整机模型由驱动棘轮、连接传动箱、拉簧杆、肥量调整装置、肥箱体、牵引架、地轮、小弹性齿、侧护板、松土器、成形器和仿垄压板组成,如图 1 所示。



1. 驱动棘轮 2. 连接传动箱 3. 拉簧杆 4. 肥量调整装置  
5. 肥箱体 6. 牵引架 7. 地轮 8. 小弹性齿 9. 侧护板 10. 松土器  
11. 成形器 12. 仿垄压板

图 1 中耕起垄施肥机整机模型

Fig. 1 The model of cultivator - fertilizer

该机牵引架与拖拉机采用三点悬挂方式连接。作业时,拖拉机拖动整机前进,小弹性齿将垄两边的杂草除掉,通过松土器、成形器与仿垄压板三者的配合,完成了起垄工作。其中,垄宽、垄高及培土量可通过

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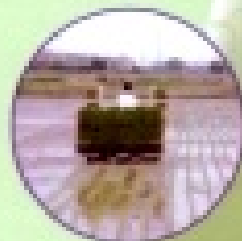
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# 马铃薯杀秧机的优化设计与分析

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摘要: 马铃薯收获前的杀秧处理对后期的收获效率及马铃薯品质有着非常显著的影响。为此, 针对当前马铃薯杀秧机存在作业效率低、留茬高度不均匀及带薯率高等问题, 设计了一款新型高效的马铃薯杀秧机。本机可根据不同地块、不同马铃薯品种的需要调节留茬高度, 提高了后续收获的流畅性; 刀具采用甩刀的形式并在杀秧轴上呈仿垄形分布, 极大降低了带薯率及伤薯率。同时, 对关键部件进行了有限元分析, 结果表明: 所设计的部件均满足强度要求。对样机进行了田间试验, 试验结果表明: 杀秧效率明显提高, 留茬高度均匀, 带薯率显著降低, 均满足马铃薯的杀秧作业要求。本研究对提高马铃薯杀秧机的作业效率及后续收获效率、更好地适用于马铃薯的大规模收获具有重要意义。

关键词: 马铃薯; 杀秧机; 甩刀; 仿垄形; 有限元分析

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## 0 引言

十三五期间, 为了贯彻落实新形势下粮食安全战略部署, 国家启动了马铃薯主粮化战略, 且马铃薯将成为国内继三大主粮之后的第四大主粮作物<sup>[1-3]</sup>, 因此实现马铃薯全程机械化迫在眉睫。

目前, 在马铃薯收获过程中均需要杀秧处理, 这样可提高收获效率, 促进薯皮老化, 进而有效地降低马铃薯在收获过程中的破皮率。此外, 杀秧处理对减小收获机薯秧分离器负载、提高薯秧分离效率及降低故障率具有重要意义<sup>[5]</sup>。国内马铃薯杀秧机械明显落后于国外<sup>[4]</sup>, 其主要代表有中机美诺 1804 型杀秧机<sup>[8]</sup>、青岛农业大学设计的小型杀秧机<sup>[7]</sup>及甘肃农业大学设计的甩刀式杀秧机<sup>[4]</sup>等。国内现有杀秧机存在一系列问题, 如茎秧易缠绕机器、打碎长度不均、易带薯及护罩粘土严重等, 导致国内杀秧机械主要依靠进口来满足需要。因此, 国内市场急需一款稳定性好、适应性强及工作效率高的马铃薯杀秧机<sup>[5]</sup>。

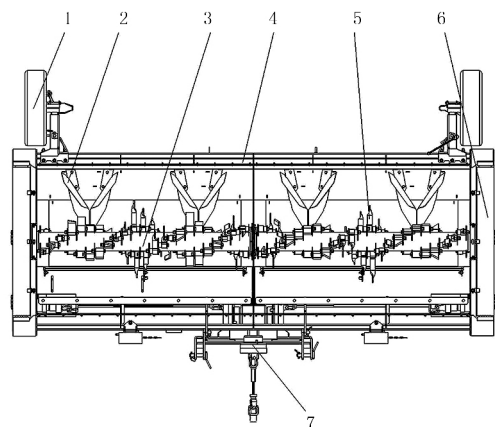
本文通过对杀秧刀的结构参数及排列方式的改进, 设计了一款新型四垄仿垄形杀秧机, 该机可以根据不同的留茬高度要求完成杀秧作业, 作业效率明显

