Edition 2021

Meat Processing Technologies

Edited by

Dr. Nitin Mehta
Dr. Om Prakash Malav
Dr. Rajesh V. Wagh
Dr. Parkash Singh Brar
Dr. Shahaii Phand

Guru Angad Dev Veterinary and Animal Sciences University Ludhiana, Punjab
&
National Institute of Agricultural Extension Management, Hyderabad

SVU- GADVASU & MANAGE, Hyderabad

Meat Processing Technologies

Programme Coordination
Guru Angad Dev Veterinary and Animal Sciences University
Ludhiana, Punjab

Jointly Published By

Directorate of Extension Education,
SVU-GADVASU, Ludhiana, Punjab
&
MANAGE, Hyderabad

Meat Processing Technologies

Editors: Dr. Nitin Mehta, Dr. Om Prakash Malav, Dr. Rajesh V. Wagh, Dr. Parkash Singh Brar and Dr. Shahaji Phand

Edition: 2021.

ISBN: 978-93-91668-41-9

Citation: Nitin Mehta, Om Prakash Malav, Rajesh V. Wagh, Parkash Singh Brar and Shahaji Phand.(2021). *Meat Processing Technologies*[E-book]. Hyderabad: National Institute of Agricultural Extension Management (MANAGE) & SVU - Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.

This e-book is a compilation of resource text obtained from various subject experts of SVU-GADVASU & MANAGE, Hyderabad, Telangana on “Meat Processing Technologies”. This e-book is designed to educate extension workers, students, and research scholars, academicians related to veterinary science and animal husbandry about “Meat Processing Technologies”. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

Published for Dr.P.Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr. Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

Meat and meat products are valuable source of high quality nutrients including proteins, fats, minerals and vitamins. Meat industry is growing at the rate of 10-12% per annum due to increased market demand of processed and value added meat products, and exports especially buffalo meat. India with a meat production of 8.11 million tonnes ranks 5th in the world. It has become essential to develop effective strategies for processing and value addition of meat. Developing entrepreneurship through training in processing and value addition shall help in sustaining and enhancing the above growth rates. With a significant growth in food processing sector, a need of trained manpower is always being felt. The aim is to produce people who have technical and managerial skills so as to make them self-sufficient in meat processing. The processing of livestock produce into value added products is a promising area which can generate greater returns to the producer and can also prevent the post-harvest losses to a major extent.

It is a pleasure to note that, SVU- Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana, Punjab and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on “Meat Processing Technologies” from 12-14 October, 2021 and coming up with a joint publication as e-book on “Meat Processing Technologies” as immediate outcome of the training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for stakeholders across the country. I extend my best wishes for success of the program and also I wish SVU- GADVASU, Ludhiana, Punjab many more glorious years in service of Indian agriculture and allied sector ultimately benefitting the farmers. I would like to compliment the efforts of Dr. Shahaji Phand, Center Head-EAAS, MANAGE, Hyderabad and Dr. Parkash Singh Brar, Director Extension Education, SVU-GADVASU, Ludhiana for this valuable publication

Dr. P. Chandra Shekara
Director General, MANAGE

MESSAGE

Indian meat industry is growing at very fast pace since two decades. However, still the gruesome of clandestine slaughtering of meat animals in the lanes and bylanes of human habitat are common. Such unwelcomed practices lead to the unwholesome meat production and thereby unsafe meat food to the consumers. Therefore there is an urgent need of hygienic and scientific approach of slaughtering of animals and advances in recent developments in meat processing technologies for a healthy human population. In addition, the future growth of livestock sector depends on the adoption of modern technologies for improved processing, preservation, value addition and successful marketing.

It is pleasure to know that Department of Livestock Products Technology, College of Veterinary Science, GADVASU in collaboration with Directorate of Extension Education, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana and MANAGE, Hyderabad is organizing an online training Programme on “Meat Processing Technologies” from 12-14 October, 2021 for the Meat scientists, extension officials of state/central animal husbandry departments, veterinarians, faculty of SAUs/SVUs/KVKs/ICAR institutes, etc.

The e-book developed from this online training is precisely designed to expose the trainees to various aspects of information on the hygienic meat production, utilization of slaughter byproducts, development of value added meat products, their packaging, standards for quality control, marketing requirements and information on the promotional schemes run by the banks and different government agencies. I hope that the participants from different parts of the country would be vastly benefitted.

I would like to take this opportunity to congratulate Department of Livestock Products Technology, College of Veterinary Science, GADVASU and MANAGE for their fruitful collaboration towards benefits for the farmer community and scientific fraternity of the country. I also congratulate course coordinator Dr. Nitin Mehta and course co-coordinators Drs. O. P. Malav and Rajesh V. Wagh for their untiring work and high level of enthusiasm.

Dr. Parkash Singh Brar
Director Extension Education,
GADVASU

PREFACE

This e-book is an outcome of collaborative online training program on “Meat Processing Technologies” from 12-14 October, 2021 for the Meat scientists, extension officials of state/central animal husbandry departments, veterinarians, faculty of SAUs/SVUs/KVKs/ICAR institutes, etc. This training programme is conducted with the intention of providing knowledge about the latest developments in the area of meat processing including hygienic meat production, slaughter house byproducts utilization, value addition, advances in ingredients and processing technologies, packaging, quality control of meat and meat products, safe transport and storage of meat and meat products.

The livestock industry is contributing to the social transformation since ages and is an asset for poor population. The livestock products viz. milk, meat and eggs has a huge domestic and export market. The value addition and processing of meat has not been given due emphasis, though it harbors immense potential. This practice will not only increase the dividends of the farmers but also mobilize youth and women to take it up as an enterprise. The expanding Indian economy has laid an emphasis on the building up of a character that stimulates self-dependence and employment generation. Entrepreneurship can provide a firm answer to ever rising problems of unemployment and poverty. India has a vast population of youth in age group of 15-45 years and we should initiate some mechanisms to channelize this energy in a comprehensive and constructive manner. So, any programme which can provide them a platform to learn, adopt and perform is of national importance.

The financial assistance provided by National Institute of Agricultural Extension Management (MANAGE), Hyderabad for conducting this training and generating e-book is duly acknowledged.

The valuable suggestions for future improvements are always welcome.

October, 2021

Edited By
Dr. Nitin Mehta
Dr. Om Prakash Malav
Dr. Rajesh V. Wagh
Dr. Parkash Singh Brar
Dr. Shahaji Phand

CONTENTS

Traditional Meat Products of India- An Overview

Sunil Kumar and Z. F. Bhat
Division of Livestock Products Technology
Faculty of veterinary Sciences and Animal Husbandry
Sher-e-Kashmir University of Agricultural Sciences and Technology, R.S. Pura, 181102, Jammu (J&K), India

Introduction

India is a country with diverse climate, culture, language and geography. This variation in climate creates an abundance of different kinds of cereal grains, fruits, vegetables and livestock products. A wide variation in type of food products produced and food habits can be easily noticed from J&K to Kanyakumari. Owing to different ethnic groups and varying food habits, a variety of meat products with indigenous taste and aroma are being prepared and consumed in different parts of India. While some communities are voracious meat eaters, some are strictly vegetarian. Most of the meat products consumed in India are native in origin and termed as traditional or indigenous meat products. The technology for preparation of some of these meat products is still confined to certain artisans who pass on these technologies to next generations. Traditional meat products are sometimes also referred as heritage meat products, though the literal meaning of two terms differ from each other. Indigenous or traditional meat products have played a major role in the development and preservation of cultural characteristics of different regions from ancient time. Traditional meat products include those products which have had been consumed locally and regionally over an extended period. Preparation methods of traditional meat products are part of the folklore of a country or a region. These products may be defined as the products with a specific function that sets it apart from all other similar products in the same category. These differences in the composition, texture, taste and aroma may occur due to difference in the use of traditional ingredients from which the primary product has been prepared, formulation of the traditional products or the traditional methods of preparation or production. This implies that throughout the preparation process of indigenous foods, raw or primary products are used, either alone or as ingredients, which are identifiable in a specific geographical region and remain in use even today.

Traditional meat products reflect the intimate relationship of our ancestors with farm animals and birds. In some families, for preparation of traditional products, the farm animal and birds are especially grown to develop peculiar taste. This relationship is continuing even today. Indigenous meat products had an important bearing on the socio-cultural life of the people. Even today, these products are the symbols of wealth and status of people in the society. These traditional meat products are served in special utensils to honor the guests in social functions and gathering by rich families and emperors.

Meat production in India has been estimated at 8.6 million tons in 2019-20, standing fifth in rank in world's meat production. It includes about 4.34 million tons of poultry meat and 4.26 million tons of red meat production. Due to changes occurring in the lifestyle of today's population, some of the traditional products are at a risk of disappearing. Therefore, it is very important that these products are arched and documented and saved as part of a national, state or region culture. Traditional meat products with their extraordinary variety and richness have served people's needs for better nutrition and good health. With wide range of traditional meat products from different region of the country have provided a wide array of culinary dishes and other specialties that are a gourmet's delight. These meat products also fulfill the requirement of good quality proteins, iron besides providing the satiety value to the customers.

Although the process of making traditional meat products have undergone continuous change, but this is the high time to integrate traditional methods with modern meat processing technologies to cater the need of consumers with greater convenience with better quality products with extended shelf life without compromising the traditional taste and aroma of the meat products

Market Profile for Traditional Meat Products

In the developing world, following factors determine the prospects of traditional meat products:

1. Increased urbanization and per capita income:

   In India and developing world, millions of peoples are moving from villages to towns, cities and other urban areas. Increased urbanization has increased disposable income and consequent demand for greater variety in value added foods. Increase in per capita income is also fueling the demand for meat products as they are the rich source of quality proteins.

2. Increase in health consciousness:

   With increase in the awareness, most of the consumers today demand for traditional foods with health benefits. Most of the traditional meat products being rich in traditional herbs and exotic spices are full of antioxidants, saliva releasing juices which in turn improve the peristaltic movement and decrease constipation. However, consumption of some of the products is associated with increased risk of coronary heart diseases.

3. Outings for dining:

   During last few decades a rapid surge has been noticed in person going outside their home for dinner. On these occasions, most of the persons/families like to have those food products whose technologies are not well known or whose consumption at home is difficult due to some social stigma. Rapid growth of fast-food chain witnesses the "Eating out phenomenon" which can be easily seen through heavy crowd on roadside food vendors selling traditional meat products. Increase consumption of traditional meat products outside the home has posed a new challenge to meat industry to find out a solution to provide indigenous taste with modern technologies.

The production and marketing of traditional meat products has steadily grown over the years in our country. As an estimate more than 70% of Indian population is non-vegetarian. The traditional meat products industry has great socio-economic importance and necessitates development on scientific lines. Scope exists not only for hygienic production but also for improvements in the traditional practices followed in the formulation and preparation of these meat products, thereby enhancing their quality and shelf-life. Locally available wild herbs and plant extracts may be tried to increase their shelf life, making safe food available to the consumers, broaden their marketing and promote exports. Thus, there is a need to improve the technology used to prepare traditional meat products in all relevant aspects.

Categories of Traditional Indian Meat Products

Based on the region of origin and cultural and religious influence, different types of red and white meats are used for production of indigenous meat products in different parts of the country. Attempts are being made in all related areas to document and modernize the processing technology on scientific lines to commercialize the products and improve the nutritional security of the people of our

country. The indigenous meat products can be broadly classified into four categories based on their region of origin and popularity.

A. Meat Products of Northern Region:

In India, J&K is famous for its picturesque natural sceneries and for its cuisine of indigenous meat products, which have made the state of Jammu and Kashmir (J&K) a gourmet's heaven. A variety of traditional meat products are prepared here. The cuisine is collectively termed as Wazwan' which was once a specialty restricted to royal feasts only. Preparation of most of the products of Wazwan are a specialized culinary practice mostly restricted to a limited category of people called "Waza" (Chefs who cook Wazwan for occasions such as feasts served on marriages). This is generally a family profession and provide their services at a high price. The Wazwan constitutes flavorful ready-to-eat meat products which are usually freshly prepared and served hot as part of splendid meals. Being immensely popular, these meat products have created a niche for themselves and have become predominant component of meat products available in the market. Besides fulfilling local demand, these products also cater to the fast-food requirements of a large number of domestic and foreign tourists and are relished by one and all visiting the Union territory of Jammu and Kashmir. These delicious meat products include Rista, Harrisa, Gostaba, Nate Yakhni, Tabak-Maz, Aab-Gosh, Rogan-Josh, kabab, dopyaza etc. For preparation of these products usually mutton or lamb is used as raw material. Some of these products are of Persian origin while others have been developed in Kashmir valley during the past few centuries. Two Wazwan products, viz. Rista and Goshtaba form the main and essential components of Wazwan and are inalienable part of this world-famous traditional Kashmiri cuisine. Rista and Goshtaba are emulsion type meat products prepared from comminuted (pounded) meat. These are essential components of Wazwan due to their highly appealing flavor, texture and other palatability characteristics. In Northern plains of the country, tandoori chicken, butter chicken, meat and chicken pickles, korma, curry and large varieties of kababs and biryanies can be listed as indigenous products. Some of the products are described here:

1. Harrisa:

Harrisa is very much relished by people of Jammu and Kashmir and many other states of India particularly in winter months during early morning hours. It has a spice rich flavor and is in great demand within and outside the state and also liked

abroad. It is a convenience ready to eat meat product. Harrisa is usually made from mutton, chevon or beef but particular styles could be prepared from other meat animals like chicken, fish etc. It has a pasty consistency with a particular spice rich flavor. To develop the product meat, salt and spice mix are added to the water and cooked in large vessels (overnight) for 5-8 hours or until a clear paste is obtained i.e., no intact muscle fibers should be visible. Subsequently rice paste and condiments are also added and the paste is simmered for 15 minutes. There after preheated refined oil is added and the mixture is again simmered for 15 min or till thick consistency is obtained. Harrisa is prepared by cooking bone-in mutton. After cooking, the bones are separated and the mixture is stirred vigorously until it becomes smooth and pasty in consistency. Nowadays it is also sold at fast food outlets and bakeries. It is easy to prepare and could be served to many people in relatively short time. In Kashmir valley it is served at breakfast with local bread with hot oil poured on top and sometimes garnished with saffron, methi-maz and kabab pieces.

2. Tabaq-Maz:

One of the main course products of Wazwan, Tabaq-Maz is a ready-to-eat meat product prepared from rib portion of lamb, chevon or beef. The product is prepared by braising the ribs portion in a traditional way in water or sometimes milk containing spices, condiments and salt till the meat becomes tender and picks the rich spice flavor. Thereafter the ribs are broken down into small rectangular pieces and fried in ghee for several hours at a low flame using partially burned wood pieces till the product becomes crispy and semi-dry. The product has a unique crunch and flavor and is often served as a main product or as a snack/starter in restaurants in J&K.

