MODEL RELATIVE ADAPTIVE CONTROL (MRAC) FOR TEMPERATURE REGULATION OF HERB DRYING SYSTEM

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ABSTRACT

This project describe the development of temperature regulation for herb drying system. The most important factor for herb drying is temperature. The purposes of temperature are to maintain the quality of herb, prevent degradation of product and also to fast the dry process. The design of this project based on PID and MRAC. PID used as the benchmark on this project. For PID controller, P and PI controllers also build to do the comparison. There are two model of MRAC used which are standard MRAC and modified MRAC. Model reference adaptive control without integral (MRACWI) lastly achieve a better regulation temperature for herb drying system. Based on the results, it is shows that the MRACWI have better percentage improvement in term of settling time compared to PID and standard MRAC. For percentage of performance for MRACWI with 45℃, in terms of settling time it has 80.58% better than PID. For 50℃, it has 71.75% while when 55℃, it has 64.85% and 56.35% when 60℃. In conclusion, the biggest temperature, the lesser percentage of performance. It also shows that MRACWI has none overshoot. It provide that MRACWI is capable to provide robust and precise performance in controlling the temperature and produce better performance in terms of rise time, settling time and percentage overshoot as compared with PID controller and standard MRAC.

ABSTRAK

Projek ini menerangkan pengembangan peraturan suhu untuk sistem pengeringan ramuan. Faktor yang paling penting untuk pengeringan herba adalah suhu. Tujuan suhu adalah untuk menjaga kualiti ramuan, mencegah degradasi produk dan juga mempercepat proses kering. Reka bentuk projek ini berdasarkan PID dan MRAC. PID digunakan sebagai penanda aras projek ini. Untuk pengawal PID, pengawal P dan PI juga membina untuk melakukan perbandingan. Terdapat dua model MRAC yang digunakan iaitu MRAC standard dan MRAC yang diubah suai. Model kawalan adaptif rujukan tanpa integral (MRACWI) akhirnya mencapai suhu pengawalseliaan yang lebih baik untuk sistem pengeringan ramuan. Berdasarkan hasilnya, ditunjukkan bahawa MRACWI mempunyai peningkatan peratusan yang lebih baik dari segi masa penyelesaian berbanding dengan PID dan MRAC standard. Untuk peratusan prestasi untuk MRACWI dengan 45 ℃, dari segi masa penyelesaian, ia mempunyai 80.58% lebih baik daripada PID. Untuk 50 ℃, ia mempunyai 71.75% sementara ketika 55 ℃, ia mempunyai 64.85% dan 56.35% ketika 60 ℃. Kesimpulannya, suhu paling besar, semakin rendah peratusan prestasi. Ini juga menunjukkan bahawa MRACWI tidak mempunyai kelebihan. Ini menunjukkan bahawa MRACWI mampu memberikan prestasi yang mantap dan tepat dalam mengawal suhu dan menghasilkan prestasi yang lebih baik dari segi waktu kenaikan, waktu penyelesaian dan peratusan kelebihan berbanding dengan pengawal PID dan MRAC standard.

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LIST OF SYMBOLS AND ABBREVIATIONS

MRAC	-	Model Relative Adaptive Control
MRACWI	-	Model Relative Adaptive Control Without Integral
PCR	-	Process Reaction Curve
PID	-	Proportional-Integral-Derivative
℃	-	Temperature
s	-	Seconds
K	-	Gain
θ	-	Time delay
τ	-	Time constant
K_P	-	Proportional gain
K_i	-	Integral gain
K_d	-	Derivative gain
T_i	-	Integration time
T_d	-	Derivative time
T_s	-	Settling time
γ	-	Adaptation gain

CHAPTER 1

INTRODUCTION

1.1 Background of the study

For thousands of year herbs are used for medicinal as well as culinary purposes. Dietary herbs are used in many delicious cuisines to improve the taste and flavour of food. Studies from recent years have revealed that herbs contribute as dietary nutrients which have a range of beneficial health properties. Work is currently underway to classify the pharmacologically active herbs which are often used for disease prevention and health promotion purposes.