提高, 秧草缠机率、带薯率显著降低, 为马铃薯杀秧机的进一步研究提供了参考。

## 1 总体结构及主要技术参数

### 1.1 总体结构及工作原理

4JM-360B 型悬挂式马铃薯杀秧机采用仿垄形设计, 用于马铃薯收获前杀秧处理, 可一次完成薯秧切除及梳理分流作业, 为后续的高效低能耗收获提供条件。本机主要由机架、传动装置、杀秧轴、地轮及导流隔板等组成, 如图 1 所示。



1. 地轮 2. 导流隔板 3. 杀秧轴 4. 机架 5. 杀秧刀  
6. 护罩 7. 传动总成

图 1 马铃薯杀秧机结构图

Fig. 1 The model of potato seedlings cutter

杀秧作业过程中, 拖拉机牵引马铃薯杀秧机沿垄方向前进, 拖拉机动力输出轴通过万向节与变速箱

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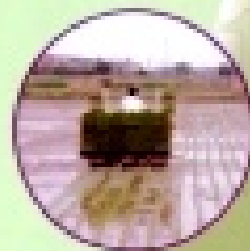
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# 农机化研究

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# 马铃薯智能精密播种系统的研制

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摘要: 针对现有马铃薯播种机播种株距调整麻烦、土壤状况对播种精度影响较大及振幅调整不便等问题, 研制了一种马铃薯智能精密播种系统。该精密播种系统采用液压马达驱动播种单元, 实现播种株距的无极调整, 提高了马铃薯播种机的适应性和抗干扰能力。该系统通过检测实际株距与设定株距的差值, 自动修正薯种输送带的运行速度, 确保实际株距始终保持在设定株距范围内; 通过检测模块采集播种过程的漏种情况, 自动调整输送带的振动幅度, 减小重种、漏种率, 提高播种精度; 通过人机交互模块设定播种参数, 实现播种状态的可视性。本研究对提高马铃薯播种机的作业效率、减轻劳动强度, 更好地适用于马铃薯的大规模种植和服务现代农业具有重要意义。

关键词: 马铃薯; 智能; 精密播种; 播种株距; 漏种率

中图分类号: S223.2<sup>+3</sup>

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## 0 引言

马铃薯粮菜兼用, 营养丰富, 种植广泛<sup>[1-3]</sup>。马铃薯“主粮化”政策指出, 到 2020 年国内马铃薯种植面积将达到  $6.7 \times 10^6 \text{hm}^2$ , 这有助于保障国家粮食安全, 推进现代农业的发展。但是, 目前国内马铃薯生产机械化水平明显滞后于其它主要粮食作物<sup>[4-5]</sup>, 因此实现马铃薯生产全程机械化迫在眉睫。

现有马铃薯播种机田间作业时, 因播种品种、土壤状况及栽培需求等不同, 对株距及输送带振动幅度的调整均需停机后人工手动完成, 增加劳动强度的同时也会影响播种效率及流畅性。此外, 田间作业时除驾驶员外, 至少还需配备 2 名辅助人员随时观察重种、漏种情况, 发现重种、漏种过多时便停止播种调整振幅, 极易因调整不当或调整不及时而导致重种、漏种现象严重。因此, 应从农机与农艺融合等方面入手研发智能化精密播种装备, 促使马铃薯机械化装备的升级换代。

本文研制的马铃薯智能精密播种系统可根据用户单位面积的播种株数设置播种株距, 根据检测模块采

集的株距和重种漏种信息自动调整输送带转速和输送带的振动幅度, 实现播种状态的可视性及在线调整, 这对于提高播种作业效率、减轻劳动强度, 更好地适用于马铃薯的大规模种植和服务现代农业具有重要意义。

## 1 播种单元结构及控制原理

### 1.1 现有马铃薯播种机调整原理

现有马铃薯播种机作业过程中可通过更换不同齿数的主、从动链轮(见图 1)调整其传动比来实现株距的调节<sup>[6-7]</sup>, 但无法实现株距的无极调整; 种植户根据经验人工转动微调螺杆(见图 2)调整振幅大小来控制重种和漏种率。

这要求操作人员具有较丰富的播种经验, 增加了播种难度, 影响了播种效率。此外, 田间作业过程中由于土壤条件的变化, 易造成地轮滑移量变化和运行平稳性, 进而导致播种株距不够均匀。

