UNIVERSITI PUTRA MALAYSIA

APPLICATIONS OF PULLULAN ACTIVE PACKAGING INCORPORATED WITH GREEN SYNTHESIZED CURCUMIN (C-AgNPs) AND PULLULAN (P-AgNPs) MEDIATED SILVER NANOPARTICLES ON QUALITY OF BROILER MEAT

JAMSHED MUHAMMAD

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By

JAMSHED MUHAMMAD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

June 2021

DEDICATION

This thesis is dedicated to

My beloved parents,my wife and lovely kids

With respect, affection and fragrance of lovely memories

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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June 2021

Chairman :Professor Awis Qurni Sazili, PhD
Institute :Tropical Agriculture and Food Security

Active meat packaging is an innovation to maintain the quality, sensory characteristics, safety and shelf life of meat containing the "active" component as an antibacterial or antioxidant substance. Application of 'nanoparticles', have been reported in last decade. Green silver nanoparticles (AgNPs), synthesis by various physical and chemical routes, have been adopted by food industry as antimicrobial substances. The oxidative rancidity of meat can cause the formation of hazardous chemical compounds without the synthetic anti-oxidants (butylated hydroxyl-toluene, Butylated hydroxyl-anisole, propyl gallate). Moreover, curcumin (C-AgNPs) and pullulan mediated silver nanoparticles (P-AgNPs) have, limitedly, been reported as green anti-oxidant substance for meat preservation. Similarly, pullulan active packaging, incorporated with C-AgNPs and P-AgNPs, are not being reported as active meat packaging so far. Based on these facts, the current study was planned to obtain green C-AgNPs and P-AgNPs from chemical and physical methods. The impact of C-AgNPs and P-AgNPs incorporation on physico-chemical characteristics of pullulan active packaging along with oxidative stability and organolaptic properties of broiler meat treated with pullulan active packaging were also examined. The synthesis of C-AgNPs was achieved by reduction of silver nitrate ($AgNO_3$) in an alkaline medium. The formation of C-AgNPs was evaluated by the dark colour of the colloidal solutions and UV-vis spectra, with 445 nm as the maximum. The size of the crystalline nanoparticles, recorded as 12.6 ± 3.8 nm, was confirmed by HRTEM, while the face-centred cubic (fcc) crystallographic structure was confirmed by powder X-ray diffraction (PXRD). The synthesis of P-AgNPs was achieved through ultraviolet (UV) irradiation for 96 h. P-AgNPs were formed after 24h of UV-irradiation time and expressed spectra maxima as 415 nm, after 96 h, in UV-vis spectroscopy. The crystallographic structure was "face centred cubic (fcc)"as confirmed by PXRD. HRTEM analysis proved that P-AgNPs were covered with a thin layer of pullulan, with a mean crystalline size of 6.02 ± 2.37. Pullulan edible films were prepared by mixing glycerol and xanthan gum in pullulan