Herbs are generally used as plants with savory or aromatic characteristics used to flavor also garnish food, for medicinal purposes, fragrances and other plants for macronutrients [1]. Usually the culinary use differentiates herbs. Herbs typically refers to the fresh or dried leafy green or flowering parts of a plant, while spices are generally dried and extracted from other parts of the plant, including seeds, bark, roots and fruits. Dried herbs should be kept in a cool, dark, and dry spice cabinet in their sealed jars.

The demand for herb is growing. There is a growing interest in new culinary experiences [1]. Taste and new varieties of taste makers are part of these experiences. This developed provides opportunities for herbs, but also for new varieties of dry herb. Consumers are often inspired by cooking programs on television and online recipes. There are also growing demand of herb in medical. Markets in Indonesia faced high demand for local medicinal herbs resulting in a price hike by 20% - 30% from normal rates [2]. The growth of medicinal herb market is expected to flourish with high profit margins for the players, thus making the market more lucrative.

Usually, herbs are used for spicing and garnishing foods or fragrance. Herbs are also the most crucial part of food that has been used for thousand years as a traditional medicine. Herbs usually refer to the new or dried leafy parts that are green or flowering. The next best fresh thing is getting the plant dry out. Drying herb helps retain the herb's essential oils, which also help preserve its flavor [15]. When the herbs are dried, these are free of bacteria, mold and yeast, and will remain potent for at least six to 12 months. For example, thyme, basil, oregano and mint are type of herb. Drying method is one of the main elements influence the quality of dried herbs and its influence has been extensively studied.

In herb drying, one of the most important factor is temperature [15]. The purposes of temperature are to maintain the quality of herb, prevent degradation of product and also to fast the dry process. In medical, most essential oils are volatile and sensitive in the air conditions (humidity, temperature and velocity). Drying temperatures is the most crucial thing to preserve the active ingredients of volatile oil in gland cells, which are very sensitive to temperature increase.

For example, on basil, the drying temperature is important because when did not control the temperature, it can lead to less fresh-like aroma and increase in spiciness, hay-like, sweet, earthy and woody flavours.

There are many modelling methods on herb drying. One of the current modelling method used drying herbs is by a predicting model combining ARX with wavelet neural network (WNN) [3]. It based on system identification. ARX model includes a timing structure analysis approach and depending the ability of WNN's nonlinear function approximation. Hybrid-drying technique [4] also showed results on improving the consistency of dried herbs for both color and flavor. A system for mathematical and simulation build on Matlab-Simulink [5] platform based on the first principle using equations of mass balance and moisture balance.

One of current controller on herb drying is by develop a smart control uses a fuzzy PID controller's method to limit fluctuations in drying system. Also a genetically optimized fuzzy immune proportional integral derivative controller (GOFIP) [6] which is the combination of intelligent fuzzy immune feedback control and traditional control is one of the current controller. Fuzzy rules used to imitate the mechanism of biological immune feedback to automatically adjust the parameter of the PID and a genetic algorithm is used to optimize the initial parameter of the controller.

1.2 Problem statement

From the traditional to the modern way, there are several processes for herb drying started. Start with just drying the herb under the sunlight, air drying and use the microwave. Until now, however, there has only been limited time in term to use these traditional ways. For example, if want to dry herb using sunlight, it can not be done in raining day and there has only been limited industrial use of microwaves in the processing of agricultural crops and in particular for medicinal and aromatic plants. This is due to the need for special knowledge on the application of particular microwave energy, the individual power absorption of each plant species and the polarity of important ingredients such as essential oils that determine the absorption of microwaves.

Nowadays, as technology advances, there are easier way for herb drying by used varies of controller rather than used the traditional ways.. Eventhough, there are challenge in controlling temperature on herb drying or heating when used controller such as nonlinearities, change of set point, vary time delay or time constant and large time delay. Based on the challengers, new advanced controller needed.

One of the controlled that have not been used is Model Relative Adaptive Control (MRAC). MRAC was system where the parameter is not accurately known the response of a system using ordinary feedback loop turns inaccurate, so adaptive control used. Adaptive control dealing with complex system that have unpredictable parameter deviations and uncertainties. The ability of MRAC to cope with time varying dynamic, unknown process parameter and gives desired response to the reference signal are among the factors that contribute on the implementation of MRAC in improving herb drying system [31]. MRAC also capable to cope with nonlinearities, response output based on reference model, capable to handle non stationary system.