### 1.2 精密播种单元结构及控制原理

改进后的精密播种单元如图 3 所示。其摒弃了传统的地轮驱动薯种输送带的驱动方式, 改用液压马达驱动薯种输送带运转; 摒弃了传统的依靠更换链轮调整株距的方式, 采用改变马达转速调整薯种输送带速度的方式调整株距; 利用步进电机驱动微调螺杆转动来调整振幅大小进而控制重种、漏种率。自动振幅调整装置如图 4 所示。

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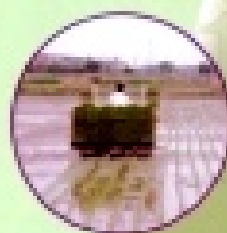
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# 马铃薯全程机械化生产技术与装备研究进展

魏忠彩<sup>1,2</sup>, 李学强<sup>2,3</sup>, 张宇帆<sup>1,2</sup>, 李洪文<sup>1,2</sup>, 孙传祝<sup>2,4</sup>

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摘要: 在国家倡导马铃薯主粮化战略背景下, 农机、农艺相互适应与融合, 实现马铃薯生产全程机械化与装备智能化迫在眉睫。为此, 以马铃薯种植农艺和全程机械化技术与装备为切入点进行梳理总结与展望, 指出了现有种植、中耕和收获机械所存在的一些问题, 并建议以种床的高质量整备、种植装备智能化、田间管理多功能、高效低损联合收获以及安全储藏保鲜等技术作为今后马铃薯生产全程机械化研究的参考方向。

关键词: 马铃薯; 全程机械化; 智能化; 农艺

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## 0 引言

马铃薯粮菜兼用, 营养丰富, 产品附加值高, 目前逐步延伸、应用于食品加工业和生物能源方面, 国内种植面积居世界首位<sup>[1-2]</sup>。但是, 目前马铃薯生产装备及精深加工配套设备均无法满足产业化需求, 也未能充分提高马铃薯产业的经济附加值, 其全程生产机械化水平显著滞后于小麦、玉米和水稻等主要粮食作物。

农业部启动的“马铃薯主粮化”战略有助于保障国家粮食安全及一些地区脱贫攻坚。但是, 由于对马铃薯种植农艺方面研究较少, 加之传统农机具作业存在着种床整备质量不高, 易因产生漏种、重种而导致种植合格率低, 达不到精准施肥、喷药, 收获过程伤薯率高, 清选分级自动化程度低, 储藏保鲜设备落后及劳动强度大等一系列问题, 使得农机农艺融合程度不够, 智能化水平不足。因此, 发展与完善马铃薯全程机械化生产技术与装备, 提高马铃薯从种床整备、种植、田间管理、收获到储藏全程机械化程度, 逐步推进区域标准化种植, 对发展现代农业意义重大<sup>[3]</sup>。

本文从马铃薯种植农艺和生产全程机械化为切入

点进行梳理总结与展望, 在此基础上认为种床的高质量整备、种植装备的智能化、田间管理多功能化、高效低损联合收获, 以及安全储藏保鲜等技术应作为马铃薯生产全程机械化研究方向。

## 1 马铃薯种植农艺

马铃薯宜种植于土松地肥、湿润且通气性好的沙质土壤中, 其种植模式分为平作和垄作。其中, 垄作分为平播起垄和垄上直播, 具有土壤不易板结且便于中耕及增产增收等诸多优点<sup>[4]</sup>, 使得马铃薯生长昼夜温差大、营养成分易积累, 更适宜于其生长习性, 常见有单垄单行和单垄双行 2 种形式。垄形参数如表 1 所示。

表 1 不同种植模式马铃薯垄形参数

Table 1 Different potato planting pattern of ridge type parameters

种植模式	垄距 <i>L</i> /mm	株距 <i>d</i> /mm	垄顶宽 <i>l</i> <sub>1</sub> /mm	垄底宽 <i>l</i> <sub>2</sub> /mm	垄高 <i>H</i> /mm
单垄单行	800~900	200	300	600	300
单垄单行	650~700	250	250	550	300
单垄双行	1 100~1 300	270~280	300	700	300

单垄双行和单垄单行种植模式分别如图 1(a) 和图 1(b) 所示。种植初期, 薯种植入垄中间的垄沟底部, 垄顶宽度和垄高只有 100~150mm, 其垄形参数在中耕时形成。总体上, 薯垄周长一般控制在 1 100mm 左右, 根据种植区域和土壤肥沃程度, 株数控制在 5~8 株/m<sup>2</sup> 之间, 种植深度控制在 120~180mm 之间, 垄形如图 1(c) 所示。