(5% w/v) aqueous solution. The solution was homogenized at 80 ± 1°C. C-AgNPs and P-AgNPs were incorporated at a rate of 2% v/v in pullulan edible film to prepare four active meat packaging i.e. control (PF-CTRL); with C-AgNPs (PF-C-AgNPs); with P-AgNPs (PF-P-AgNPs); and with mixed AgNPs (PF-M-AgNPs) as active meat packaging. Significant differences ($p \leq 0.05$) were observed in chromatography (ΔE), sharpness (L^*), green appearance (a^*), yellowness (b^*), chroma, hue, volume and area of pullulan active packaging incorporated with AgNPs (PF-C-AgNPs; PF-P-AgNPs and PF-M-AgNPs) or without AgNPs (PF-CTRL). For *in-vivo* anti-oxidant activity, a bi-layer pullulan active packaging (PF-CTRL, PF-C-AgNPs, PF-P-AgNPs and PF-M-AgNPs) was applied on clean broiler breast meat (*Pectoralis major*) and stored at 4°C for 0, 7 and 14 days. Significant differences were observed in pH, drip loss percentages, chromatography (ΔE), lightness (L^*), redness (a^*), yellowness (b^*), chroma, hue, and total expressible fluid percentages of meat samples wrapped into pullulan active packaging from control meat samples (CTRL). The meat samples treated with PF-C-AgNPs active packaging showed highest expressible fluid percentage (63.375 ± 10.53) at day 7 as compared to the controlled (CTRL) meat samples (32.751 ± 7.26), PF-CTRL (43.76 ± 7.19), PF-P-AgNPs (49.714 ± 4.38), and PF-M-AgNPs (49.263 ± 2.365) active packaging. The drip loss percentages for the meat samples treated with PF-C-AgNPs and PF-M-AgNPs was lowest at 7th (0.78 ± 0.128; 0.99 ± 0.119) and 14th day (2.60 ± 0.584; 3.60 ± 0.601) of refrigerated storage. PF-C-AgNPs active packaging exhibited statistically higher antioxidant capacity (ABTS/ DPPH) along with lower MDA contents (mg/ kg of meat) as compared to the other pullulan edible active packaging i.e. PF-CTRL, PF-P-AgNPs and PF-M-AgNPs. It is concluded that PF-C-AgNPs and PF-P-AgNPs active packaging can be adopted as green anti-oxidant alternate to preserve the quality of broiler meat during 14 days of refrigerated storage.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

APPLICATIONS OF PULLULAN ACTIVE PACKAGING INCORPORATED WITH GREEN SYNTHESIZED CURCUMIN (C-AgNPs) AND PULLULAN (P-AgNPs) MEDIATED SILVER NANOPARTICLES ON QUALITY OF BROILER MEAT

Oleh

JAMSHED MUHAMMAD

Jun 2021

Pengerusi : ProfesorAwis Qurni Sazili, PhD
Institut : Pertanian Tropika dan Sekuriti Makanan

Pembungkusan daging aktif adalah satu inovasi untuk mengekalkan kualiti, ciri sensori, keselamatan dan jangka hayat daging yang mengandungi komponen "aktif" sebagai bahan antibakteria atau antioksidan. Penggunaan 'nanopartikel, telah dilaporkan dalam dekad yang lalu. Nanopartikel perak hijau (AgNPs), disintesis dengan pelbagai cara fizikal dan kimia, telah diadopsi oleh industry makanan sebagai bahan antimikrob. Ketoksikan daging boleh menyebabkan pembentukan sebatian kimia berbahaya tanpa anti-oksidan sintetik (butylated hydroxyl-toluene, butylated hydroxyl-anisole, propyl gallate). Tambahan pula, laporan 'curcumin' (C-AgNPs) dan nanopartikel perak yang dimediasi pullulan (P-AgNPs), sebagai bahan anti-oksidan hijau untuk pengawetan daging adalah terhad. Begitu juga, pembungkusan aktif pullulan, yang digabungkan dengan C-AgNP dan P-AgNP, tidak dilaporkan sebagai pembungkusan daging aktif setakat ini. Berdasarkan fakta-fakta ini, kajian semasa diaksanakan untuk memperoleh C-AgNPs dan P-AgNPs dari kaedah kimia dan fizikal. Kesan penggabungan C-AgNPs dan P-AgNPs terhadap ciri fizik-kimia, pembungkusan aktif pullulan bersama kestabilan oksidatif dan sifat organolaptic daging pedaging yang dirawat dengan pullulan aktif juga dikaji. Sintesis C-AgNPs dicapai dengan pengurangan perak nitrat ($AgNO_3$) di dalam medium alkali. Pembentukan C-AgNPs dinilai dengan perubahan warna larutan koloid dan spektrum UV-vis, dengan catatan maksimum 445 nm. Ukuran nanopartikel kristal, dicatat 12.6 ± 3.8 nm, dan disahkan dengan Mikroskopi electron transmisi resolusi tinggi (HRTEM), sementara struktur kristalografi kubik (fcc) berpusat pada muka dikesan dengan 'powder X-ray diffraction' (PXRD). Sintesis P-AgNP dicapai melalui penyinaran ultraviolet (UV), dengan panjang gelombang 365 nm, selama 96 jam. P-AgNPs terbentuk dengan penyinaran UV selama 24 jam dan spectrum maksimum adalah 415 nm, setelah 96 jam, dalam spektroskopi UV-vis. Struktur kristalografi adalah "kubik berpusat muka (fcc)" seperti yang dikesan dengan PXRD. Mikroskopi electron transmisi resolusi tinggi (HRTEM) membuktikan bahawa P-AgNPs ditutup dengan lapisan pullulan yang