So based on the capability of MRAC but no research yet, it can be used to improve the temperature control on herb drying.

1.3 Aim and Objectives

This research work embarks on the following objectives:

a) To design and develop the performance of MRAC and MRACWI for temperature regulation of herb drying system.

b) To design and develop the performance of P, PI and PID controller for temperature regulation of herb drying system as benchmark.

c) To analysis and compare the performance of MRAC, MRACWI, P, PI and PID controller for temperature regulation of herb drying system.

1.4 Scopes of study

This project based on simulation using Matlab and in order to achieve the objective. The scope of this project are:

a) The herb drying system for P (Proportional), PI (Proportional-Integral), PID (Proportional-Integral-Derivative), MRAC (Model Relative Adaptive Control) and MRACWI (Model Relative Adaptive Control without Integral) build on Simulink in Matlab software.

b) The simulation only test for range of 45°C to 60°C.

c) The simulation study only based on first order system transfer function.

1.5 Outline of the report

This project report comprises of five chapter. Chapter 1 discuss about the background of the study by giving a general overview of the research project. The research problem statements are introduced at the same time to provide a distinctive insight into the study. In addition, the aims and scope of the project are clarified to provide the different steps taken to carry out this study. The literature review of herb drying system, MRAC and MRACWI is discussed in Chapter 2. In Chapter 2, it discuss about an overview of current knowledge, identify relevant theories, methods, and gaps in the existing on this research.

The methodology strategy used for the project is discussed in Chapter 3. The project flow chart and design were explained. In design the circuit of P, PI, PID, MRAC and MRACWI, it based on the equation of each controller. Chapter 4 discussed and analyzed the results obtained from the design simulation. The comparison for these 3 controller also discussed. Finally, Chapter 5 was discussed and provided with the conclusion and recommendation of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will focus on studies, fact, and research project on a topic of this project. This chapter also review on herb drying, importance temperature, temperature controller and MRAC with the application and design.

2.2 Herb Drying

Drying is an ancient food preservation technique & food shelf life extension and it also reduce transport cost and storage cost [9]. Natural drying is the process in which the natural source such as sun used to dry food products. Known as drying by sun or solar. The implementation is limited because required long drying time and favorable weather conditions. Due to the natural source of drying sun drying is cheaper process. Although it is a slow operation, it is very vulnerable to pollutants and is dependent on environment. That is why commercial size is not most popular.

While, mechanical drying is the mechanical drying method used to dry foods. The system which is used for the drying of food material produces hot air. In the field of food's technology, the researcher develops several mechanical dryers. Different types of mechanical drying system including hot air convective drying, freezing drying, vacuum drying, fluidized bed drying, spray drying, microwave drying, vacuum assisted microwave drying, microwave assisted fluidized bed drying.

In a fixed-bed dryer on [10], the drying kinetics of coriander leaves and stems, with or without blanching, were studied at 50, 60, 70, and 80 °C at constant air velocity (1.5 ms-1). The experimental data were fitted in with Henderson and Pabis, Midilli et al. and the Logarithmic. It was confirmed that the rise in drying air temperature increases the drying rate of the coriander leaf and plant, according to the results obtained. Blanching used as a pretreatment favors an improvement in the stem's drying phase. A good explanation of the air-drying curves of coriander leaves and stems was found in the drying model Midilli et al.

Uraria crinita (UC) is widely used as a popular folk drink but little is known about how UC's chemical composition and bioactivity are affected by post-harvest operations. Metabolomics approaches and bioactivity assays used oven-drying, air-drying and sun-drying, as well as the oven-drying temperature [11]. The samples tested at 40°C have a greater effect on estrogen receptor-alpha activity levels and the nuclear factor erythroid 2-related activity, anti-oxidant activity and cyclooxygenase-2 inhibition compared to the other samples. A multivariate analysis showed a clear distinction between the 40°C oven-dried samples and the other samples, which is consistent with the bioactivity assay results. Such findings are ascribed to at least double increases in flavonoid, spatholosineside A and triterpenoid concentrations in oven-dried samples relative to the other groups. The proposed 40 °C oven-drying method results in an improved UC efficiency.