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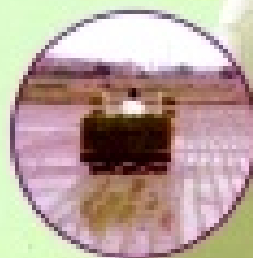
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# 农机化研究

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# 智能马铃薯堆垛机的设计

孙景彬<sup>1a</sup>, 盖金星<sup>2</sup>, 李学强<sup>2</sup>, 王相友<sup>1a</sup>, 李 栋<sup>1b</sup>

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摘 要: 马铃薯收获后需要对其入库贮藏,目前马铃薯入库堆垛机械的作业效率较低、成本高,需要大量人工辅助作业。针对这一系列问题,设计了一款具有较高作业效率的智能马铃薯堆垛机。该机可根据所需的堆垛高度进行作业,控制方便,伤薯率低,为马铃薯的长时间贮藏提供了保障。对样机做了相关试验,结果表明:该机满足堆垛要求,且堆垛过程中的伤薯率明显降低,可以控制在 1% 以下。因此,此款机器的设计对解决农忙时节用工荒、提高马铃薯的入库效率及马铃薯的贮藏品质具有重要意义。

关键词: 马铃薯; 堆垛机; 智能; 控制; 传感器

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## 0 引言

伴随着马铃薯主粮化的战略部署,国内马铃薯的种植面积逐年增加,年产量也达到世界领先水平,实现马铃薯产业的全程机械化迫在眉睫<sup>[1]</sup>。由于马铃薯的产量很高,为避免其发芽、变质,需要对其进行仓储。但是,当前马铃薯经过分选清选之后的入仓作业还未完全实现机械化,需要大量的劳动力。

目前,国内马铃薯方面的仓储机械尚未成熟,具有代表性的机型主要有姚建辉等设计的装仓堆垛机<sup>[2]</sup>、内蒙古凌志马铃薯科技有限公司设计的马铃薯堆垛机等。但这些设备仍存在着一些不足:控制部分自动化程度较弱,作业效率较低,易对马铃薯块茎造成损伤。

为了解决马铃薯收获季节的用工荒问题,降低用工成本,最大程度地减少马铃薯仓储过程中产生的不必要损失,提高其贮藏品质,本文设计了一款智能马铃薯堆垛机。该机可以对收获后经过清选分选的马铃薯进行堆垛处理,且堆垛高度可根据不同需求进行人工或自动控制,作业效率明显提高。

## 1 总体结构与工作原理

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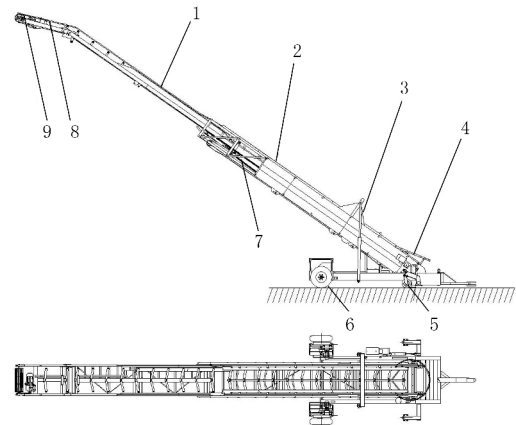
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### 1.1 总体结构

该智能马铃薯堆垛机主要由机架、伸缩式输送单元、电动液压推杆、液压站、主动前轮、万向后轮和总控制箱等部分组成,如图 1 所示。堆垛机的作业参数如下:水平长度为 9.5~14.5m,最大高度为 7.5m。



1. 伸缩式输送单元 2. 机架 3. 电动液压推杆 4. 进料斗  
5. 万向后轮 6. 主动前轮 7. 链条 8. 输送带 9. 限位开关

图 1 智能马铃薯堆垛机总体结构

Fig. 1 General structure of intelligent potato stacker

### 1.2 工作原理

收获后的马铃薯首先做分选清选处理,然后经多道输送线运输至堆垛机进料斗处,在电动机驱动下输送带将马铃薯运至所需要的高度位置,完成马铃薯的堆垛作业。

其中,伸缩臂升降装置中的电动液压推杆是通过油管路与液压站相连接,靠油缸电机来驱动。机器的移动是由置于两个驱动前轮之上的电机驱动来完成,根据不同的方位需求来完成各个方向马铃薯堆垛作业。防撞限位传感器置于伸缩输送臂两侧及驱动