3. Goshtaba:

This product is traditionally prepared from meat and fat pounded together on a slab of stone using a wooden mallet. The meat is pounded till it results in a smooth emulsion and changed into big round balls which are cooked in a white colored gravy of dahi, water, salt, spices and condiments. The product has a particular slightly sour flavor and is served with rice.

4. Rista:

Similar to goshtaba in preparation, the product is prepared from meat and fat pounded together on a slab of stone using a wooden mallet. The resulted meat emulsion is turned into balls which are usually small in size compared to goshtaba and

are cooked in red gravy containing spices, water, condiments. The typical red colour of Wazwan gravies is achieved by using saffron or *Celosia argentea* flowers.

5. Nate Yakhni:

One of the most popular meat products of J&K that is prepared by the Kashmiri families on festivals and occasions and is also an important dish of Wazwan. The product is prepared using mutton or chevon in a white colored gravy of curd (dahi). First the pieces of meat are cooked in water for some time till it becomes partially tender which is followed by cooking in gravy prepared by constant stirring of curd containing spices, condiments, animal fat (such as ghee), salt and meat broth. The product is often sprinkled with dried mint powder and is served with rice.

6. Seekh Kababs

Seekh kababs are one of the popular ready to eat meat products of Wazwan and are served in restaurants and food outlets worldwide as starters or along with main course. Prepared on skewers using course ground mutton, chevon or beef and spices and condiments and usually grilled or broiled on charcoal. Particular styles could be developed using meat of other animals such as chicken and fish. Meat is course ground along with spices, condiments and a binder such as egg and given a shape of cigar on a skewer and cooked on charcoal. The product is turned several times till it gets cooked and semi dry. The product is often smeared/brushed with fat while cooking.

7. Methi-Maaz

This is the first product that is served in Wazwan and is prepared from lamb offal's such as stomach (rumen and reticulum) and small intestines. The stomach/intestines are first given a thorough cooking in boiling water along with spices and condiments. The offals are chopped into minute pieces and cooked together in gravy using spices, fat, condiments and fenugreek leaves powder. This product has thick gravy like consistency and is served with rice and has a very rich flavor and taste.

B. **Meat Products of Eastern Region**:

There are several popular traditional meat products prepared and served in Eastern parts of the country. Some important products are:

1. Meat Curry:

Prepared from bone-in chevon or mutton chunks in a curry using salt, spices and condiments. The chunks are either marinated in salt, spices, condiments and sour

curd or cooked without marination. The meat chunks are cooked after frying on low flame till the meat becomes tender.

2. Mutton Dopiyaza:

This meat product is prepared from mutton, onions, spices condiments, sour curd and lemon juice. The product is consumed with chapati or rice.

3. Mutton Korma and Rapka:

Mutton korma is a popular meat dish in northern India as well. The product is prepared by frying the previously marinated medium size meat pieces in ghee along with spices and onions. The meat is cooked with a mild heat in a pan with a lid and curd is added and cooking continued till the meat gets tender. While korma can be prepared from lamb, chevon or chicken, rapka is prepared from meat of yak and Mithun and is quite famous in Arunachal Pradesh. This semi-dry and smoky flavored meat product is prepared in bamboos kept over traditional fire source for weeks.

C. Meat Products of Western, Southern and North-Eastern Region

While there are several traditional meat products prepared in western part of the country, most of them are undocumented and demand scientific attention. Some of the popular products are meat rolls which are prepared from pork ham or shoulder; vindaloo prepared from pickled meat chunks which are deep fat fried; and shakudi which is prepared by cooking meat in coconut milk or grated coconut along with spices.

Compared to other parts of India, southern meat products are spicier and hotter and include curries, fried products and biryanies prepared from chicken, mutton and chevon. A dried and salted meat product known as Biltong is popular in states like Andhra Pradesh and Tamil Nadu.

Numerous varieties of traditional meat products are prepared by ethnic and tribal groups in north-eastern part of the country. These products are prepared and preserved using local traditional methods. Some of these meat products are preserved for months or years and use chicken, chevon, beef or mutton. Some of the popular products of the region are Kargyong, which is an indigenous product of Sikkim, Darjeeling and Ladakh and is a hard to soft brown sausage like product prepared from beef, pork or yak. Cheu is an indigenous pork-based product cooked over fire using bamboo sticks. Doh kpu is a mince pork-based product of Meghalaya region prepared by making emulsion which is turned into shape of balls and deep fat fried in oil. Eg-

adin banum is a pork-based product prepared by cooking marinated pieces of pork using bamboo sticks over fire. Products based on meat of unconventional animals such as frogs, snakes and lizards are not uncommon in north-eastern part of India.

Conclusions

Several traditional meat products are prepared in different parts of India. Some of these products have gained national popularity and are available in restaurants throughout the country and in abroad. The traditional meat products contribute to nutrition and revenue generation for local communities. Immediate scientific attention is required to document, standardize and modernize the processing technology for some of these indigenous meat products. Efforts are required to study the packaging requirements and develop suitable packaging systems for indigenous meat products. Further, extensive research is needed to improve the shelf life of some of the indigenous meat products using natural and environmentally friendly ways such as through use of plant extracts and biodegradable or cellulose based packaging materials.

Processing technologies for meat-based snacks

Pavan Kumar, Nitin Mehta, Rajesh V. Wagh and Om Prakash Malav

Department of Livestock products Technology,

Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab.

Snacks are food products that are preferably consumed in between regular meals to satisfy short-term hunger and partially fulfilling nutrients and energy requirements. Snacks are the fastest-growing segments in the food sector due to changing lifestyles and food habits due to industrialization and urbanization, nuclear family, availability in wide variations, and improved sensory attributes. The meat snack sector focuses on further improving quality and enhancing storage stability of traditional meat snacks or launching novel products with improved nutritional value, functional attributes, more convenient and compact packaging, and improved organoleptic attributes such as flavour, taste, appearance, packages, etc. This has increased opportunities for the meat industry personnel, consumers, and professionals in this sector. Snacks are ready-to-eat or prepare (RTE/RTP) convenient food products generally eaten in between regular meals to satisfy short-term hunger and supply energy, protein, minerals, etc. According to the American Heritage dictionary, snacks are "hurried or light meal" or "food eaten between meals." Macrae et al. (1993) defined snack as convenient ready-to-eat or ready-to-prepare food products, small-sized, hot, or cold products in solid or liquid form intended to satisfy immediate hunger. Snack food makes a significant component of our food by fulfilling nutrient and energy requirements. These are generally compact, transport friendly and available in wide flavours, tastes and aromas. Snacks are preferred by all sections of society ranging from kids, school-going students, adolescent, working people and older persons. However, snacking depends upon several other reasons such as availability, options available in meetings or functions, psychological or emotional stimuli and ethano-cultural factors or traditions, genetic makeup (Faith et al., 2006), people in groups increases the intake of snacks (Lumeng and Hillman, 2007), and host of environmental factors such as pressure related to study or workload, health problems and personal habits (Hsieh 2004).

Snacks are considered as an important source of essential nutrients such as, dietary fiber, iron, folate, and vitamin E, C and monounsaturated fatty acids (MUFA) (Stroehla et al., 2005; Talegawkar et al., 2007). Based on their production process, snacks are broadly grouped under three main categories viz. first-generation snacks (baked crackers and potato chips), second-generation snacks (directly expanded snacks) and third-generation snacks (semi-products or pellets, half-products, or intermediate-products) (Pansawat et al., 2007). However, the traditional snacks are mostly cereal-based made from cereals, pulses, potatoes, fat and are regarded as energy-dense food products with lower nutrient density (Nielsen et al., 2005; Sturm, 2005). Unlike the traditional meat snacks such as meat jerky, meat stick, kilshi, vegetable snacks are cereal/flour based. The quality characteristics of these traditional flour-based snacks depend upon quality and quantity of ingredients used during preparation. They are deficient in some essential amino acids like lysine, threonine and tryptophan (Verma et al., 2014). The incorporation of meat as source of animal protein in these snacks during processing resulted in increasing nutritional quality and organoleptic properties. With the increasing awareness and growing interest in animal protein, the growth of such meat incorporated snack is increasing day by day. Moreover, with the availability and preference towards high protein diets, meat snack is nowadays very common, similar to munching on potato chips or cookies (White, 2004).

Current scenario:

The snack food sector is growing rapidly due to rapid urbanization and industrialization resulting in changing lifestyles, increasingly working peoples leaving little or no time for preparation of meal at home, nuclear family, and preference by children in snacks due to crispy texture, flavour, variety, and mouth watery taste. There are a wide range of meat snacks varieties available in the market. The global snack market was valued at US$ 472.0 billion and further expected to maintain this growth with a CAGR of 3.37% during 2021-2026. Asia-Pacific due to its large population and huge market potential, represents the largest and fastest-growing market for snack food products, followed by North America in size due to the increasing demand from the developing countries of China, India, Indonesia, etc. The total market value of snack foods was US$ 493.4 billion in the year 2020 and expected to grow at CAGR of 6.7% and will reach US$ 732.6 billion in the year 2026 (https://www.prnewswire.com/2021). According a survey conducted

between January 2013 to March 2014, about 39% of American households eat meat snacks and beef jerky. In another survey, meat stick was found most popular with 55% total sale followed by beef jerky with 16.7% total sale of the meat snacks in US (www.statista.com). These two meat snacks contributed more than 70 % of the total meat snacks sold in US in 2013.Jerky continue to be one of the most valuable meat snacks in US due to its high protein, low calories and highly profitable enterprises.

The meat snack industry is focusing on introducing novel meat snacks with improved functionality, convenient packaging, and enhanced organoleptic attributes such as flavour, appearance, crispiness, aroma, taste etc. With the growing consumer preference for minimally processed and green consumerism, there are increasingly meat snacks available in the market claiming naturalness, devoid of artificial additives, colour, or preservatives.

Processing of meat snacks

Extrusion technology is instrumental in the preparation of meat snacks of different shapes, size and dimensions. Extrusion is a technique in which raw ingredients is forced to pass through die to manufacture products with fixed cross section from and/or puff dry extrudates with fine finish (Rhee et al., 1999a). In addition to this, during extrusion several other operations such as cooking, expansion, grinding, mincing, melting, texture alteration, mixing, etc also performed. By extrusion technology, cereals, tubers, and their derivatives food products can be easily transformed into snack foods, and deboned meat can be firmly compressed and reshaped into the desired shape of snacks. By using different shapes and sizes of extruder die and their modifications viz. single screw, multiple and twin-screw extruders, snack with desired dimension and are produced such as fish crackers, French fries, meat *papad*, meat biscuits, meat noodles, meat croquets etc. Many of the snacks, mainly meat-based snacks, are produced by extrusion technology. Extrusion technology has been widely used to prepare meat and cereal-based snacks by blending meat with various non-meat products like flours (Shaviklo et al. 2011).

In 1930, extrusion technology was first applied by the snack industry to make corn curls, which was later introduced for preparation of improved/ advanced categories of snacks (Moore, 1993). Broadly the extrusion process can be divided into two categories viz. hot extrusion and cold extrusion. Hot extrusion is done at higher temperature and used for preparation of ready-to-eat (RTE) snacks such as meat biscuit, meat *papad*s, whereas cold extrusion is done at normal temperature and used

for preparation of ready-to-cook / prepare (RTC/RTP) snacks such as pasta. Under hot processing, the raw ingredients are heated at high temperature so cooking of the product is completed during extrusion and ingredients remain more flexible to be passed through die. Extrusion cooking depends upon the rate of extrusion, size and nature of raw ingredients, water content, barrel temperature and screw speed. For meat snacks, extrusion technology is preferred to traditional methods due to its technological advantages.

Besides cooking, there are several below mentioned additional advantages of extrusion cooking -

i. Extrusion improves textural attributes of meat snacks such as texture, shear force, hardness, chewability, etc due to complex interaction between protein, fat and starch.

ii. It improves the digestibility and palatability of snack protein

iii. It denatures naturally active anti-nutritional factors and toxins in present in raw ingredients

iv. The high temperature inactivates enzymes in raw ingredients

v. It improves moisture and nutrient retention in snacks

vi. Extrusion cooking decreases the microbial load in the final products and improve microbial quality and storage stability.

vii. It initiates several structural and rheological changes in starch such as starch gelatinization, degradation of starch and conversion of starches

viii. The high temperature during extrusion causes destruction of heat labile vitamins

Some of the meat snacks are enrobed/ coated with batter of mixture of edible material comprising flours, whole egg liquid. These forms a thin edible layer around products and enhances the acceptability of products, improve texture, colour and flavour, increase crispiness, retain juiciness by preventing moisture loss, decrease oil uptake during frying and provide mechanical protection. In extruded snack products, the quality evaluation is correlated with sensory, instrumental and microstructure attributes which all together determine the overall acceptability of these snacks

(Anton and Luciano, 2007). The textural attributes of snacks such as shear force, expansion, chewiness, gumminess, density, hardness, crispiness etc. plays major role in the acceptability and marketability of these products. The shear force of meat snacks should be within prescribed range as a lower than normal value indicates lower bulk density, higher expansion ratio and higher water absorption by products (Park et al., 1993). With the increase in the meat levels in snacks, there was decreased expansion (Mohamed, 1990) due to low levels of moisture. Extruded type snack products are mostly packaged in laminated pouches for convenience and to maintain their quality.

Salient Features of meat snacks

The meat snacks have the following features:

1. Several varieties of meat snacks are readily available in the market. This is materialised by application of extrusion technology and different processing techniques such as smoking, coating, curing, grilling, frying etc.
2. Meat snacks are products with low water activity. In these products, the amount of salt and spices are higher. All these attributes lead to extension of shelf life and make them stable at ambient temperature and appealing in nature.
3. The traditional cereal based snacks are energy dense and lacks essential amino acids such as threonine, lysine and tryptophan (Kumar et al., 2012). Meat incorporated snacks made by replacing parts of cereal flours to meat, have high nutritive value with supplying essential amino acids content and high biological value animal protein with improved organoleptic properties such as like flavor and taste (Raja et al., 2014).
4. These are considered as nutrient dense food products with low calorific value. With the introduction of healthier meat snacks such as low salt, high fibre, low calorie content makes them superior to the most of other meat products available in the market.
5. Meat snacks are very crispy in texture, brittle (if water content <5%), attractive appearance and colour, and hot and spicy flavour, which obvious make them products of consumer's choice.
6. Many meat-based snack products are very low in fat and marketed as "fat free" (97- to 98-percent fat-free).
7. Meat snacks without wheat flour are marketed as gluten free snacks for targeting peoples with gluten intolerance.