In late decades, numerous spice drying tests have completed and numerous spice drying methods have actualized. The cost of business dried spices anyway remains lower than that of new spices. The impact of drying methods and pre-drying medicines on the fragrance and shade of dried spices are assessed in this [4], so as to give an audit of different created innovative procedures to improve the nature of sweet-smelling spices for their modern drying. Half breed drying strategies indicated brings about improving the consistency of dried spices for shading and flavor. Notwithstanding the mechanical turns of events, as spices are profoundly delicate to various states of the drying procedure, as far as shading and smell, getting excellent dried spices is as yet an issue. What's more, dried natural consistency is exceptionally touchy to spice structure, gather season, post-reap rehearses, plant age and capacity conditions. For each sort of spice, accordingly, quality improvement requires concentrating every particular pre-drying and drying technique.

Using cabinet tray dryer properly helps reduce the losses and improves product quality [12]. The experiments were carried out to grow dehydrated mint leaves to increase the availability of mint leaves in off season. In study, fresh mint leaves were classified into untreated leaves (control) and blanched 1 min in boiled water. The leaves were dried at a loading density of 1,5,3,0,4,5 kg / m2 with three temperature levels (45 °C, 55 °C, 65 °C) under dryer cabinet tray. They also dried untreated mint leaves as control samples. Experiments were also carried out to studies effect of dry conditions of the chlorophyll and vitamin content on dried mint leaves. In untreated samples, the chlorophyll content and ascorbic acid content were found to be higher than in blanched treated samples.

Basil (Ocimum viride) leaves were dried using five different methods of drying which are power 3 microwave drying, 110 °C oven drying, 100 °C hot-air drying, 33 °C sun-drying and 28 °C ambient-air drying. The goal was to examine effect of the drying methods of the spicy basil leave 's nutritional characteristics. The fresh and dried leaves' moisture content was calculated using laboratory ovens held at 105 ± 3 °C for 24 hours. Protein, iron (using UV spectrophotometer) and carbohydrates (using handheld refractometer) were examined for extracts from fresh and dried leaves. Microwave-drying and oven-drying were the methods that produced the best results compared to the fresh herb for preserving most nutrients, while ambient-air-drying, hot-air-drying, and sun-drying resulted in substantial losses of nutritional values in basil leave. Microwave drying was the preferred approach for basil leave drying [13] as it allowed a shorter treatment period of 4 min and offered the better protein and carbohydrate preservation compared to 17 min oven drying, preserving 42 per cent (wt) of iron.

2.3 Importance Temperature on Herb Drying

Basil is an aromatic and annual herb which is most common. Drying is by far the most widely used treatment, which must be done with great care and preciousness in order to preserve the aroma and color of the leaves. Drying treatment and experimental fluidized bed drying was conducted at temperatures of 45 ° C, 55 ° C and 65 ° C to identify and recommend the optimum drying state for the acquisition of quality dried basil leaves and phytochemical leaves such as uginol, basil caryophyll. The increase in drying air temperatures from 45 °C to 65 °C the total drying time' is significantly reduced recorded. Recommended to maintain the various phytochemicals for the best drying temperature is 45°C of basil leaves, fluidized bed dryer at 45°C for 30 seconds steam blanched sample ensuring the best results in consistency and phytochemicals from basil leaves [7].

Hot air, conceal, microwave drying and the separate drying time discovered dried out mint leaves to diminish the dampness content from 88% to about 5% individually. The dried item characteristics were assessed by deciding the dampness, chlorophyll, carotenoid, polyphenols, shading and unstable oil. In microwave drying, there were huge misfortunes of unstable oil, chlorophyll and different parts contrasted with the new mint leaves, regardless of the less drying time. Hot Air Drying (HAD) at 45 ^{0}C in [8] followed by Micro Wave Drying (MWD) at 900 Watts would do well to quality boundaries in dried items demonstrating that Hot Air Drying (HAD) was progressively worthy, despite the fact that it took longer than Micro Wave Drying (MWD).