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## 智能控制马铃薯精密播种机的研制

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**摘要:** 针对现有马铃薯播种机播种精度低、株距和振幅调整麻烦等问题, 在现有马铃薯播种机的基础上设置了智能株距控制装置, 当检测到播种机的行驶速度等信息发生变化时, 将控制电液伺服阀实时自动修正液压马达转速, 保证播种株距合格率始终控制在允许范围内; 设置了智能重种漏种控制装置, 当检测到的薯种信号多于1枚或未检测到薯种信号时, 控制步进电机实时调整输送带及其薯种碗的振动强度。结果表明, 实际漏种率  $\xi_{ls}$  为 6.4%~7.9%, 实际重种率  $\xi_{cs}$  为 8.2%~10.1%, 较佳的允许漏种率  $\xi_{ly}$  的设定范围为 6.0%~8.0%。该智能控制马铃薯精密播种机有效地提高了播种精度和作业效率, 提高了马铃薯播种机对不同地区、不同马铃薯品种的适应能力。

**关键词:** 智能控制; 精密播种; 马铃薯; 株距; 重种漏种; 播种机

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## Research on the Intelligent Control of Potato Precision Planter

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WEI Zhongcai<sup>2,4</sup>, WANG Xiangyou<sup>2,5</sup>, WANG Shijun<sup>2,3</sup>

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**Abstract:** In order to solve the problems of low seeding precision, difficult row spacing and amplitude adjustment of potato planter, this experiment installed intelligent row spacing devices on existing potato planter. The device of intelligent row spacing would auto-correct the electro-hydraulic servo valve to correct speed of hydraulic motor, when it detected the change in planter speed, etc. messages, so as to assure the qualification rate of row spacing within a permissible range. When the device detected more than one potato seed message or did not detect any message, it would adjust the conveyor belt and vibration intensity of potato seed bowl classifier. The result showed the actual missing rate  $\xi_{ls}$  was 6.4%~7.9% and resetting rate  $\xi_{cs}$  was 8.2%~10.1%, and the better allowed missing rate  $\xi_{ly}$  was 6.0%~8.0%. This intelligent controlled potato precision drill could effectively improve the seeding accuracy and operation efficiency. At the same time, it also improved its adaptability to different areas and different potato varieties.

**Key words:** intelligent control; precision planting; potato; row spacing; resetting and missing; planter

马铃薯种植广泛, 营养丰富, 素有“地下苹果”和“饮食新贵”之美誉, 是继玉米、小麦和水稻

之后的世界第4大粮食作物。2015年1月6日农业部正式启动“马铃薯主粮化”国家战略, 2016

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**摘要:** 针对马铃薯收获与清选分级入库机械化过程中伤薯问题, 对机械工作部件、农田土壤条件、薯农种植习惯等多种伤薯因素进行了总结与分析, 指出了需要解决的问题, 认为应尝试将新型防损材料、高频低幅振动分离等技术应用于马铃薯收获装备, 探讨切土、压土理论, 优化与增设马铃薯收获机械减损机构, 并结合弹塑性理论和接触力学模型等来分析收获过程中的马铃薯力学特性, 对于研制与改进马铃薯收获、清选分级及入库装备具有重要的意义。在此基础上, 提出了进一步增强各生产环节损伤模拟与检测的可控性等建议和措施, 以期实现马铃薯机械化生产中破皮与机械损伤的综合控制, 进而为实现高效低损收获、精细化清选分级提供有用参考。

**关键词:** 马铃薯; 收获; 清选分级; 机械化; 伤薯

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## Analysis of Potato Mechanical Damage in Harvesting and Cleaning and Sorting Storage

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**Abstract:** Aiming at solving the problems of potato damage during the mechanization of harvesting, cleaning, sorting storage, and grading, this article summarized and analyzed the multiple injury factors, such as mechanical working parts, farmland soil conditions, potato planting habits, etc. and pointed out problems needed to be solved. The paper thought some new anti-damage material and high frequency low amplitude vibration separation technology should be used in potato harvesting. The paper also discussed the theory of soil cutting and pressing, optimized and added the device to reduce the damage, and analyzed the mechanical properties of potato by combining the elastoplastic theory and contacting mechanics model. It was of important significance to develop and improve the warehousing equipment for potato harvesting, cleaning and grading. Based on these, the paper put forward suggestions and measures to further enhance the control ability of damage simulation and detection in various production processes, so as to realize the integrated control of broken peel in mechanization production and reduce mechanical damage. Thus, the paper provided useful reference for achieving low damage harvest and fine chemical cleaning and grading.

**Key words:** potato; harvest; sorting and grading; mechanization; damaged potato

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