Common meat snacks

Some common meat snacks are enlisted here-

a. Jerkey
b. Popped pork rind
c. Kilishi
d. Pepperettes
e. Meat biscuit
f. Meat cookies
g. Meat noodles
h. Meat chips
i. Meat stick
j. Meat wafer
k. Meat cutlets
l. Meat caruncles
m. Meat rings
n. Meat *papad*
o. Meat curls
p. Meat mom

Some important meat snacks are described as follows-

a. Jerky

The term jerky has been originated from a Spanish word "charqui" which means to burn (meat).Jerky is a one of the oldest, popular shelf stable meat products traditionally prepared by American Indians from sliced whole muscle of large animal by curing and drying under sun or smoky fire for long period of time. Its popularity as meat snack is largely due to its simple procedure for preparation, nutrient density, light weight, shelf-stable at room temperature (Choi et al., 2008). Jerky is prepared by meat from different species such as beef, pork, poultry, chevon, venison, emu, yak, deer, fish etc. with seasonings, antioxidants and stabilizers by application of suitable technologies viz. comminution, curing, smoking, drying, and packaging (Konieczny et al., 2007). Jerky can also be prepared from various byproducts (such as heart, tongue), restructured from meat trimmings or poor meat cuts or by comminuted meat.

b. Popped pork rinds

These are crunchy, savoury snacks prepared by deep-fat frying of pig skin. Bacon skin is processed at high temperature to get puffed off to many times its original volume thereby giving a crispy and friable texture with different shapes viz. pellets, curls, sticks to the product. Treating the rind in acetic acid solution for 15 seconds prior to puffing increases the puffing (more than double than original size) by weakening the reticular tissue that interferes during puffing. These are further fried at high temperature (200-225°C) in refined oil or animal fat. The puffs are sprinkled with salt, herbs or other seasonings to enhance taste. On an average, popped pork rind contains over 99% total solids with high protein content (57%), fat (34%), carbohydrate (5%) and ash (4%).

c. Kilishi

Kilishi / Nigerian beef jerky is a sun-dried roasted traditional African intermediate moisture meat (IMM) product prepared mainly from beef slices after removing bone and fat, into sheet shape and sun dried. The dried sheet is coated with a paste of peanut, spices, onion, garlic and some sweetener and again put for drying followed by roasting. Kilshi has long storage life at ambient temperature. It is valued for its distinct exotic flavour, brown colour, light weight, shelf-stability at ambient temperature, rich in protein and other vital nutrients. It has wider consumer acceptance across the sub-Saharan region and even beyond. Legne et al. (2010) recorded 7.5% moisture, 50.2 % protein, 18% fat and 9.6% minerals in Kilishi. Kilishi is traditionally stored unpackaged and wrapped in cardboard paper for selling at shops, restaurants, hotels etc.

d. **Pepperettes:**

Pepperettes/ pepperoni sticks are sausage like acidic fermented meat products prepared from ground meat of turkey, beef and pork mostly. They resemble to hot dogs in appearance. There are several variations available such as all beef or beef/pork (55%/ 45%) fermented sausage having a moisture/ protein (M/P) ratio of 1.6.1 (Faith et al., 1997). The texture of pepperettes depends upon the fat content and intensity of drying. These are prepared by filling the batter into casings of small diameter, and put for further processing by smoking and drying, smoking only and drying only, all with various levels of fermentation at 41°C to pH 4.6 or pH 5. The heating of pepperoni sticks after fermentation to an internal temperature of 54°C significantly reduced *E. coli* 0157:H7 count.

e. Meat Biscuits and cookies:

The word 'Biscuit' is originated from the Latin words 'Bis' (meaning 'twice') and 'Coctus' (meaning cooked or baked). Biscuits are one of the most popular snacks relished by all sections of society throughout the world. Biscuits are mainly cereal based snacks with high fat and energy content and lacking in essential amino acids like tryptophan, threonine and lysine. By incorporating meat in the form of minced meat or meat powder not only improves nutritive quality but also sensory attributes such as flavour, odour and aroma (Verma et al., 2014). The preparation of meat powder has significant effect upon the quality of meat biscuits.

Rajkumar et al. (2012) reported good quality of chicken meat powder by treating in microwave at 720 MHz for 18 min. with turning meat after 10 min. followed by drying in oven for 20 min. to remove residual moisture. Rajkumar (2012) prepared chicken meat biscuit by chicken meat powder (upto 50% of flours), refined wheat flour, milk powder, shortening, flavourings, spices, baking powder, salt and glucose. Shortening plays an important role in determining plasticity parameters, modifying texture, mouthfeel, colour, flavour, richness and tenderness. Several studies have been reported of incorporation of various functional ingredients in biscuit dough to increase the nutritive and functional value of meat biscuits such as addition of bran as source of dietary fibre, decreasing fat by carbohydrate-based fat replacers (like polydextrose, maltodextrin, guar gum or inulin), incorporation of essential oils, antioxidants, powder of various herbs/ spices such as 0.2% clove powder, 0.2% caraway powder, 0.2% nutmeg powder and 0.3% cinnamon powder incorporated in biscuit dough by Singh et al. (2014). They reported 0.2% clove powder most effective and safest natural antioxidant to be used in meat biscuits. Bukya et al. (2013) prepared chicken meat biscuit by using different levels viz. 5%, 10%, 15%, 20% and 25% of defatted chicken and refined wheat flour. Ibraim (2009) supplemented salt biscuits with 5% fish by-products (fish protein concentrate) and reported increased water holding ability, protein content, especially essential amino acids (EAAs) without affecting colour and other attributes.

The word cookie originated from Dutch word *'koekje'* meaning 'little cake' and commonly used in North America whereas in UK, these are grouped under biscuits. English biscuits are smaller in size and crispy compared to soft and chewy, bigger North American cookies. Berwal et al. (2013) prepared chicken meat cookies by

adding refined wheat flour, minced chicken meat (10%), sugar, shortening, whole egg liquid, milk and other ingredients in bowl mixer to form emulsion. The emulsion was filled into cookies dropping bag having stainless steel nozzle of desired shape at end and emulsion was dropped in tray followed by baking in preheated hot air oven at 160ºC for 15-20 minutes or till golden brown. The developed cookies were possessing high nutritive value (11.8% protein, 23.58% fat and 1.1% minerals) and were shelf stable at room temperature for 3 months without compromising sensory attributes

f. Meat Cutlets:

Meat Cutlets are flat croquette of minced meat and other ingredients like shredded potato, flours, pulses, nuts, spices, condiments and often coated with rusk crumbs. Meat cutlets due to their low calorific content, dietary fibres and higher protein content proves suitable alternative to non-vegetarian populations. Singh et al. **(**2015; 2014**)** developed chevon meat cutlets with improved nutritive and organoleptic properties. They optimized levels of chevon meat (77%), shredded potato (5%), water (3%), condiments (10%), spices (2%), gram flour and salt in the development of chevon meat cutlets. They also reported increased dietary fibre content and nutritive value upon incorporating processed oat powder (4%) and sorghum flour (6%) in the cutlets (Singh et al., 2015a, b). The shelf life of chevon cutlets was reported to enhance upon adding clove oil (100 ppm).

Singh (2015) prepared chicken meat cutlets by optimizing the levels of minced chicken meat cutlets (71%), broccoli powder (4%), carrot powder (3%), shredded potato (10%), refined wheat flour, rice flour, salt, vegetable oil, red chilli powder and spice mix. The incorporation of meat emulsion (30%) by partial replacement of minced meat has been reported to enhance the binding. As with other food products, cooking is critical for development of meat cutlets. The pre-heating of meat cutlets in a pre-heated oven at 175ºC for 15 min. with turning after 10 min. ensured lower uptake of fat during frying and improved colour and appearance. The common battering mixture applying for coating of meat cutlets has been whole egg liquid, bread crumbs or rusk powder. The breading on the meat cutlets has been reported to improve flavour, texture, juiciness and appearance.

g. **Meat noodles**

Noodles are basically cereal based snack widely consumed in Asian due to characteristics flavour, nutrition, and longer shelf life at room temperature, versality, reasonable price and varieties. Forbes recognized noodle industry as world's largest

industry (www.Forbes.com) and has global market of US $46.73 billion in 2020. Several studies had been carried out to incorporate meat (in powder or minced form) during preparation of noodles by partially replacing various flours to enhance nutritional as well as functionality of noodles. Noodles are prepared by extrusion process followed by steam treatment for completion of gelation and drying in hot air oven. Verma et al. (2014) incorporated meat (30%) in noodles by replacing whole wheat flour in noodle dough and moulding it into noodles followed by cooking at in hot air oven at 65 ± 2°C for required time (7-8 hours). The other important ingredients used during preparation of chicken meat noodles were rice flour, corn starch, salt along with taste maker comprises onion, garlic, ginger, dry cardamom, nutmeg, anise, black pepper, capsicum, fenugreek, clove, coriander, cumin seed and turmeric powder. The incorporation of chicken meat in noodles significantly increased ($P<0.05$) in the ash, protein, fat, moisture and water absorption index as the levels of chicken meat increased. Khare et al. (2014) reported increased shelf life of chicken noodle upon incorporating natural preservatives such as EDTA, chitosan, eugenol, peppermint. Chicken noodles were prepared by mixing tenderized chicken meat (by treating with 0.15 M calcium chloride and 2.5 g papin /Kg chicken meat for 40 hrs at refrigerated temperature) with refined wheat flour, spice, vegetable oil and salts to form dough. The dough was cold extruded to form noodles. The raw noodles were gelatinize by steaming for 12 min and hardened by quick chilling. The noodles were put in cabinet tray drier drying.

h. **Meat chips**

Chips are the most unique and universal nutrient fast food items widely consumed throughout the world. Devalakshmi et al. (2010) developed meat chips by utilizing spent hen meat (80%) with various extenders such as gram flour (15%) and other ingredients viz. potato, corn flour (3%) refined wheat flour, salt, baking powder, spice mix, condiments and antioxidants. Chips were prepared by rolling the above dough into 3 mm layer on flat surface covered with aluminum foil, cutting in square shape followed by drying in hot air oven to an internal temperature of 100°C for two hours. The storage period of these chips has been reported to over two months at room temperature. The chicken chips were deep fat fried.

Biswas et al. (2014) prepared poultry meat finger chips using combination of turkey and spent hen meat by applying cold extrusion technology. Chips were put for microwave cooking. On the basis of various physico-chemical and sensory attributes,

formulation containing 70% meat mince at 50:50 ratio of turkey and spent hen meat was found most suitable. Sharma and Nanda (2002) also successfully developed chicken chips by adding spent hen meat into flour, common salt, condiments, spices and preservatives into extruder and cooking by deep fat frying. The developed chips scored high on meat flavour intensity and colour. Sagar et al. (2013) developed ready-to-fry chicken meat-based chips formulation comprising 60% spent hen meat, 25% tapioca pearls flour, 10% corn flour and 5% potato starch. Products were dried to get moisture content less than 10%.The sensory attributes of developed chips were recorded significantly higher acceptability than control chips. The developed chips have been reported to have potential to compete effectively with commercial potato or corn based chips.Kieras et al. (2007) developed comminuted rabbit and sweet potato dehydrated snack chip (Chiparoo) and reported marked reduction of food borne pathogens.

Meat snacks have an important place in our lifestyle mainly due to convenience, healthy choice and meal replacement. There are several technological interventions have been develop to prepare meat snacks with functional properties and from comparatively cheaper sources of meat such as animal by-products.

Management of meat industry effluents and byproduct utilization for better profitability

Om Prakash Malav, Nitin Mehta, Rajesh V. Wagh and Pavan Kumar

Department of Livestock products Technology,

Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab.

1. Introduction

There are about 3,900 licensed slaughter houses in the country authorized by local bodies. In addition, there are around 26,000 unauthorized slaughter houses. However, there are now 13 export-oriented, modern, integrated abattoirs or meat processing plants registered with the Agricultural and Processed Food Export Development Authority (APEDA). There are also 24 meat processing and packaging units, which receive dressed carcasses from approved municipal slaughter houses for the export of meat. The slaughtering and other meat processing operation results in production of valuable by-products in addition to main product i.e. meat. Slaughter byproducts or meat industry byproducts may be defined as every part of a slaughtered animal except dressed carcass (also called as offal or fifth quarter). It may range from 40-60% of the total weight of the animal and normally not utilized to its full potential.

According to BAHS (2018-19) total meat production in our country is 8.11 million tonnes. The proportion of meat produced by different animal species is as follow: Poultry-50% buffalo-19.05%, goat-13.53%, sheep-8.36%, pig-4.98% and cattle-4.02%. Annual growth rate of meat production is about 5%. Large number of animals and birds are slaughtered to produce the meat for domestic consumption and export. It leaves huge loads of by-products. Efficient utilization of animal by-products has direct impact on the economy and environmental pollution of the country. Non-utilization or under-utilization of by-products not only lead to loss of potential revenues but also lead to the added and increasing cost of disposal of these products along with major aesthetic and serious health problems. It has been estimated that 11.4% of the gross income from beef and 7.5% of the income from pork come from the by-products.

It is an astonishing observation that the livestock sector alone contributes nearly 29.82% of value of output at current prices of total value of output in Agriculture, Fishing and Forestry sector (National Accounts Statistics-2019). The

overall contribution of Livestock Sector in total GDP is nearly 5.10% at current prices during 2018-19. This contribution would have been much higher had the animal by-products been also efficiently utilized. The economic analysis has been carried out and it was observed that the financial loss to nation through non or underutilization of animal byproducts is around Rs. 1000 crores/ annum.

The by-product management is in turn is associated with environmental sustainability. The animal industry by-products are potential environmental polluters if are not used adequately and disposed without any treatment as they are very rich in non-biodegradable organic matter. There has been a lot of hue and cry in public about installation of any slaughter house in their vicinity as foul and stinking smell emanates from decaying organic by products. The important environmental impact of the animal processing industry results from the discharge of wastewater. The animal industry has operations which demand a lot of water for the different operations such as washing, cleaning the excreta, cleaning the slaughter house flour, drinking water for animals etc. The discharge of waste waters having high polluting potential may result in depletion of oxygen leading to death of aquatic life through eutrophication.

The disposal of animal byproducts without utilization also results in loss of animal proteins and other nutrients that could have been utilized for human and animal consumption. So, it becomes imperative that all the wastes and by products generated from slaughtering needs to be converted into valuable commodities.

2. Utilization of Meat Processing Industry By-products

As mentioned above, the utility of animal industry byproducts is immense and technological intervention is always required for effective utilization of these by products. The general uses of animal byproducts in various forms have been described in Table 2. Value addition of animal byproducts is seen as a promising approach for efficient utilization without compromising the environmental health. Value addition is economically improvement of a commodity and inculcating characteristics that makes it more favourable to a market. Though the consumption of by products are not to the level as that in other countries but the insistence on value addition can Create a preferred market. A number of technologies for value addition of animal industry byproducts like emulsification, restructuring and enrobing are now commonly used. Processing of meat along with by products in a stipulated ratio is also being tried in steaks, chops, cutlets etc. This helps in increasing value and palatability of spent meat and reduction in price of meat product too.