tipis, dengan ukuran kristal adalah 6.02 ± 2.37. Filem pullulan terbentuk dengan mencampurkan gliserol dan gum Xanthan dalam larutan berair pullulan (5% w / v). Larutan ini dihomogenasikan pada suhu 80 ± 1°C. C-AgNPs dan P-AgNPs digabungkan pada kadar 2%v/v dalam filem pullulan bagi membentuk empat pembungkusan daging aktif iaitu kawalan = PF-CTRL; dengan C-AgNPs = PF-C-AgNPs; dengan P-AgNPs = PF-P-AgNPs dan dengan AgNP campuran = PF-M-AgNPs sebagai pembungkusan daging aktif. Perbezaan yang ketara ($p \leq 0.05$) diperhatikan dalam kromatografi (ΔE), ketajaman (L*), penampilan hijau (a*), kekuningan (b*), kroma, rona, isipadu dan keluasan aktif pullulan yang digabungkan dengan AgNP (PF-C-AgNPs; PF-P-AgNPs dan PF-M-AgNPs) atau tanpa AgNPs (PF-CTRL). Pembungkusan aktif pullulan yang digabungkan dengan AgNP campuran (PF-M-AgNPs) berbeza secara signifikan ($p \leq 0,05$) daripada kumpulan rawatan lain (PF-CTRL, PF-C-AgNPs dan PF-P-AgNPs) dari segi pH, ketelusan, ketumpatan dan kandungan lembapan filem. Pembungkusan aktif pullulan dwi-lapisan (PF-CTRL, PF-C-AgNPs, PF-P-AgNPs dan PF-M-AgNPs) digunakan pada daging dada ayam yang bersih (*Pectoralis major*) dan disimpan pada suhu 4°C untuk 0, 7 dan 14 hari. Perbezaan ketara diperhatikan dalam pH, peratusan kehilangan titisan air, kromatografi (ΔE), ketajaman (L*), penampilan hijau (a*), kekuningan (b*), kroma, rona, dan jumlah peratusan cecair yang dapat dinyatakan dari sampel daging kawalan dalam pembungkusan aktif pullulan. Sampel daging yang dirawat dengan pembungkusan aktif PF-C-AgNPs menunjukkan peratusan cecair ekspresi tertinggi (63.375 ± 10.53) pada hari ke-7 berbanding dengan sampel daging terkawal (CTRL) (32.751 ± 7.26), PF-CTRL (43.76 ± 7.19), PF-P-AgNPs (49.714 ± 4.38), dan PF-M-AgNPs (49.263 ± 2.365) pembungkusan aktif. Peratusan kehilangan titisan untuk sampel daging yang dirawat dengan PF-C-AgNPs dan PF-M-AgNPs adalah terendah pada hari ke-7 (0.78 ± 0.128; 0.99 ± 0.119) dan hari ke-14 (2.60 ± 0.584; 3.60 ± 0.601) penyimpanan sejuk. Pembungkusan aktif PF-C-AgNPs menunjukkan kapasiti antioksidan yang tinggi secara statistik (ABTS / DPPH) bersama dengan kandungan MDA yang lebih rendah (mg / kg daging) berbanding dengan pembungkusan aktif pullulan lain iaitu PF-CTRL, PF-P-AgNPs dan PF-M-AgNPs. Pembungkusan aktif PF-P-AgNPs dapat digunakan sebagai alternative anti-oksidan mesra alam untuk menjaga kualiti daging ayam pedaging selama 14 haripenyimpanan sejuk.