The distinctive drying temperatures on the cancer prevention agent action for thyme leaves being concentrates in [14]. Different spectrophotometric strategies (DPPH, FRAP) are utilized to considers the thyme plants cancer prevention agent exercises. The cell reinforcement action is influenced by the drying temperature. The cancer prevention agent movement of the considerable number of concentrates examined diminished with expanding temperature causing all out phenol decline. The consequences of this investigation are explained as breakdown of the cancer prevention agent movement of thyme plant by drying temperature. The perfect drying condition was preferred in the shade over toward the beginning of the day, or in the stove. The more than 35° C drying temperature brought about lower cancer prevention agent action for thyme plants.

In current research, the effects of drying temperature (40, 60, and 80 °C), relative humidity (20%, 30%, and 40 %) and air velocity (1.0, 1.5, and 2.0 m/s) on Savory leaves' drying kinetics were investigated in a forced convective dryer to maximize drying conditions. The experimental data selected to explain the drying behavior of the savory leaves were applied to nine commonly used empirical thin layer models. Three statistical parameters were used to determine the best fit which are higher values of the determination coefficient (R2) and lower sum square errors (SSE) and root mean square error (RMSE), respectively. The Midilli et al. model was considered, according to the statistical analysis, to be the best models representing the drying curves of savory leaves by a higher correlation of the coefficients and lower reduced SSE and RMSE. The drying constant is determined by the airflow conditions characteristics which are temperature, velocity, and relative humidity. The effect of air temperature on drying rate and drying time, for higher moisture content values, increased drying air temperature caused drying rate to rise and subsequently decreased drying time [15]. The effect of air relative humidity on drying rate and drying time, which reduces the relative humidity, increases drying rate change by drying time. The effect of air flow velocity on drying time was observed with increased air velocity, increased drying rate and, subsequently, decreased drying time.

This decoupling calculation is planned to take care of the issue of coupling in meat drying rooms among temperature and relative mugginess. There is no more noteworthy control accuracy of the new ordinary PID control calculation for temperature and relative moistness frameworks. Along these lines, the proposed decoupling control is created with the fuzzy PID calculation to take care of the coupling issue. This work basically identifies with the creation and plan of the decoupling controller to determine the impact of temperature and relative mugginess because of a coupling impact in the meat drying condition. The proposed approach viably expelled the temperature and relative moistness coupling, controlled the impact of temperature vacillations and diminished vitality utilization [16].

The motivation behind [17] is to decide the impacts of temperature and weight on drying the red seaweed growth. Chamber temperatures of 50, 60, and 70 °C in a vacuum stove utilized in the investigation, with drying pressures from 10 kPa to 20 kPa. For seaweed growth tests, the drying temperature changes enormously diminished the drying time. In any case, inconsequential the vacuum pressure caused in the stove occurred. The drying curves made on the said tests demonstrated a steady decline in the dampness content as for the drying time frame, until harmony was reached on different examples like numerous other drying qualities. Statistical analysis confirmed that the vacuum drying process had just a little impact on the drying temperature.

In a pharmaceutical freeze-drying process, monitoring of product temperature and identifying the ending point of the ice sublimation stage is required. In addition, estimating the heat and mass transfer coefficients could be worthwhile, so that a mathematical model may be used to refine the cycle inline (or off-line, in a successive run). All results can be obtained by calculating the temperature. Three different methods, the simple use of the temperature scale, the combination of temperature measurement with a process model, and a soft sensor introduced [18].

The leaves of Ambarella (Spondias Dulcis, Soland) are a crop rich in benefits. This [19] was carried out to determine the chemical components, drying temperature influence, antioxidant activity and toxicity of the Ambarella leaves. The study conceived with 5 treatments and 3 repetitions using Completely Randomized Design (CRD). Data were statistically anlaysed using ANOVA and continued at 5 percent significance levels with Duncan 's New Multiple Range Test (DNMRT). The treatments were conducted via a drying process at 50 °C, 60 °C, 70 °C, 80 °C, and 90 °C temperatures. The chemical analysis that is being performed on the product such as water content, ash content and antioxidant activity. The best items are those observed such as tannin content, total polyphenols, antioxidant activity, compounds of triterpenoids, flavonoids, and toxicity. Based on the study of raw materials, the leaves of Ambarella were obtained by 33.81% water content, 9.33% ash content, and 60.07% antioxidant activity, while the qualitative test resulted in a positive flavonoid result. Leaf tea product is best ambarella leaf tea for 180 minutes at temperature 700C. The drug has 7.46% water content, 7.72% ash content, 29.03% total polyphenols, 40.71% antioxidant activity, 6.61% tanin content and LC50 value of 1261.82 ppm.