Table 2: Common Meat Processing Industry By-products and their general uses (Ockerman and Hansen, 2000; Chatli et al., 2005; Jayathilakan et al., 2012; Irshad et al., 2015)				
By Product	**% of live weight**	**Raw by products**	**Processed by products**	**Uses**
Blood	7	Edible raw blood	Plasma and Red blood corpuscles	Adhesives for sausages, pharmaceutical products, blood sausages or pudding
Bones	20-30	Inedible raw blood	Blood meal, poultry feed, blood albumen	Additives for livestock feed, leather finishing agent, plywood adhesive, fertilizer, mordant
		Raw bone classified as edible	Edible fat pieces	Shortening, bone gelatine, bone meal, livestock and poultry feed
		Raw bone classified as inedible	Inedible fat pieces	Lubricant gelatine: photographic, pharmaceutical, printing. Tallow: soap, cosmetics, food, bone ash, ceramics. Glue: adhesive, abrasive.
Hide	6-8	Hides	Preserved hide, hair and wool	Leather products, falls, upholstery
		Hide and pelt	Trimmings for inedible rendering	Fertilizers and textiles. Collagen: cosmetics, face creams, shampoo, detergents
		Pig skin	Edible	Used in various comminuted meat product up to 7-10%.
		Pig skin	Tanned skin	Leather products
Intestines	2		Sausage casings	Sausage skins, edible, Surgical sutures, sports guts, musical strings, prosthetic materials, collagen sheets, burn dressing, dialyzing membrane, animal feed, heparin, protein meal
Horns and hooves	0.6	Cattle feet	Neat's foot oil	Fine lubricant
		Horns & hoofs	Gelatin extracted protein	Gelled food products, foaming in fire extinguishers, felt, upholstery, brushes
		Toe nails	Meal	Mixed with livestock feed or fertilizers
Hair, Bristles and Wool		Hair		Pelting, fabrics and pillow
		Bristles		Brushes
		Wool		Yarn, blankets, carpet, lanolin, fertilizer
Stomach	2		Pharmaceuticals	Trypsin, bate, insulin pharmaceuticals
Liver	1.2		Edible	Direct consumption, variety meat, sausage ingredient

Fat	Variable	Edible raw fat	Edible fat oleostearein cracklings	Fatty acids, frying purpose, margarine, shortening, candy chewing gum, pet foods or meat meal
		Inedible raw & mixed condemned materials	Inedible fat, meat and bone meal	Lubricants, soaps, candles, glycerin additives for livestock and poultry feed
		Inedible raw fat	Inedible (rendered) fat	Lubricants, soap, candles, glycerin, additive for livestock and poultry feed
Glands	Variable	Discussed in Table: 5		

Other important uses of meat processing industry by-products are given as follow:

2.1 Livestock Feed

Animal by products including condemned carcass can be utilized as feed supplement for livestock and poultry. Animal blood is a source of quality protein and is an important edible byproduct. It is frequently used in preparation of blood pudding, blood sausages, biscuits etc. But it is employed in development of livestock feed in form of blood meal. The advantages of using these byproducts as feed for livestock ensure better health and productivity. Addition of 10% level in feed helps in meeting out the essential requirements of amino acids like lysine, tryptophan and methionine. The meat meal can be included in diets of pigs and poultry of any ages. Other than that, bone meal is mixture of crushed bones which is used for feeding livestock. It is a source of phosphorus and calcium which in present in a ratio of 1:2. Meat-cum-Bone meal is also prepared which can be fed to animals. Poultry industry byproducts like feathers can be used for preparation of feather meal. This not only helps in better utilization of feathers but also prevents environmental degradation as feathers are potent pollutants. The feathers are having keratin which are hard to degrade at lower temperature. So the digestibility is somewhat questionable. A technological intervention that can be employed is biodegradation of feathers by keratinolytic microorganism like *Bacillus linciformis*. Rendering is frequently used for preparation of the livestock feed from byproducts and it will be discussed in detail in forthcoming sections.

2.2 Pet foods

Utilization of offals and slaughter house by-products for the production of pet foods may fulfil the nutritional requirement of all categories of pets (i.e. different age

groups and physiological conditions) which have absolute requirement of animal proteins in diet along with sparing the grains for human consumption. It will also help in minimizing the economic losses and environmental pollution resulting from discard of animal by-products. Slaughter house byproducts utilization in pet food formulation will give more ingredient option to the pet food manufacturers. This will open gates for employment generation as well as growing income for the slaughter house owners and pet food manufacturers. Common pet treats from the byproducts are Abomasums, Achilles Tendon, Bone Chews, Braided Skin, Omassum, Muzzle chew, Heart, Hock Tendon, Head skin, Intestine Braid, Intestine Knott, Intestine Plain, Intestine Twist, Knee Tendon, Knotted Bone, Lamb Ears, Lamb Heart, Lamb Legs, Lamb Trachea, Lamb Tripe, Liver, Liver Bites, Lolly Pop, Lung Sliced, Lungs, Dried tail, Smoked Bones, Dried ear, Dried braided pizzle, Schaslik atc.

Slaughterhouse waste or meat processing industry by-products such as liver, lung, kidney, gizzard, bones, brain, spleen and tripe has high nutritive value and these can be efficiently utilized for the production of pet foods as the animal proteins are the integral part of their diet.

- Pork tail: highest fat and lowest moisture content of all meat byproducts.
- The liver, tail, ear and feet of cattle has equivalent protein content as that of lean meat.
- The vitamin content much higher than lean meat tissue.
- Kidneys and liver contain 5- 10 times more riboflavin (1.69-3.63 mg/100g) as compared to lean meat.
- Pork liver, lungs and spleen are rich sources of iron. Also, they contribute 90-350% RDA for copper.
- Thymus and sweetbreads contain highest levels of phosphorus (393-558 mg/100g) and potassium (360-433 mg/100g) amongst meat by products.

2.3 Fertilizers

After rendering, the finished product can be either used as livestock feed or fertilizer but it depends on the nature of the material. Clean and fresh material is used to make good stock feed while material which is contaminated and decomposed is suitable for fertilizer preparation. Animal by-products can be used as a valuable resource as agricultural fertilizer and soil conditioner. Their application improves the soil health through addition of carbon and nutrients that feed the microorganisms or through better plant growth, which in turn adds the organic matter. Their application leads to higher infiltration, better moisture and nutrition retention. The disadvantage associated with the application is that soil structure may get damaged during

application by compaction and other contaminants like salts and metals may be added. However, these risks can be reduced by good management practices.

2.4 Pharmaceutical byproducts

Animal by-products like glands provide many chemical extracts having pharmaceutical and cosmetic applications. These glands like pituitary gland, adrenals, liver, lungs etc. secrete many enzymes and hormones. The glands/tissues are collected only from healthy animals and locating the glands requires experience because some of the glands are often small and are often encased in other tissue. Different animals have different glands that are important, and their function is dependent on the species, sex, and age of the animals. The best method of preserving most glands is by quick freezing without any degradation of their active principle. Before freezing, the glands must be cleaned and trimmed from surrounding fat and connective tissue. After careful wrapping, they are stored at -18 °C. Then the glands are dried and defatted and converted to powder form which is later on dispensed as capsules or tablets. Various glands and products of pharmaceutical value derived there from are presented in Table 4.

Table 3: Slaughter house By-Products of pharmaceutical value and their uses

Glands/organs	Active compounds	Use
Adrenal gland (suprarenal capsules)	1. Adrenal cortex – Corticosteroids (cortisone) 2. Adrenal medulla i. Epinephrin ii. Norepinephrine	✓ Addison's disease- progressive anemia, low blood pressure, loss of weight, dark skin pigmentation, diarrhea, loss of strength and a depletion of sodium.; anti-neoplastic and anti-inflammatory agents, and for treating shock. ✓ To arrest hemorrhaging, shirk blood vessels, prolong the effects of local anesthetics, stimulate heart action, and overcome shock. ✓ Shrink blood vessels, reduce peripheral blood flow, and slow the rapid heartbeat.
Arteries (bovines)	Carotid arteries	✓ Implantation into humans as a femoropopliteal or iliofemoral substitute.
Bile	1. Ruminants gall i. Cholic acid ii. Deoxycholic acid 2.Pig gall i.Chinodeoxycholic acid	✓ In synthesis of corticosteroids-prednisone, prednisalone and progesterone. ✓ Treatment of human gall stone to suppress cholesterol synthesis.

Bone cartilage	1.Xiphoid and xiphisternal cartilage from young cattle	✓ To replace facial bone of human.
Heart	1.Pigs heart valves (young)	✓ Implantation into the human heart in place of defective valves.
Intestine	1.Heparin (pork and beef)	✓ In the treatment of frostbite and burns.
Liver	1. Vitamin B12 2. Heparin 3.Catalase enzyme (hog)	✓ Pernicious anemia and sprue ✓ Anticoagulant and the treatment of frostbite and burns. ✓ Cold sterilization of milk for cheese making.
Lungs	1.Heparin	✓ Anticoagulant and the treatment of frostbite and burns.
Ovaries (sow)	1. Estrogen 2. Progesterone 3. Relaxin (corpora lutea)	✓ Treatment of menopausal syndrome. ✓ Prevent abortion ✓ Used in child birth.
Pancreas (pork)	1. Insulin (β-cells) 2.Glucagon (α-cell) 3.Pancreatin 4. Trypsin 5. Chymotrypsin	✓ Treatment of diabetes. ✓ To elevate blood sugar and treat insulin over dose ✓ Intestinal disorders and cystic fibrosis. ✓ Remove death tissue and speed healing after surgery or injury. ✓ Milk curdling proteolytic enzyme.
Parathyroid	1.Parathormone	✓ To treat human parathyroid deficiency.
Pineal gland	1.Melatonin	✓ For the treatment of Schizophrenia, mental and physical development problems, and mental retardation.
Pituitary (pork)	1.ACTH 2.Oxytocin 3. ADH 4.Prolactin hormone	✓ In the treatment of rheumatism, arthritis, eye inflammation some skin disorders and multiple myeloma (a form of leukemia). ✓ Use to assist child birth and in obstetrical complication, let down of milk. ✓ In the treatment of diabetes insipidus ✓ Use to stimulate milk secretion from mammary gland.
Seminal vesicles	1.Postaglandins	✓ To induce parturition and in large doses induce abortion.
Testes	1.Hyaluronidase 2.Androgen	✓ Spreading factor-has ability to digest mucoplolysaccharides, and thus increase the rate of absorption. ✓ Control male characteristics.

Thymus	1. Thymosin	✓ Helps the body in resisting infection, calcification of bone and prevent rickets.
Thyroid (hog)	1. Thyroxin 2. Calcitonin	✓ To treat cretinism in (infant) and myxoedema (in adult). ✓ In the treatment of 'Pagets disease'.

2.5 Tallow and Lard

Animal fats are important byproducts of animal industry and the major edible fats are lard and tallow. Tallow is the rendered fats of cattle or sheep while lard is rendered fat of pig. These are obtained by dry and wet rendering procedures. Animal fats provide important amounts of fats used in the world today, both for foods and for many non-food applications. Animal fat is a versatile, sustainable and natural basis for many products. Worldwide, they are used in explosives, paints, soaps, lubricants, insecticide, wax etc. Prior to its use as a food ingredient, the lard or tallow is often bleached and deodorized. Wordwide, 172 million tonnes of vegetable and animal oils and fats are produced annually, from which approximately 25 million tonnes (14%) are estimated to be of animal origin (REA, 2013). These animal fats are mainly categorized as tallow, lard, fish oil, and butter.

3.6 Biodiesel Production

The energy sources especially petroleum based products are depleting vary fast due to rapid utilization without due replenishment. This has led to a search of alternative sources and biodiesel presents a potential substitution. It is produced from the fat extracted from byproducts after rendering operation. It is biodegradable and nontoxic which emits lesser obnoxious chemicals when burnt as compared to petroleum based products. The technology that is adopted for converting rendered fat to biodiesel is trans esterification. It reduces the viscosity of oil /fat to a range of (4-5mm^2/s) closer to that of petro diesel. The use of biodiesel is getting popular throughout the world. It is generally blended with diesel at the level of 20 percent. No modification in design of engines is required for this substitution.

3.7 Biogas Production

Animal waste like GI tract contents are digestible and can yield biogas. The waste product is utilized effectively and contributes to the continuous generation of an efficient energy source. The animal wastes constitutes a good substrates for biogas production with methane potential of 619 dm^3kg^{-1} from mixed animal wastes, which is much higher than simple manure (20- 30 dm^3kg^{-1}) (Hejnefelt and Angelidaki, 2009).

Power plants have been designed to produce biogas (60% methane, 30% carbon dioxide and traces of hydrogen, carbon monoxide etc.) by digestion of animal waste (Sharma, 2003). Biogas is produced from animal wastes due to their anaerobic fermentation in airtight tanks called digesters. The resulting gas is then compressed in tanks and distributed for consumption. It is used for steam production and utilized to force turbines and create electricity. It can also be used to cooking, heating, lighting and even power car engines.

2.8 Leather

Hide constitutes around 6-8 % of live animal weight whereas the skin from sheep and goat constitutes around 12-15 % of live animal weight. Leather is prepared after the processing of hide and skins through tanning. India's leather industry has grown drastically, transforming from a mere raw material supplier to a value-added product exporter. The Indian leather industry accounts for around 12.93 per cent of the world's leather production of hides/skins. Leather is one of the most widely traded commodities globally. The growth in demand for leather is driven by the fashion industry, especially footwear. Apart from this, furniture and interior design industries, as well as the automotive industry also demand leather. The leather industry has a place of prominence in the Indian economy due to substantial export earnings and growth. Exports of Leather & Products in India averaged Rs 11.90 Billion from 1991 until 2017, reaching an all-time high of Rs 36.46 Billion in August of 2014 and a record low of Rs 1.81 Billion in June of 1991.

During Apr-Jun 2017, the major markets for Indian leather products were US (14.66 per cent), Germany (11.22 per cent), UK (10.05 per cent), Italy (7.03 per cent), Spain (4.63 per cent), France (5.15per cent), Hong Kong (4.52 per cent), UAE (5.04 per cent), China (3.09 per cent), Netherlands (3.05 per cent), Poland (2.23 per cent) and Vietnam 1.88 (per cent). At 47.54 per cent, footwear (leather and non-leather) and footwear components accounted for the lion's share of leather exports in April-June 2017, followed by leather goods and accessories with 23.34 per cent share, finished leather with 16.77 per cent share, leather garments with 9.79 per cent share and saddlery & harness with 2.56 per cent share.