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Awis Qurni bin Sazili, PhD
Professor
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Chairman)

Jinap binti Selamat, PhD
Professor
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Member)

Suriya Kumari a/p Ramiah, PhD
Senior Research Officer
Institute of Tropical Agriculture and Food Security
Universiti Putra Malaysia
(Member)

Kamyar Shameli, PhD
Associate Professor
Malaysia-Japan International Institute of Technology (MJIIT)
Universiti Teknologi Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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LIST OF ABBREVIATIONS

NPs:	Nanoparticles
Ag:	Silver
UV:	Ultraviolet
P-AgNPs:	Pullulan mediated silver nanoparticles
FESEM:	Field emission scanning electron microscopy
HRTEM:	High resolution transmission electron microscopy
SAED:	Selected area electron diffraction
PXRD:	Powder X-ray diffraction
FT-IR:	Fourier transform infrared spectroscopy
fcc:	Face centred cubic
$AgNO_{3}$:	Silver nitrate
rpm:	Revolution per minute
CTRL	Controlled (negative; without pullulan edible film)
PF-CTRL	Controlled (positive; with pullulan edible film but no nanoparticles)
PF-C-AgNPs	Pullulan edible film incorporated with curcumin arbitrated silver nanoparticles
PF-P-AgNPs	Pullulan edible film incorporated with pullulan mediated silver nanoparticles
PF-M-AgNPs	Pullulan edible film incorporated with mixed silver nanoparticles
TBARS	Thiobarbituric acid reactive substances
TBA	Thiobarbituric acid
w/v	Weight/volume
v/v	Volume/volume

ANOVA	Analysis of variances
Nm	Nanometre
DPPH	2, 2- diphenyl-1-picrylhydrazyl
MDA	Malondialdehyde
ABTS	2, 2- azinobis (3-ethyl-benzothiazoline-6-sulfonic acid)

CHAPTER 1

INTRODUCTION

1.1 Background

Meat is considered as the major source of nutrients of high biological values including protein with more essential amino acids required for human health. Due to the chemical composition, meat obtained from animal origin is susceptible to microbial and chemical deterioration (Sánchez-Ortega *et al.*, 2014).

The quality and shelf life of fresh meat is, mainly, dependent on air exposure and bacterial contamination.Pre-slaughtering handling of animals, slaughtering techniques and all post-slaughtering and handling procedures related to meat count for the meat quality and safety (Djenane & Roncalés, 2018; Dave & Ghaly, 2011). The post slaughtering and handling procedures of meat include meat handling, processing, transportation, storage, exposure to environment and bacterial contamination. Meat packaging system, packaging quality, gas and moisture contents of packaging, gas, moisture bacterial barriers can affect meat quality (Dave & Ghaly, 2011**).** Due to inappropriate meat handling and packaging the degradation of meat chemical components, formation of slim, discoloration, change of aroma, abnormal texture alongwith dreadfulmeat colour/ appearance, and oxidation of lipids/protein can occure (Djenane & Roncalés, 2018; Dave & Ghaly, 2011). The formation of hydroperoxides, ketones and aldehydes, due to oxidation of protein and lipids, may reduce the nutritive value of meat with an abnormal pigmentation (Dave & Ghaly, 2011).

Lipid oxidation, along with reduced nutritive value and abnormal pigmentation of meat, can introduce the hazardous compounds (carcinogenic) in the form of ‘malondialdehyde (MDA)’ (Djenane & Roncalés, 2018).