2.4 Modelling and Temperature Controller on Herb Drying

Prediction model that consolidates ARX with neural wavelet organize (WNN) [3], in light of gadget acknowledgment hypothesis. ARX model incorporates a planning structure examination approach that can be utilized to address the issue of delay in the creation procedure. At that point, contingent upon the capacity of WNN 's nonlinear capacity estimate to do nonlinear capacity planning of dried cut tobacco moisture content and different procedure boundaries, for example, steam temperature and barrel temperature. The model in the long run taught and tried utilizing information from the drying procedure of a cigarette processing plant.

A genetically engineered Fuzzy Proportional Integral Derivative Controller (GOFIP) [6] is developed, a mixture of smart fuzzy immune feedback control and traditional control. Fuzzy guidelines are to emulate the instrument of input's natural resistant to consequently modify the boundaries of the (PID) and a hereditary calculation is utilized to streamline the underlying boundaries of the controller, which can conquer the deficiency of the general fuzzy immune PID control. The GOFIP controller is a solid and exact control strategy which consolidates components of vulnerability and can likewise give a powerful reference to controlling complex frameworks.

Mathematical model of grain drying process is grain drying machine design, drying operation automatic control and optimization of the essential basis of drying technology, cross-flow drying [20] is one of the currently widely used types of grain drying. This paper is mainly about Page model which is applied to the continuous grain in cross-flow drying and briefly introduces the model predictive control method and its application in the research and application of continuous cross-flow grain drying machine.

Drying is one of the complex and profoundly vitality expending process unit tasks utilized in numerous enterprises, for example, materials, paper, synthetics, pharmaceuticals, agro-and food preparing, sugar. Major R&D activities to improve dryer innovation and tasks to expand its vitality quality are in progress in the last over 10 years. A framework for numerical demonstrating and reenactment is worked for turning dryer on the Matlab-Simulink stage [5]. The model is semi-observational dependent on the primary standards utilizing conditions of mass equalization and dampness balance among vegetables and hot air. Afterward, the alteration of the rotational dryer model made a numerical model for material dryer machine.

Smart Fuzzy strategy for investigation of deficiency tree is utilized to examine the dependability of ordinary temperature control framework [22]. Right off the bat, the customary temperature control framework deficiency tree model is created. Besides, in light of the fuzzy theory, the rising methodology is utilized to unravel the deficiency tree's base cut set. The statement of the likelihood of event of the base occasion is spoken to by typical sort fuzzy numbers, and the technique for figuring of the top occasion fluffy sets is proposed. At last, there is given a shortcoming area and screening strategy dependent on the criticalness of the fuzzy probability. Blames in PLC correspondence are determined and dissected for instance. The discoveries show that the strategies for investigating dependent on the estimation of the fluffy probability will viably expand the adequacy of the area of the shortcoming.

A temperature control strategy for drying process change of air temperature in a warming zone proposed. The controller configuration is cultivated utilizing a way to deal with internal model control (IMC) [24]. When estimating the IMC controller boundaries from a genuine procedure move include determined through an open-circle stage reaction with input stage change from 50% to 60% at a reference air speed of 1.20 m/s, the temperature controller yield was tentatively checked by fluctuating air speed between 1.32 m/s and 1.57 m/s, individually. The exploratory outcomes demonstrated a high fitness of the IMC controller to direct the drying temperature.

2.5 Model Relative Adaptive Control (MRAC)

The system to be controlled, which includes unknown parameters, a reference model for the overall and compact determination of the desired system output, a feedback controller with adaptive (adjusted) parameters and an adaptation mechanism for updating the controller parameters are four basic components (unit) [25].

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