The Indian Leather Industry holds a noticeable place in the Indian economy. This particular sector is known for its consistency in the high export earnings and is also among the top ten foreign exchange earners for the country. The export market for leather and leather products have increased over the past decades and touched to

around US$ 5.91 billion during 2013-14, recording a growth rate of about 14.77% in 5 years. Kanpur is the largest center of the leather industry, other top 7 leather centers in India are Unnao, Chennai, Ambur, Kolkata, Agra and Ranipet. Chennai contributes far more than 50 percent of India's total leather exports. It also has a CSIR research institution named the Central Leather Research Institute. According to the CLRI survey on capacity utilization, there are 2091 tanneries in the country out of which 1803 units are in the small scale sector and 288 are DGTD units. Tamil Nadu with 934 units, West Bengal with 538 units and Uttar Pradesh with 378 units, account for 89 percent of the tanneries in the country.

The Council for Leather Exports (CLE) is an autonomous non-profit organization, which is entrusted with export promotion activities and the development of the Indian leather industry. About 3,500 companies manufacturing/exporting leather and leather products are members of the Council.

2.9 Bone meal

Bones constitutes around 20-30 % of live body weight of animals. Important products prepared from bones are gelatin, glue, bone meal, fertilizers etc. Bone meal is mixture of crushed bones which is used for feeding livestock. It is a source of phosphorus and calcium which in present in a ratio of 1:2. Major manufacturers/suppliers of bone meal are Aarti Traders Delhi, Andhra Agro-Vet Associates Pvt. Ltd. Himayatnagar, Hyderabad, Frigorifico Allana Ltd. Allana House, Allana Road, Colaba Mumbai, Maharashtra, Frigorifico Allana Ltd. Paithan Road Aurangabad, Maharashtra, Hindustan Crushers & Fertilisers Co. Agra, Uttar Pradesh, Jas Agro Vet – Industries Khaderpet Vaniyambadi, Tamil Nadu, Kerala Chemicals & Proteins Ltd. Ernakulam Kochi, Kerala, Khatauli Manure Mills (P) Ltd. Meerut, Uttar Pradesh, Mount Wool Growth & Exports Ltd. Gujarat, Nandyal Aqua Feed Pvt. Ltd. Kurnool, Andhra Pradesh, Parle Chemicals, Mani Majra Chandigarh, Rupa Poultry Enterprises, Warangal, Andhra Pradesh, Shaw Wallace Gelatines Ltd. Calcutta, West Bengal Standard Agro Vet Industries Unnao, Uttar Pradesh, Vet Chem Industries Kanpur, Uttar Pradesh, Vetstar Agros Pvt. Ltd. Hyderabad.

2.10 Gelatin

Gelatin is important product prepared from bones. Gelatin is broadly classified as edible and inedible. Inedible gelatin is used is cosmetics manufacturing industry such as nail polish and in photographic papers and film. The edible variety of gelatin is used in different manufacturing industry like food processing and pharmaceutical.

Global production of gelatin is 4,00,000 tons per annum while India accounts for 5% of the total production at 20,000 tons. In India, bulk of the gelatin is consumed by pharmaceutical industry but worldwide, it is more consumed by the food industry. The global market is growing at a rate of 4% per annum while in India it is growing at a rate of 10%. The major players for the gelatin production in India are- Nitta Gelatin India Ltd (BSE: 506532), India Gelatines & Chemicals Ltd (BSE: 531253) and Narmada Gelatines Ltd (BSE: 526739).

Table 4: Export of slaughter house products from India

Sr No.	Products	**2017-18**	**2018-19**
		Value (Rs)	**Value (Rs)**
1	Edible offals (Fresh, Chilled/frozen)	12923744063	16293367066
2	Raw hides and skin of bovines	14724126	15186251
3	Raw skin of sheep and lambs	2429911	1057998
4	Other raw hides and skins	864001	---
5	Tanned/crust hides and skin of bovines	41332465	135547185
6	Tanned/crust skin of sheep and lambs	394032	31543267
7	Tanned/crust hides and skin of other animals	21732354	272167172
8	Leather from bovines	36184134662	30612525049
9	Leather from sheep and lamb	5420145290	6248504021
10	Leather from other animals	14292663204	12865493605
11	Laminated leather/metallized leather	363434604	275061948
12	Casings	32744360000	48066260000

Source: DGCI&S Kolkatta

3. Treatment of meat industry effluent

For hygienic reasons slaughter house, use large amount of water in processing operations (slaughtering and cleaning), which produces large amount of wastewater or effluent. The major environmental problem associated with this abattoir wastewater is the large amount of suspended solids and liquid waste as well as odour generation. For the safe disposal of liquid and solid waste, the following action should be taken:

3.1 **Separation of blood:** The blood from slaughtered animals will coagulate into a solid mass, which may block up both open and closed drains. It is therefore recommended that the blood is collected and used for human consumption, stockfeed production or fertilizers.

3.2 **Screening of solids:** Solids (meat or skin trimmings, hair, pieces of bones, hooves, etc.) must be screened. This may be done by providing the drains with vertical sieves.

3.3 **Trapping of grease:** Effluents from slaughterhouses always contain small amounts of fat (melted fat or small pieces of fatty tissues). Grease traps should be

installed in the drains. The fat solidifies, rises to the surface and can be removed regularly.

3.4 **Biological treatment:** Involves aerobic and anaerobic processes for the conversion of complex soluble and insoluble organic compounds into simple non polluting compounds.

4. Constraints: Indian meat industry has inherent handicaps which hamper the proper utilization of the meat industry by-products. At present we have very limited number of industries based on by-products processing. The major constraints are:

- Lack of collection and transportation of byproducts
- Lack of cold storage facilities
- Poor facilities for the collection of bones
- Unorganized/non-scientific slaughtering
- Poor collection facilities for dead and fallen Animals/Birds
- Lack of by-products processing facilities
- Lack of trained/skilled human resources
- Lack of research in the area of byproducts utilization
- Synthetic Substitutes
- Agitation by ethical groups
- Identification of markets

Conclusions

The byproducts from the meat processing industry are of great importance. Efficient utilization of animal by-products has direct impact on the economy and environmental pollution of the country. Non-utilization or under-utilization of by-products not only lead to loss of potential revenues but also lead to the added and increasing cost of disposal of these products along with major aesthetic and serious health problems. Various important value added edible, inedible and pharmaceutical value products can be prepared from the meat industry byproducts such as leather, animal feed, pet food, neat's foot oil, gelatin, hormones, enzymes etc which may generate extra income to the meat processors. There is an urgent need to create the facilities for timely collection, transportation and processing of the slaughter house byproducts.

Role of bioactive peptides in meat processing and preservation

Akhilesh Kumar Verma, Pramila Umaraw and V.P.Singh
Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut-250110, (Uttar Pradesh) India

Bioactive peptides are small chain peptides obtained from enzymatic hydrolysis of proteins that exhibit various physicochemical activities. These show good nutritive value, antioxidant, antimicrobial, antifungal, antihypertensive, antithrombotic, anticarcinogenic as well as anticytotoxic activity. They also enhance the physicochemical properties of meat model system by improving the water holding capacity, cooking yield, colour, texture and sensorial properties. Meat and meat products are good source of bioactive peptides. Bioactive peptides with various functional activity (antioxidant, antimicrobial, ACE-inhibitory, antihypertensive) have been generated from meat, meat by-products and meat products The present review focuses on the use of bioactive peptides in processing and preservation of meat and meat products.

Proteins have long been our area of interest. The term protein was derived from Greek word "*proteios*" meaning "primary" and it is still the epicentre of all biological research although the studies now focus on its components like amino acids and small segments of proteins known as peptides. Peptides are small sequence of amino acids that are produced by enzymatic degradation of proteins. Peptide chains that exhibit physiological or biochemical activities are known as bioactive peptides. These generally range from three to twenty amino acid sequences with low molecular weight and have exhibited good nutritive value, antioxidant, antimicrobial, antifungal, antihypertensive, antithrombotic, anticarcinogenic as well as anticytotoxic activity. Peptides when administered orally, influences all systems of body depending on its composition and amino acid sequence. These have been found to influence nervous system, immune system, cardiovascular system and digestive system. The functionality of peptides depends on its open structure, its helicity, charges, its hydrophilicity or hydrophobicity. Its functionality may also extend to regulating satiety, opiod, mineral carrying and modulating immune system. These are being explored for treating psychological disorders, lifestyle diseases such as obesity and diabetes as well as in cancer treatments. Bioactive peptides have also attracted interest of food scientists all over the world as now they are being explored for their bioactive

functionality which might open new avenues for peptides as natural preservatives and additives in food processing.

Meat is the primary source of protein in non-vegetarian diet. It is a rich source all essential amino acids and has high biological value (74-94), desirable protein efficiency ratio (0.42 – 0.70) and good protein digestibility corrected amino acid score (0.9-1.0). Thus, it is the choicest food item for good health and well-being. The demand and consumption of meat products have increased with increasing urbanisation and availability of disposable incomes. Highest meat consumption is in the developed countries and within countries, in the developed cities. These are the places where the demand for processed meat products have also escalated. Processed meat products provide an opportunity for quick convenient and ready to eat or ready to cook as well as can be the major source to meet the rising meat products demand.

Processing of meat exposes to processes like cutting, chopping, comminution, mincing or grinding etc. which increases its chances for microbial and enzymatic degradation. Incorporation of spices, herbs and various additives help to reduce these deteriorative changes. The use of chemical additives incorporated in processed meats have been authorised by federal agencies, government, public health organisations etc. and their limits are declared in the labels. But their unjudicial use and increased consumption of processed meats have led to health concerns among consumers. Nowadays, consumers are demanding for natural and chemical free products. Alternatives for chemical preservatives are widely being explored, of which bioactive peptides have shown promising results.

Peptides, are functional 3-20 amino acid chains that when administered exhibit positive physiological activity. Bioactive peptides can be generated by enzymatic hydrolysis of proteins. Such enzymatic hydrolysates have also shown potential functional activities like bioactive peptides. The functionality of fish proteins, egg proteins as well as milk protein concentrate was improved by enzymatic hydrolysis (Shahidi et al 1995; Wang and Wang 2009; Banach et al 2013) that might be attributed to the disruption of tertiary protein structure, generation of small chain peptides of low molecular weight and free amino acids, change in the charges and opening of active sites (Kristinsson and Rasco, 2000). The solubility, emulsion stability and foaming ability of milk protein concentrates were significantly improved by hydrolysis (Banach et al 2013).

Meat protein derived antioxidant peptides

There are several studies that demonstrate the ability of proteins to inhibit lipid oxidation in foods. The antioxidant activity of hydrolysates from porcine myofibrillar proteins was explored by Saiga *et al* (2003). Porcine myofibrillar proteins were hydrolysed either with Actinase E or Papain for 24 h at a temperature of 37 ºC and pH 7. The antioxidant activities of the hydrolysates were tested with the linoleic acid peroxidation system, the DPPH radical-scavenging activity and the metal-chelating activity assay. In the linoleic acid system, the Papain hydrolysates showed highest antioxidant activity, very similar to the activity of α-tocopherol; in the DPPH radical-scavenging activity assay both of the hydrolysates showed antioxidant activities which were lower than that reported for α-tocopherol and both hydrolysates showed metal-chelating activity (Saiga *et al.*, 2003).

Kim *et al* (2009) isolated and identified the peptides exhibiting anti-oxidative properties from venison protein hydrolysates, by using enzymatic hydrolysis. The identified antioxidant peptide sequences were Met-Gln-Ile-Phe-Val-Lys-Thr-Leu-Thr-Gly and Asp-Leu-Ser-Asp-Gly-Glu-Gln- Gly-Val-Leu. The free radical scavenging activity of former was higher than that of latter peptide, and IC50 values of hydroxyl, DPPH value, superoxide, and peroxyl radical scavenging activities were measured as 44, 77, 217, and 85 µg/mL respectively. Liu *et al* (2009) investigated the antioxidant activity and functional properties of porcine blood plasma protein hydrolysates (PPH) prepared with Alcalase at 6.2%, 12.7% and 17.6% of degree of hydrolysis (DH). The PPH showed stronger radical-scavenging ability and possessed stronger Cu^{2+}-chelation ability and a reducing power than non-hydrolysed plasma protein ($P<0.05$). The antioxidant activity of PPH, indicated by thiobarbituric acid-reactive substance (TBARS) values in a liposome-oxidising system, increased with increasing DH ($P < 0.05$). The Alcalase hydrolysis increased protein solubility from its original 68.46–81.79% (non-hydrolysed) to 82.95–94.94% (hydrolysed) over a broad pH range (3.0–8.0).

Animal protein derived antimicrobial peptides

Bioactive peptide derived from food protein also shows a broad range of activity against microorganisms of spoilage and/or health significance. The antimicrobial peptides derived from animal source proteins present the great advantage of being produced from harmless and inexpensive sources. Hence there is a

growing interest in utilization of these bioactive peptides as food grade bio-preservatives or as health-promoting food supplements in the food industry.

Antimicrobial peptides (AMP) mostly act as bactericidal. All AMPs interact with the cell wall or membrane of bacteria. AMPs have an affinity for the anionic phospholipids and lipopolysaccharides found in cell walls and membranes of bacteria (Barzyk *et al* 2009). Antimicrobial peptides usually have less than 50 amino acids, of which nearly 50% are hydrophobic and have a molecular weight below 10 kDa. These peptides can be generated in vitro by enzymatic hydrolysis. Research regarding isolation and identification of antimicrobial peptides derived from animal muscle has not been as extensive as for antioxidant peptides from animal protein. A wide variety of organisms produce antimicrobial peptides as a primary innate immune strategy. In medicinal applications, antimicrobial peptides are sometimes preferred to conventional bactericidal antibiotics because they kill bacteria faster. The methods described here will be useful for the identification of novel peptides with good antimicrobial activities. Several methods for testing the antimicrobial activity of hydrolysates or peptides have been used. The agar diffusion assay (or inhibition zone assay) is a common method used to test the antimicrobial activity of peptidic hydrolysates and peptides. This method quantifies the ability of antibiotics to inhibit bacterial growth. The diameter of these zones increases with concentration.

Zhang *et al* (2008) found an antimicrobial component in the skin homogenate of *Epinephelus fario* using a Trypsin digest. After screening the skin homogenate of *E. fario*, which showed activity against *E. coli* the homogenate was treated with Trypsin for 90 min at 37 ˚C, and its antimicrobial activity against *E. coli* completely stopped. Salampessy *et al* (2010) isolated two antibacterial peptide fractions (fractions 9 and 12) from bromelain hydrolysate derived from leatherjacket (*Meuchenia sp*.) insoluble muscle proteins. An assay for antimicrobial activity showed that fraction 12 had a MIC against *B. cereus* and *S. aureus*, while fraction 9 only showed some activity against *B. cereus*. Wang (2003) investigated the effect of porcine leukocyte antimicrobial protein on the proliferation of *S. aureus* and *E. coli* inoculated in ground meats. Antimicrobial protein hydrolysates were predominantly of 6 and 7.5 kDa molecules.