Pigment oxidation and photo-oxidation of fresh meat are the other factors which require more attention to enhance the quality of fresh meat (Djenane & Roncalés, 2018). The discoloration of fresh meat due to the formation of ‘deoxymyoglobin’ may be experienced by the meat retailers in the fresh meat when the meat is exposed to air or microbial contamination (Djenane & Roncalés, 2018). This factor has been reported to decrease the meat prices by 15% at retailer shop (Mancini & Hunt, 2005) resulting in the more economic losses. Metmyoglobin (MetMb) formation is induced when the fresh meat is exposed to light resulting in brownish coloured appearance of meat (Djenane *et al*., 2001). A negative correlation has been found by Cho*et al*., (2011) and Lee *et al*. (2011) between the light intensity and lipid oxidation of meat requiring the attention of researchers to develop meat packaging technologies for the safety of normal appearance of meat.The packaging of meat is mainly done to protect the product from microbes, dirt, discoloration, bad smell, abnormal texture and toxic substances during processing, storage and transportation (FAO, 2007).

New and modern techniques have been introduced for the meat packaging in recent years to maintain the quality, appearance and shelf life including vacuum packaging, modified atmosphare packaging (MAP) and air permeable packaging (Lee, 2010). The main aspects of meat packaging include simple preservation, convenience, economical, safe, and environment friendly (Han, 2014). '*Active meat packaging*' is an innovation to maintain the quality, safety and shelf life of meat (Ahvenainen, 2003) while '*Intellegent meat packaging*' can provide the product and its surrounding environment informations (date of production, pH, bacterial contamination, lipid oxidation, temperature etc.) to the producer, retailer and consumer (Kerry *et al*., 2006).

1.2 Influence of active ackaging on meat quality and safety

Active meat packaging not only influence the convenience, contamination,and protection but also influence the safety and quality of meat in a positive or negative manner (Robertson, 2016). Moreover,active packaging, influence the meat physiocochemical, organolaptic or eating quality, and microbiological characteristics during the shot term as well as long term refrigerated storage (Papuc *et al*., 2017; Djenane & Roncalés, 2018; Holman *et al*., 2018).For the consumer health and safety, the simple and convenient approach is 'ready to consumption' not preservation (Licciardello, 2017).

Sustainability, biodegradability, reuse and environment friendly behaviour of meat active packaging have attracted the attention of most of the researchers and meat industry during last decades (Ingrao *et al*., 2015). Due to environment friendly behaviour and biodegradability the concept of "active packaging" has been introduced (Schumann & Schmid, 2018). Active packaging means that all the materials, used for the food packaging, are intended to increase the shelf life or maintain or improve the conditions of the packed food, incorporatedwith any active component that may be released or absorbed into the packed food (Schumann & Schmid, 2018). Some of the biodegradable films are being reported as active meat packaging due to their non porous, and inert behaviour with a lower adhering capacity to the meat surface (Domínguez *et al*., 2018). Biodegradable active packaging, incorporated with certain anti-oxidants, can be prepared from polysaccharide and protein edible films for the refrigerated storage of meat (Domínguez *et al*., 2018). A multi-layered or mono-layered active meat packaging can be applied on the meat surface but the pourus, strong, and transparent mono-layered active packaging, incorporated with any antioxidant, can be utilized for meat preservation (Domínguez *et al*., 2018). The use of absorbant pad is necessary when no vacume is applied during meat storage to reduce the loss of active component (from active packaging) and moisture from meat surface (Domínguez *et al*., 2018; Gómez-Estaca *et al*., 2016; Gómez-Estaca *et al*., 2014).