Bioactive peptide/ hydrolysate in meat processing

The functional activity of peptides or hydrolysates are not much affect by processing conditions and thus, remain stable and active even after cooking. Shi et al.,

(2019) obtained ACE -inhibitory peptides with molecular weight less than 3kDa from duck meat with IC_{50} 0.62 mg/mL. The functionality of these peptides was not affected by processing conditions such as by heating at temperature varying from 25 - 100 ^{o}C and by processing ingredients such as glucose and NaCl. Similarly, Hwang (2010) also observed no change in the ACE inhibitory activity of peptides obtained from tuna cooking juice by heating at temperatures 20 ^{o}C to 100 oC for two hours.

Effect of bioactive peptides on texture

Texture is one of the most important sensory characteristic of meat products that influences consumers preferences and affects products acceptability. Studies have reported that incorporation of potato protein hydrolysate does not significantly affect hardness, structure deformability and cohesiveness in cooked frankfurters. Hydrolyzed potato protein studied exemplified excellent antioxidant as well as emulsifying capacity in raw emulsion and in cooked frankfurters (Nieto *et al* 2009). Intarasirisawat *et al* (2014) investigated the effect of snakehead (Channa striata) protein hydrolysate (CSPH) on textural properties of fish sausages. The hardness, cohesiveness and springiness fish sausages were slightly increased by incorporation of hydrolysate at higher levels. Contrarily, Cavalheiro et al., (2014) reported softer texture of mortadella type sausage prepared with incorporation of 10, 20, 30% mechanically deboned chicken meat protein hydrolysate. Incorporation of shrimp hydrolysate in preparation of fish tofu resulted in soft textured tofu (Ketnawa et al., 2016).

Effect of bioactive peptides on water holding capacity (WHC)

Water holding capacity of meat and meat products influences the cooking yield, textural characteristics as well as the final eating quality of meat products. Hydrolysis increases the free amino acid content, opens the tertiary structure, exposes active groups, carboxyl, amino and generates smaller peptides that show functional activities (Kristinsson and Rasco 2000). Peptides become more hydrophilic and tend to interact more with water as polar groups adsorb more water. Ibarra et al., (2013) improved the water retention in sous vide processing of salmon fillet by combination of salmon byproduct hydrolysate (14 g/100 g) and very low level of salt (0.2 g/100 g salt). This combination of hydrolysate and salt produced product with same standards as that produced by adding 2 % salt. Nunez et al., (2021) have reported synergistic effects of peptides in bovine skin gelatin hydrolysate (BSGH) on the water-holding capacity (WHC). Maillard reaction products from enzymatic hydrolysis of

mechanically deboned chicken residue obtained at heating 90 ^{o}C and 100 ^{o}C, when added into Cantonese sausage at the rate 3% significantly decreased the hardness value (Sun et al., 2010).

Effect of bioactive peptides on product colour

Colour is one of the first quality attribute perceived by the consumers. It is one of the most important cues influencing the purchasing behavior of consumers. Pea protein hydrolysate (2 g/100 g) added ground beef maintained its colour stability better than control during storage at 2 oC for 9 days (Sun and Xiong, 2015). Pea protein hydrolysate retarded colour fading by decreasing decomposition of nitrosyl hemochrome and by hampering oxidative deterioration. Nieto *et al* (2009) also studied the colour of the raw emulsions as well as cooked frankfurters. Meat emulsions with added hydrolyzed potato protein (HPP) were darker (lower *L**) than those made without HPP and also had lower values of *a** and *b**. These changes in colour were mainly attributed to the typical brown/dark appearance of the HPP solutions. Zakaria & Sarbon, 2018 contemplated the effect of snakehead (Channa striata) protein hydrolysate (CSPH) on fish sausages and observed no significant effect on L*, a*, and b* values during storage. Protein hydrolysate obtained from Red meat of yellowfin tuna (*Thunnus albacares*) was used to substitute egg yolk in mayonnaise preparation which resulted in decreased lightness and increased redness and yellowness.

Bioactive peptide/ hydrolysate in meat preservation

The incorporation of the protein hydrolysate in packaging materials with increased in its concentration considerably alters the mechanical properties of films while maintaining oxygen and water vapor permeability (Schmid et al., 2013). Bourbon et al. (2011) also conferring that addition of protein in films caused a decline of tensile strength and gas permeabilities. Zhang et al. (2019) reported that addition of protein hydrolysates into the coating with a higher degree of hydrolysis (DH) leads to increasing in tensile strength of films. The addition of protein hydrolysates in to the packaging materials increase the shelf-life of packaged food products as well as improved in mechanical properties of film. (Valdes et al., 2017). It has been reported that that enzymatically hydrolyzed whey proteins form films with better flexibility than non-hydrolyzed proteins, while maintaining the same oxygen permeability (Sothornvit and Krochta, 2000).

Effect of bioactive peptide/ hydrolysate on sensory attributes of meat products

Wang et al. (2020) reported that incorporation of protein hydrolysate obtained from mutton ham to meat patties increase the oxidative stability of meat patties, as well as positive effect on its sensory attributes. The increased in sensory attributes might be due to presence of free amino acids, peptides, taste nucleotides and minerals being the factors for creating these delicious tastes (Deng, 2009). However, Jin et al. (2015) also stated that the incorporation of hydrolysates from mechanically deboned chicken meat may cause an adverse effect on the sensory quality due to presence of some bitter peptides.

Conclusion

The contemporary literature has revealed that the meat derived hydrolysates and peptides have multi facet functionality which can be utilized for sustenance of meat industry and consumer well-being. The antioxidant and antimicrobial activity of bioactive peptides has been well established in various food models including meat products. The effect of processing on peptides is also being explored. But for the use of bioactive peptides as an alternative for chemical additives, thorough knowledge about the bio-availability, pharmacokinetics, pharmacodynamics and toxicity is essential. Furthermore, legal guidelines for their use should be formulated. Thus, the quality and safety must be defined before industrialization of bioactive peptides in food processing and preservation.

Application of Proteomic Technologies in Meat Quality, Processing and Safety Studies

Naveena, B.M. and Rituparna Banerjee

ICAR-National Research Centre on Meat, Chengicherla, Hyderabad-500092

The term "proteome" was coined during post-genomic era to reflect protein complement of genome and indicate the specific impact of genes and proteins in biological sciences. Proteomics, an emerging area encompassing the study of the structure, function, and interaction of proteins, relies largely on two major pillars: fractionation techniques and mass spectrometry analyses. The robustness of the proteomic technologies has allowed the researchers to explore the biomarkers as indicators of meat quality, safety and authenticity. Proteomics, which is considered as the molecular link between the genome and the functional quality characteristics of the food, was utilized extensively in past few decades to address the basic aspects of meat quality and to characterize the biomarkers of the quality attributes.

We are now in an exciting period where many new opportunities are presented to researchers through the application of genomics, proteomics and other 'omic' approaches. The great progress in biotechnology in recent years has resulted in the development of new scientific research areas such as genomics and proteomics, which are used to study the complex patterns of gene and protein expression in cells and tissues. Ability to simultaneously analyze hundreds or thousands of genetic polymorphisms (genomics), transcripts (transcriptomics), proteins (proteomics) and metabolites (metabolomics) on dedicated arrays or with specific tools have increased our knowledge of the molecular organization of living organisms. These tools have been implemented in recent years to reveal genes, proteins or metabolites whose expression level or abundance is associated with a phenotype of interest such as the quality of the meat.

After genomics, proteomics is considered the next step in the study of biological systems. Proteomics tools consist of 2-Dimensional gel electrophoresis (2-DE), mass spectrometry (MS) and bioinformatics. Proteomics permits visualisation of the protein content of the cell under varying conditions, combining powerful separation techniques with highly sensitive analytical mass spectrometry. Proteomic analyses describe the identity, relative quantity, and state of proteins in a cell, under a specific set of conditions (Vaidyanathan and Goodacre, 2003). All the proteomic

studies require protein separation and purification of crude sample before further analysis and characterization.

Protein separation

A. Gel-based separation

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) has long been the method of choice for resolving proteins based on molecular weight for a variety of biochemical analyses (Laemli, 1970). Evidence from the available database (http://www.expasy.ch) suggests that 2-DE is the most widely used tool for large scale proteomics.Established in the mid 1970s, modern 2DE technology make use of first dimension, isoelctric focussing (IEF) using highly reproducible immobilized pH gradient (IPG) strips. In 1^{st} dimension (IEF), proteins are separated based on their charge followed by separation based their molecular weight using SDS-PAGE (2^{nd} dimension). The DIGE (Differential gel electrophoresis) technology has more recently been used for direct quantification of abundance changes on a global scale without interference from gel-to-gel variation. This is done using spectrally resolvable MW and charge-matched fluorescent dyes (Cy2, Cy3 and Cy5) to pre-label protein samples which are then multiplexed onto 2D gels. These dyes offer sub-nanogram detection limits. Lametsch and Bendixen (2001) demonstrated that when optimal extraction, focusing, and staining conditions were used, 1000 well-separated individual protein spots can be separated by 2-DE in each gel, as estimated by computer-assisted image analysis.

B. Liquid chromatography mass spectrometry (LC/MS) based separation

Liquid chromatography coupled with mass spectrometry (LC/MS) based approach offer greater sensitivity than is typically offered by the protein-staining detection limits from gel-based strategies. Here, protein identification is performed at the level of peptide fragmentation pattern acquired during tandem MS (LC-MS/MS), and which are indicative of amino acid sequence (Wolters et al., 2001).

Protein identification by mass spectrometry

With the rapid progression of many ongoing and completed genome sequencing projects, there is a growing demand for rapid and reliable identification of proteins. Mass spectrometry is a powerful technique for the identification of proteins at nanogram quantities. Proteomic samples can be exceedingly complex - a proteolytic digest of a simple cell lysate can contain several hundred thousand peptides. Many proteomic strategies contain protein identification as a major

component, and this is routinely performed using MS followed by a statistical comparison of the mass spectral data with theoretical data generated from protein sequence databases which are generated from genomic sequences (Friedman, 2011).

The most commonly used method for identification of proteins from 2-DE is peptide-mass fingerprinting by matrix assisted laser desorption ionisation-time of flight mass spectrometry (MALDI-TOF MS). This technology is sensitive, allowing identification of femtomole quantities of proteins and peptides, in a high-throughput mode.The MS produces a data characteristic of individual proteins, usually at the level of aminoacid sequence or peptides that are generated after digestion with a site-specific protease (Henzel et al., 1993). Other commonly used mass spectrometer include electrospray-ionisation triple quadrupole (ESI-QTOF). Powerful bioinformatics algorithms can then be applied to search databases that match these experimentally derived mass spectral signatures (Eng et al., 1994).

Bioinformatics

The use of computer science, mathematics, and information theory to model and analyze biological systems, especially systems involving genetic material is called as bioinformatics. Comprehensive information regarding complete and ongoing genome projects around the world can be obtained from 'genome online database (GOLD)' (http://wit.integratedgenomics.com/GOLD/). The ExPASy (Expert Protein Analysis System) proteomics server of the Swiss Institute of Bioinformatics (SIB) is dedicated to the analysis of protein sequences and structure as well as 2-D PAGE analysis data (http://us.expasy.org/ch2d/2d-index.html). Information on biologically significant protein domains, patterns and profiles that help to identify the protein family a sequence belongs to can be obtained from the PROSITE database (http://ca.expasy.org/prosite/). The Munich Information centre for protein sequence (MIPS), hosted by the Institute for Bioinformatics (IBI) supports and maintains generic protein databases (http://mips.gsf.de/).

Application of proteomics in meat science research

Modern proteomic technologies for understanding muscle biology have been successfully used for a series of investigations including mapping of muscle proteins, muscle disorders, muscle physiology, conversion of muscle to meat, understanding meat colour and texture, meat speciation, sensorial and technological meat quality traits etc. (Figure 1). Proteomics and Meat Quality Laboratory at ICAR-NRC on Meat has been working towards answering complex questions relating to meat colour and

texture, detection of meat adulteration, identification of peptide biomarkers, understanding muscle food quality etc. using state-of the art proteomic approaches. Knowledge gained from these approaches are beneficial in defining and optimising management systems for quality, providing assurance of meat quality and safety and in tailoring quality to suit market needs.

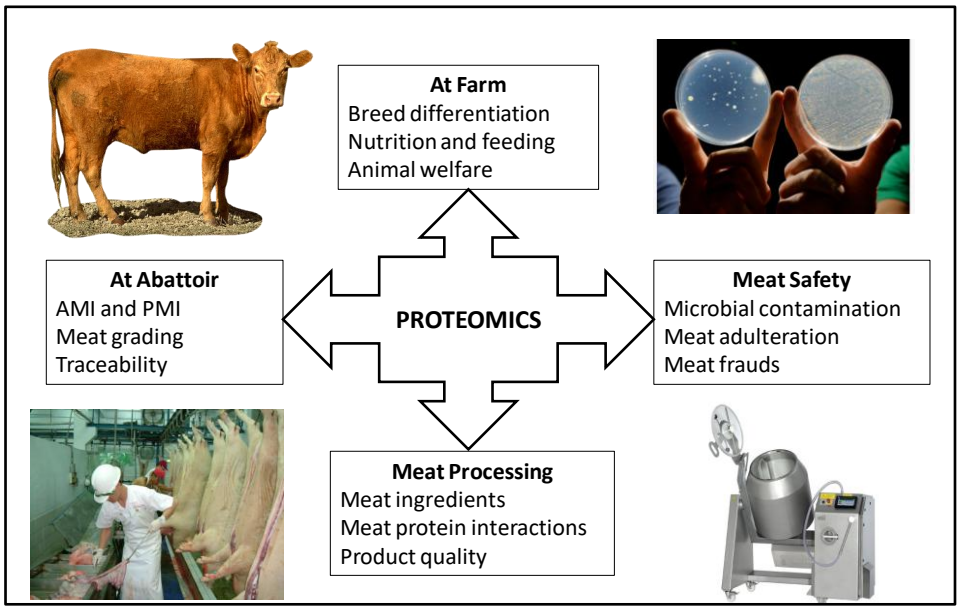


Fig. 1 Schematic representation of the use of proteomics in meat science

Proteomic characterization of meat colour

Myoglobin (Mb) is a sarcoplasmic heme protein primarily responsible for meat color and its chemistry is species specific. 4-hydroxy-2-nonenal (HNE) is a cytotoxic lipid derived aldehyde detected in meat and was reported to covalently adduct with nucleophilic histidine residues of Mb and predispose it to greater oxidation (Faustman et al., 2000). We characterized the Mb extracted from water buffalo and goat cardiac muscles using two-dimensional gel electrophoresis (2DE), OFFGEL electrophoresis and mass spectrometry (MS). Purified buffalo and goat Mb samples revealed a molecular mass of 17,043.6 and 16,899.9 Daltons, respectively. The 2DE analysis exhibited 65 (sarcoplasmic protein extract) and 6 (pure Mb) differentially expressed protein spots between buffalo and goat samples. In-vitro incubation of HNE with bright red buffalo and goat oxymyoglobin's at pH 7.4 and 37 °C resulted in pronounced oxidation and formation of brown metmyoglobin. MALDI-TOF MS analysis of Mb-HNE reaction mix revealed covalent binding (via Michael addition) of 3 and 5 molecules of HNE with buffalo and goat Oxy-Mb's, respectively.

ESI-QTOF MS/MS identified seven and nine histidine (HIS) residues of Mb that were readily adducted by HNE in buffalo and goat, respectively (Naveena et al., 2016).

Understanding tenderness variability and ageing changes

Proteomic tools were extensively used to unravel the meat texture and variation in meat quality from different meat animal species. Our laboratory at NRC on Meat, Hyderabad has characterized the biochemical basis for understanding the variation between different muscles, age group and ageing periods. Our study on characterizing proteome profile of *Longissimus dorsi* muscle between buffaloes (*Bubalus bubalis*) of different age groups (young vs. old) has revealed higher myofibrillar and total protein extractability, muscle fibre diameter, and Warner-Bratzler shear force (WBSF) values in old buffalo meat relative to meat from young buffaloes. Proteomic characterization using two-dimensional gel electrophoresis (2DE) found 93 differentially expressed proteins between old and young buffalo meat. Proteome analysis using 2DE revealed 191 and 95 differentially expressed protein spots after 6 days of ageing in young and old buffalo meat, respectively. The MALDI-TOF/TOF analysis of selected gel spots helped in identifying molecular markers of tenderness mainly consisting of structural proteins (Kiran et al., 2016). In another study we have unravelled the variation in meat quality between tender (*Psoas major*, PM) and less tender (*Longissimus lumborum*, LL) muscles of Indian water buffaloes (*Bubalus bubalis*). Higher muscle fibre diameter and Warner-Bratzler shear force was observed in LL, whereas higher water holding capacity and myofibrillar protein extractability was observed in PM. Proteome analysis using 2-DE revealed 123 differentially abundant proteins in PM and LL (Figure 2). The MALDI TOF-TOF MS analysis of selected protein spots from LL and PM with significant differences identified the proteins mainly consisting of Calcium transporting ATPase (Kiran et al., 2015).

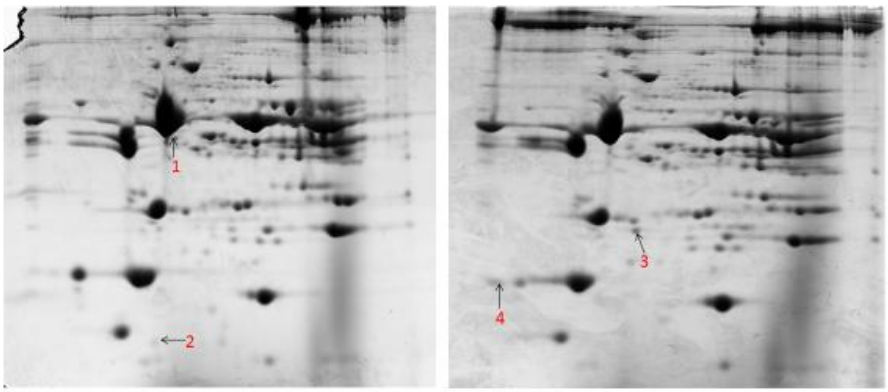


Fig. 2 Total proteins from LL and PM muscles of water buffaloes separated through 2-dimensional gel electrophoresis

Authentication of meat species using proteomic technologies

Proteomic-based method by utilizing the species-specific peptide biomarkers capable of providing information about the meat species has been reported by Sentandreu et al., (2010) and few other researchers. We developed the proteomic-based technology using in-gel (two-dimensional gel electrophoresis, 2DE) and OFFGEL-electrophoresis for authentication of meat species from three closely related ruminant species viz, water buffalo, sheep and goat in both raw and cooked conditions. The MALDI-TOF/TOF MS analysis of proteins separated using 2DE or OFFGEL electrophoresis delineated species-specific peptide biomarkers derived from myosin light chain 1 and 2 (MLC1 and MLC2) of buffalo, sheep and goat meat mix in different proportions that were found stable to resist thermal processing. The 2DE and tandem mass spectrometry based in-gel method can detect up to 1.0 per cent substitution of sheep and goat meat in buffalo meat, whereas OFFGEL electrophoresis and tandem MS approach can detect even up to 0.1 per cent substitution of sheep and goat meat in buffalo meat (Figure 3). The effectiveness of OFFGEL electrophoresis over in-gel based method is its efficiency to concentrate and enrich the low abundant proteins mainly originating from myosin light chain 1 and 2. We demonstrated the accuracy and robustness of OFFGEL-based method over 2DE based in-gel approach. The aforesaid technology envisages the robustness of high throughput proteomic approach coupled with OFFGEL electrophoresis as an alternative to other existing methods for meat speciation and pave the way for future requirements of food safety and authenticity (Naveena et al., 2016; Naveena et al., 2017).

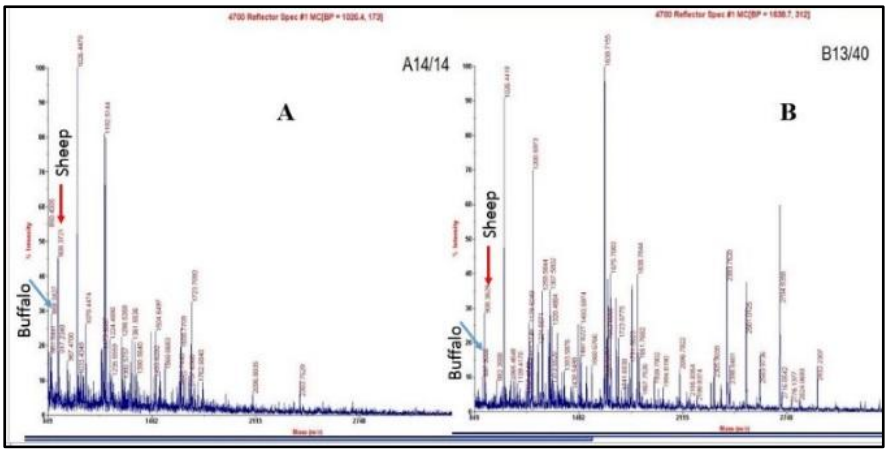


Fig. 3 MALDI-TOF MS spectrum of sheep and buffalo meat-specific peptides derived from myosin light chain-2; A-Raw and B-Cooked.

Halal meat authentication through proteomic approach

One common aspect of commercial halal meat production is the slaughter of animals without stunning which is accepted by many organizations around the world, yet it remains extremely controversial from an animal welfare standpoint of view (Grandin, 2017). In general, slaughter of food animals with stunning is referred as humane slaughter, whereas in conventional slaughtering methods viz, Halal and Kosher, stunning of animals before bleeding is not followed in several countries even though stunning before slaughter is a statutory requirement to make the animal unconscious and insensible to pain from the act of bleeding (Terlouw et al., 2008). We hypothesised that, in addition to various physiological changes the electrophoretic mobility of some important proteins will be altered due to pre-slaughter stress which may result in up-regulation or down-regulation and will prompt us to identify the new biomarkers from meat indicating welfare of the animal before slaughtering. Hence, we conducted a study to unravel the effects of pre-slaughter electrical stunning on bleeding efficiency, serum biochemical parameters, physico-chemical quality and understand proteomic changes in Nellore cross-bred sheep.

We subjected Nellore crossbred male sheep to either pre-slaughter electrical stunning followed by slaughter (ST) or traditional halal slaughter without stunning (NST). Higher pH, water holding capacity and Warner-Bratzler shear force was observed in meat from stunned sheep. Quantitative proteomic approach using DIGE was employed to find a panel of protein markers that could differentiate ST and NST muscle proteome. Comparison of muscle proteome of ST and NST samples by 2D-

DIGE and MALDI-TOF/TOF MS analysis revealed 46 significant differentially expressed proteins. Our analysis revealed changes in the abundance of proteins involved in catalytic, structural, and stress related process. Variation in the abundance of cytoskeletal proteins viz, myosin, actin and troponin was seen between ST and NST sample. Peroxiredoxin-6, a potential marker of tenderness in meat was detected in NST samples (Naveena *et al.*, 2019).

Application of Phytoextracts in Meat Processing

Rajesh V. Wagh, O. P. Malav, Nitin Mehta and Pavan Kumar
Department of Livestock Products Technology, College of Veterinary Science, GADVASU, Ludhiana, Punjab

Till date the primary concern of the food industry has been to produce and provide the safe food to the consumer. Although safety is of paramount importance, nutritional and caloric composition of foods is becoming equally important as in the case of functional foods. The food to be considered as a "functional food" which should provide health benefits beyond basic nutrition. Currently 'functional foods' are defined as those that in addition to act as nutrients may positively affect specific biological functions, improving our general state of health and/or reducing the risk of suffering distinct diseases (Zhang *et al*, 2010). Keeping this aspect in mind, nowadays, the efforts are being made towards the development of ''healthier'' products i.e. functional meat products through modifying composition and/or processing conditions to prevent or limit the presence of certain potentially harmful compounds, and/or explore the possibility of inclusion of certain desirable substances, either naturally or by external addition, with the aim to have subsequent added benefits to health.

Addition of ingredients from plant sources in meat products thus can be an approach towards conferring functional characteristics. Plant materials are the good source of several bioactive ingredients including dietary fibre, phenolic compounds and other natural phytochemicals that are acting as antioxidants. Phenolic compounds, one of the most widely occurring groups of phytochemicals, are of considerable importance since these compounds exhibit a wide range of physiological properties, such as anti-allergenic, anti-artherogenic, anti-inflammatory, anti-microbial, antioxidant, anti-thrombotic, cardioprotective and vasodilatory effects. Moreover, these compounds have been associated with the health benefits derived from the consumption of high levels of fruits and vegetables (Shan *et al*, 2005). The beneficial effects derived from phenolic compounds have been attributed to their antioxidant activity. Phenolic compounds could be a major determinant of antioxidant potentials of foods and could therefore be a natural source of antioxidants. Major groups of chemicals present in plant extracts include polyphenols, quinones, flavanols/ flavanoids, alkaloids, and lectins. Thus the addition of plant bioactive ingredients in

meat products can supply several healthful ingredients like dietary fibre, antioxidants and other bio-active ingredients. On the other hand, this approach will help to avoid the use of synthetic additives that have been widely used in the meat industry which are nowadays considered as harmful one.

Phyto-ingredients:

According to the WHO, a medicinal plant is any plant which, in one or more of its organs, contains substances that can be used for therapeutic purposes, or which are precursors for chemo-pharmaceutical semi synthesis. These non-nutrient plant chemical compounds or bioactive components are often referred to as phytoingredients/phytochemicals ('phyto-' from Greek - *phyto* meaning 'plant') or phytoconstituents and are responsible for protecting the plant against microbial infections or infestations by pests (Dorman et al, 2000). Such a plant will have its parts including leaves, roots, rhizomes, stems, barks, flowers, fruits, grains or seeds, employed in the control or treatment of a disease condition and therefore contains chemical components that are medically active. (Shan et al, 2005). Research on the health-promoting and disease-preventing potential of phytochemicals in foods have grown so much in recent years that this branch of research has been named bionutrition. The study of natural products on the other hand is called phytochemistry.

Important properties of Phyto-ingredients:

- ✓ Substrate for biochemical reactions
- ✓ Cofactors of enzymatic reactions
- ✓ Inhibitors of enzymatic reactions
- ✓ Absorbents that bind to & eliminate undesirable constituent
- ✓ Scavengers of reactive or toxic chemicals
- ✓ Enhance the absorption and / or stability of essential nutrients
- ✓ Selective growth factor & Fermentation substrate for beneficial bacteria

Phenolic Compounds in Plants:

Phenolic compounds are a group of chemical compounds that are widely distributed in nature. They are simple compounds present in most fresh fruits and vegetables, or complex compounds present in bark, roots and leaves of plants. A group of polyphenols, responsible for the color of many fruits, vegetables, and flowers, are known as anthocyanins. of phenolic compounds**.**

1. **Caretonoids:**

Carotenoids are fat soluble compounds that are associated with the lipidic fractions. From a chemicalpoint of view, carotenoids are polyisoprenoid compounds and can be divided into two main groups:(a) carotenes or hydrocarbon carotenoids only composed of carbon and hydrogen atoms and (b) xanthophylls that are oxygenated hydrocarbon derivatives that contain at least one oxygen function such as hydroxy, keto, epoxy, methoxy or carboxylic acid groups. A family of pigmented compounds that are synthesized by plants and microorganisms but not animals. In plants, they contribute to the photosynthetic machinery and protect them against photo-damage. (Botsoglou et al, 2003) Precursors to vitamin A : Provitamin A. Carotenoids with molecules containing oxygen, such as lutein and Zeaxanthin, are known as Xanthophyll's.

The un-oxygenated (oxygen free) carotenoids such as α-carotene, β-carotene and lycopene are known as carotenes.Their structural characteristic is a conjugated double bondsystem, which influences their chemical, biochemical and physical properties. This class of natural pigments occurs widely in Nature. Carotenoids are synthesized by plants and many microorganisms, so animals have to obtain them from food. Up to now, more than 600 carotenoids have been isolated from natural sources (Pfander, 1987). They are responsible for the beautiful colors of many birds, insects and marine animals, as well as the colors of many flowers and fruits (Carotenature, 2000). This attribute is of great importance in foods, since color is often a criterion of quality and is typically modified by food processing (Chen et al., 1995). In addition, carotenoid content in fruits and vegetables depends on several factors such as, genetic variety, maturity, postharvest storage, processing and preparation.