Adaptation of ‘nanotechnology’ for the food safety, bio-security, preservation and packaging is well known along with its safer utilization in food science and technology (Ramachandraiah *et al.*, 2015). The nanoparticles have a tremendous antioxidant capacity along with antimicrobial capacity even at very low concentrations against *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Streptococcus*, *Salmonella*, certain fungal species (Ramachandraiah *et al.*, 2015; Panea *et al.*, 2014). Apart from the type, size, shape and composition of nanoparticles (silver, gold, zinc etc.), their application in edible films and coatings requires *pre-testing* to establish the 'safer migration’ of nanoparticles for the product safety and human health as they can, not only damage the product quality, but also increase the chances of intoxication (Pezzuto *et al.*, 2015; Djenane & Roncalés, 2018; Schumann& Schmid, 2018). With *pre- testing* of meat packaging system, especially nanoparticle incorporated system, maintenance of organolaptic characteristics of meat will be possible along with practical application at industrial level (Holman *et al.*, 2018). The use of polysaccharides, microbes, microbial products, actinomycetes and various plant extracts in the green synthesis silver nanoparticles (AgNPs)are being adopted by the food industry for the prolongation of food shelf life (Weiss*et al.*, 2010; Raveendran *et al.*, 2003). Edible films and coatings with multiple or single layers, with any antioxidants as an active compounds, are mostly been adopted by the meat industry for long term meat preservation (Go´mez *et al.*, 2014). Various physical (corona, flame, plasma treatments) and chemical procedures (sulfuric acid, nitric acid) may increase the quality and efficacy of edible films but can enhance the chances of “toxicity” if used without precautions (Gómez-Estaca *et al.*, 2016; Farghal *et al.*, 2017). Some thermo-mechanical treatments have been suggested by the researchers to improve the strength of edible/ biodegradable films but it may damage the chemistry of ‘anti-oxidant’ compounds incorporated into them (Domínguez *et al.*, 2018). Edible films and coatings, synthesized from pullulan, incorporated with the active compounds as “antioxidant”, can enhance the helf life of fresh and processed meat when applied directly on meat surface (Schumann & Schmid, 2018; Robertson, 2016). Incorporation of nanoparticles into edible films may be considered as desired practice to control the stability and release of antioxidants to meat surface (Domínguez *et al.*, 2018).

Appliance of AgNPs as antioxidant, antimicrobial, antifungal, anticancer and anti-inflammatory agent, have been widely exercised in from the last decade (Jeyaraj *et al.*, 2013; Kumar *et al.*, 2014; Kumar *et al.*, 2016; Pugazhendhi *et al.*, 2015). AgNPs can bear high range of temperature range with very low volatility with better restraining power against the microbes, following initial contact with them (Cushen *et al.*, 2013; Lara *et al.*, 2010). The green synthesis of AgNPs, by using various physical and chemical routes through various biological and chemical compounds has been adopted by many researchers (Wu*et al.*, 2012).

Fewer studies have been reported for the synthesis of curcumin mediated AgNPs (C-AgNPs)due to the lower water solubility of curcumin, its sensitivity to heat, light, and alkaline pH (Song & Kim, 2008). Curcumin seems to be the active agent with a potential to produce environment friendly, economical and safer green AgNPs for food preservation (Raveendran *et al.*, 2003). With a tremendous “anti-oxidant capacity” it is being used in food industry with better stability of nanoparticles (Jaiswal & Mishra, 2018). It is due to "polyphenol" which may trigger the synthesis of AgNPs during reduction process (Verma *et al*., 2016) Curcumin is considered as one of the best "antioxidant compound" in the World being utilized from centuries (Alrawaiq & Abdullah, 2014).C-AgNPs surrounded by the curcumin may act as the best anti-oxidant substance when incorporated into pullulan edible films for the preservation of food items (Khan *et al*., 2019a).

Hence, the present study aims the development of pullulan active meat packaging, incorporated with green synthesized C-AgNPs and P-AgNPs, capable of maintaining meat quality for 14 days of refrigerated storage.The incorporation of green synthesized C-AgNPs and P-AgNPs into pullulan edible film, as an antioxidant substance, has never been reported. Both of the nanoparticles (C-AgNPs, P-AgNPs) were incorporated successfully into pullulan edible film in our study.

Furthermore, the formation of pullulan edible films, by utilizing pullulan powder (5% w/v), Glycerol (1.0% v/v) and Xanthan gum (0.5% w/v), is another achievement of our study. With lesser concentrations of filmogen components, our methodology is simpler, cost effective and safer to formulate 'pullulan active packaging' with an exclusive antioxidant abilities for prolonging the quality and safety of broiler meat.

1.3 General hypothesis

In general, it was hypothesized that "incorporation of green synthesizedC-AgNPs and P-AgNPsin pullulan edible film may act as a green alternate to improve the quality of broiler meat".

The research hypothesis was tested against four treatment groups as follows;

$$\mathbf{H_a}: \ \mu_{\text{PF-CTRL}} \neq \mu_{\text{PF-C-AgNPs}} \neq \mu_{\text{PF-P-AgNPs}} \neq \mu_{\text{PF-M-AgNPs}}$$

1.4 General objective of the study

The general objective of this study was "to determine the impact of pullulan active packaging, incorporated with green synthesized curcumin silver nanoparticles (C-AgNPs) and pullulan mediated silver nanoparticles (P-AgNPs), to maintain thequality of broiler meat".

1.5 Research objectives

The specific objectives of the current study are as follows:

1. To green synthesize and characterize curcumin (C-AgNPs) and pullulan mediated silver nanoparticles (P-AgNPs) using physico-chemical methods.
2. To synthesize and characterize the physico-chemical properties of green synthesized "pullulan active packaging", incorporated with C-AgNPs and P-AgNPs, and investigation of its *in-vitro* anti-oxidant capacity.
3. To determine the effectiveness of "pullulan active anti-oxidant packaging", incorporated with green synthesized C-AgNPs and P-AgNPs, in maintaining the quality and shelf life of broiler meat.

1.6 Scope of research

Green synthesis, characterization, and incorporation of curcumin and pullulan mediated AgNPs into pullulan edible films to formulate an active broiler meat packaging is the scope of the present study. The maintenance of oxidative stability, quality, physico-chemical characteristics andan extended shelf life of broiler meat, treated with pullulan active packaging, can be a break through in the field of meat safety and preservation.

1.7 Research significance

The research findings of the current study will contribute to improve the quality and shelf life of broilr meat during refrigerated storage. Moreover, the utilization of pullulan active meat packaging, incorporated with green C-AgNPs and P-AgNPs, will be a safe and simple anti-oxidant solution to replace the detrimental anti-oxidants. This will sustain broiler meat compositional integrity and oxidative stability alongwith reduced consumer health issues.

1.8 Outline of thesis

The present thesis provides an overview about various biological and environmental factors responsible for meat deterioration, consumer health issues, literature review about meat active packaging, pullulan active packaging, green synthesis and characterization of C-AgNPs, green synthesis and characterization of P-AgNPs, impact of C-AgNPs and P-AgNPs incorporation on the physico-chemical and anti-oxidant characteristics of pullulan meat packaging, utilization of pullulan active meat packaging, incorporated with C-AgNPs and P-AgNPs, in maintaining broiler meat quality, shelf life, and oxidative stability, general discussion, and conclusions.

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BIODATA OF STUDENT

Muhammad Jamshed is, currently, working as assistant professor, Department of Livestock & Poultry Production, Faculty of Veterinary Sciences (FVS), Bahauddin Zakariya University, Multan, Pakistan. He completed his degree in the field of Animal Husbandry (AH) and masters in Poultry Production (PP) from Agriculture University, Faisalabad and University of Veterinary & Animal Sciences, Lahore, Pakistan respectively.

In 2016, he was honoured with a PhD scholarship under the project "FACULTY DEVELOPMENT PROGRAM OF BAHAUDDIN ZAKARIYA UNIVERISTY" by a directive of his Excellency Prime Minister of Islamic Republic of Pakistan.

During the tenure of 13 years in teaching and research, Muhammad Jamshed has published 20 research articles and 5 monographs related to livestock and poultry production.

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