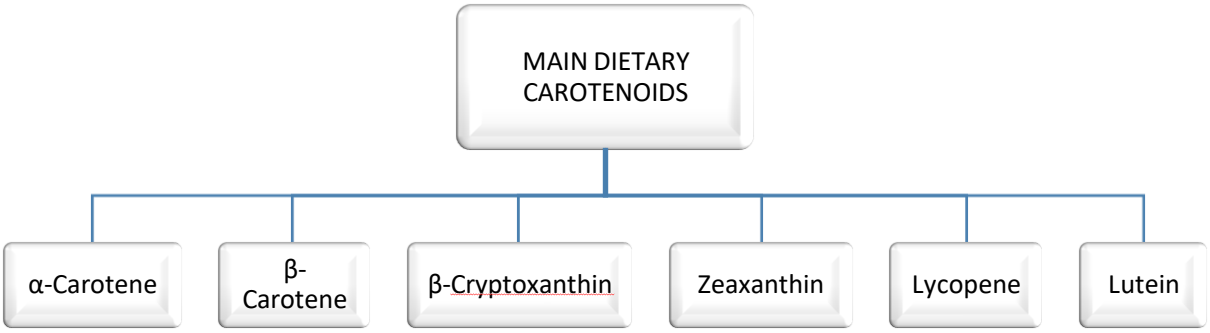
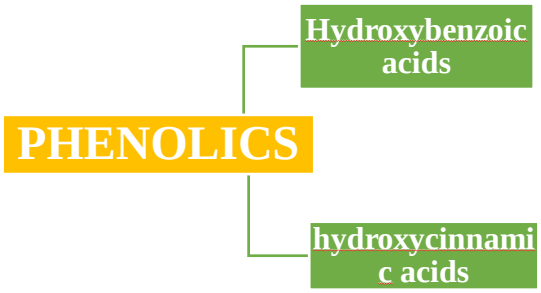


Diagram No: 1.Classification of Carotenoids (Source: Boudet A.M. 2007)

2. **Phenolic Acids:**

Hydroxybenzoic and hydroxycinnamic acids are predominant phenolic acids found in plants. Differences between their derivatives consist in the different patterns of hydroxylations and methoxylations of their aromatic rings.



Hydroxybenzoic Acids:

Hydroxybenzoic acids have a general structure of C6-C1 (Figure 1a). Hydroxybenzoic acids are commonly present in bound form. They are components of complex structures such as hydrolyzable tannins and lignins. Hydroxybenzoic acids are also found in the form of sugar derivatives.

Hydroxycinnamic Acids:

Hydroxycinnamic acids are also commonly found in foods of plant origin. *p*-Coumaric, caffeic, ferulic and sinapic acids are major hydroxycinnamic acids found in fruits. Among these, caffeic acid is the predominant hydroxycinnamic acid in many fruits. Caffeic acid represents over 75% of the total hydroxycinnamic acids in fruits. Caffeic acid has been found in plums, apples, apricots, blueberries and tomatoes. Hydroxycinnamic acids are mainly present in bound form and are rarely found in free form. Hydroxycinnamic acids usually occur in various conjugated forms. The conjugated forms are esters of hydroxyacids such as quinic, shikimic and tartaric acid,

and their sugar derivatives. The free hydroxycinnamic acids can be released from chemical or enzymatic hydrolysis during tissue extraction (Naczk *et al,2004*).

3. Flavonoids:

Flavonoids represent the most common and widely distributed group of plant phenolics. Their common structure (C6-C3-C6) consists of two aromatic rings (A ring

Subclass	Compounds	Color	Food Sources
Anthocyanidins	Cyanidin, Delphinidin, Malvidin, Pelargonidin, Peonidin, Petunidin	Blue, Red, Violet	Berries (blueberries, Red grapes, Strawberries)
Flavanols	Catechin, Epicatechin, Gallocatechin, Epicatechin gallate, Epigallocatechin gallate, Theaflavins, Thearubigins	Colorless Yellow	Apples, Tea, Beer
Flavanones	Hesperetin, Naringenin, Eriodictyol,	Colorless Pale Yellow	Citrus fruits Oranges, Grapefruit
Flavonols	Quercetin, Kaempferol, Myricetin, Isorhamnetin	Pale Yellow	Onions, Broccoli, Kale, Apple, Tea, Buckwheat
Flavones	Apigenin, Luteolin	Pale Yellow	Herbs, Parsley, Thyme, Celery
Isoflavones	Daidzein, Genistein, Glycitein	Colorless	Legumes (soybeans), soybean products (tofu, soymilk)

Yao et al., 2004, Plant Foods for Human Nutrition, 59:113-122.

and B ring) linked through a three carbon bridge that is usually an oxygenated heterocycle (C ring). Figure 2 shows the basic structure and the system used for the carbon numbering of the flavonoid nucleus. The major flavonoid classes include anthocyanidins, chalcones, flavanols, flavanones, flavones, flavonol, and isoflavones. The variability of the flavonoids is based on the hydroxylation of the pyrone ring, absence or presence of double bond, the number of hydroxyls in the A ring and B ring, and/or a double bonded oxygen atom attached to position 4 of the C ring. Flavonoids may be monomeric, dimeric, or oligomeric. Polymeric flavonoids, known as tannins, are divided into two groups, condensed and hydrolysable. Condensed tannins are polymers of flavonoids while hydrolysable tannins contain gallic acid.

Imporatant charactestics of Flavonoids:

- Anti atherosclerotic effects
- Anti platelet aggregation
- Anti thrombogenic effects
- Anti ulcer effect
- Anti viral effects: Herpes simplex virus, respiratory syncytial virus, Para influenza virus, and adenovirus
- Anti inflammatory effects
- Anti Arthritis effects: Uncooked berries, fruits
- Anti osteoporotic effects: Green Tea
- Antidiarrheal effects: Cocoa beans

Flavonoids are naturally occuring phenolic compounds which largely include anthoxanthins (flavones, flavonols, flavanones, flavanols, chalcones and isoflavones), anthocyanins, leucoxanthins and flavonoidal alkaloids (Houghton, 2002). These compounds are found in a variety of plant materials (Kong *et al*., 2003). It is well known that flavonoids possess antioxidant properties *in vitro* and *in vivo*. The flavonoids contain a number of phenolic hydroxyl groups attached to ring structures, which confer the antioxidant activity. Catechins and their epimers serve as powerful antioxidants for directly eliminating superoxide anion radicals (Chen and Chan, 1996). Proanthocyanidins from grape seeds are apparently responsible for the action on the cardiovascular system (Pekié *et al*., 1997). Kaempferol 3-O-α-rhamnoside from *Licania licaniaeflora* exhibited DPPH radical scavenging activity and quercetin derivatives from this plant showed strong antiradical activity (Braca *et al*., 2002). Epicatechin, epigallocatechin, epicatechin gallate and procyanidin B1 and B2 from grape seed extract showed strong DPPH radical scavenging activity (Guendez *et al*., 2005).

4. Stilbenes:

These are the non-flavonoid phenolics that occur in a number of plant families, including Moraceae, Paeoniaceae, Myrtaceae, Fagaceae, Celastraceae, Dipterocarpaceae, Leguminosae etc. Present in peanut, berries, dark chocolate, grapes and wine, which are its main sources in diet (Simitzis et al, 2008). However, only a few stilbenes are present in the human diet. Grape and wine main dietary source of stilbenes, resveratrol and piceid being the most common ones. Antioxidant, antibacterial, antifungal, cardioprotective, neuroprotective, antiaging and anticancer among others (Guerrero et al., 2009). Furthermore, trans-resveratrol increases stress resistance and lifespan in some organisms. Piceatannol shows pronounced antioxidant activity, as well as high bioactivity, showing anti-leukemic and anti-tumourigenic activities. Oligomers have been shown to have hepatoprotective and antioxidant properties, and to induce apoptosis of leukaemia B-cells(Guerrero et al., 2009).

5. Coumarins:

Coumarins is a fragrant organic chemical compound which is a colorless crystalline substance in its standard state. Found naturally in many plants, notably in high concentration in the tonka bean, vanilla grass, sweet woodruff, mullein, sweet grass, cassia cinnamon and sweet clover. Coumarins have shown some evidence of many biological activities, although they are approved for few medical uses as

pharmaceuticals. (Velioglu et al,1998) Anti-HIV, anti-tumor, anti-hypertension, anti-arrhythmia, anti-inflammatory, anti-osteoporosis, antiseptic, and analgesic (pain relief) & also used in the treatment of asthma.

6. Tannin :

These are the phenolic plant secondary compounds and are widely distributed through the plant kingdom. Polymeric flavonoids, known as tannins, are divided into two groups, condensed and hydrolysable. Dietary supplementation of tannin leads to various health benefits in animal production. Food items with tannins: Persimmons fruits, Berries like such cranberries and blueberries contain both hydrolyzable and condensed tannins. Nuts like hazelnuts, walnuts, and pecans Chocolate liquor contains about 6% tannins Exert various health benefits role like antioxidant, antiviral and antistress factor

Strategies for extraction of active principal component from plants:

Extraction of phenolic compounds in plant materials is influenced by their chemical nature, the extraction method employed, sample particle size, storage time and conditions, as well as presence of interfering substances (Naczk and Shahidi, 2004). The chemical nature of plant phenolics vary from simple to highly polymerized substances that include varying proportions of phenolic acids, phenylpropanoids, anthocyanins and tannins, among others. They may also exist as complexes with carbohydrates, proteins and other plant components; some high-molecularweight phenolics and their complexes may be quite insoluble. Therefore, phenolic extracts of plant materials are always a mixture of different classes of phenolics that are soluble in the olvent system used. Additional steps may be required for the removal of unwanted phenolics and non-phenolic substances such as waxes, fats, terpenes and chlorophylls. Solid phase extraction (SPE) techniques and fractionation based on acidity

are commonly used to remove unwanted phenolics and non-phenolic substances. Solubility of phenolic compounds is governed by the type of solvent (polarity) used, degree of polymerization of phenolics, as well as interaction of phenolics with other food constituents

and formation of insoluble complexes. Therefore, there is no uniform or completely satisfactory procedure that is suitable for extraction of all phenolics or a specific class

of phenolic substances in plant materials. Methanol, ethanol, acetone, water, ethyl acetate and, to a lesser extent, propanol, dimethylformamide, and their combinations are frequently

used for the extraction of phenolics

Choice of solvents:

- In particular, methanol has been generally found to be more efficient in extraction of lower molecular weight polyphenols while the higher molecular weight flavanols are better extracted with aqueous acetone.
- Ethanol is another good solvent for polyphenol extraction and is safe for human consumption.
- In preparing anthocyanin-rich phenolic extracts from plant materials, an acidified organic solvent, most commonly methanol or ethanol, is used. (Boudet , 2007)

Extraction Methods: Following are the most used methods for the extraction of Phyto extract from plant sources. (Naczk and Shahidi, 2004).

- ✓ Traditional Solvent Extraction (TSE)
- ✓ Microwave-Assisted Solvent Extraction (MSE)
- ✓ Supercritical Fluid Treatment (SFE)
- ✓ Subcritical water extraction (SWE),
- ✓ Pressurized fluid extraction (PFE)
- ✓ Accelerated solvent extraction (ASE)
- ✓ Ultrasound-assisted extraction (UAE)

Mode of application of Phytochemical extract into meat products:

- **Dietary supplementation:** Dietary supplementation of Vit E and tea catechins is very commonly used to improve the meat quality.
- **Direct addition to the product:** Most of the Phyto-extract whether in the form of extracts, powders or any other form are added directly in the formulation.
- **Spraying:** The Phyto-extract directly or their active principle are sprayed over the surface of the meat.
- **Active package:** It is another method without direct addition of the active agents to the product. Zhang W, (2010) described the promising results of a new antioxidant active packaging system; a plastic film with an embodied

rosemary extract was able to inhibit both myoglobin and lipid oxidation in beef, leading to enhanced display life of meat. Generally hypothesis of mechanism postulated is inactivation of free radicals by either migration of antioxidant molecules from the active film to the meat or scavenging of those oxidant molecules from the meat onto the active film. Simitzis et al, (2008) demonstrated that active films incorporated with oregano reacted with headspace free radicals and increased the display life of lamb and other meats. However, the legal regulatory status of active packs is so far not clear and needs to be specifically addressed.

- **Marination:** Various marinades according to consumer's acceptance are being incorporated with antioxidants such as turmeric rhizomes, tamarind, lemon grass etc.
- **Application of phyto ingredients in the development of functional meat products**

In meat and meat products the main cause of their quality loss is the Lipid oxidation (apart from microbial spoilage). A large number of compounds are generated during the oxidation processes which adversely affect texture, color, flavor, nutritive value and safety of meat products (Lahucky et al., 2010) and this limits the shelf-life of meat (Karakaya et al., 2011). To prevent or interruption these oxidation processes antioxidants can be applied. Although synthetic antioxidants have been applied to meat and meat products but in recent years their use has been discouraged because of their toxic effects and consumer interest in natural products. This has led the meat industry to search new economical and effective natural antioxidants that can replace synthetic antioxidants without adversely affecting the quality of finished products and consumer perceptions (Karre et al., 2013). Plant extracts have been used as natural antioxidants in meat and meat products by several authors (Table)

Ayo et al. (2007) reported 560 mg GAE/100 g in frankfurters with 25% added walnuts, while López-López et al. (2009) reported 820 mg GAE/100 g in a meat emulsion containing 5.6% of dried wakame seaweed. The phenolic compounds from cranberries, plums and walnuts could provide benefits because they provide for the elimination of free radicals (superoxide and hydrogen peroxide), possess anti-in-flammatory properties and inhibit lipid and protein peroxidation (Cunningham et al., 2004; Kim et al., 2003). Cao et al. (2013) studied the effect of 1% or 0.5% chitosan

(CHI), 10% or 5% aqueous extract of ginger, onion and garlic (GOG) and their composite solutions (mix 1 = 1% CHI + 10% GOG, mix 2 = 0.5% CHI + 5% GOG) on quality and shelf life of stewed-pork. pH, total volatile basic nitrogen (TVB-N), peroxide value (PV), 2-thiobarbituric acid (TBA) and sensory characteristics were analyzed periodically during refrigerated storage at 4 °C for 12 days. CHI and/or GOG treatments retarded the increases in pH, TVB-N, PV and TBA. CHI showed weaker antioxidant activity than GOG. Composite treatment had positive effect while the high concentration of composite solution (mix 1) had adverse effect on odor and overall acceptance.

Hayes et al. (2011) applied lutein (200 μg/g meat), sesamol (250 μg/g meat), ellagic acid (300 μg/g meat) and olive leaf extract (200 μg/g meat) in fresh and cooked pork sausages stored in aerobic or modified atmosphere packages (MAP). Addition of sesamol, ellagic acid and olive leaf extract reduced (P b 0.001) lipid oxidation in all packaged raw and cooked pork sausages. Antioxidant potency followed the order: sesamol 250 N ellagic acid 300 N olive leaf extract 200 N lutein 200 for both raw and cooked pork sausages. Meat treated with lutein, sesamol, ellagic acid and olive leaf extract had no detrimental effect on pH, cooking losses, tenderness, juiciness, texture or product flavor (Hayes et al., 2011). Banerjee et al. (2012) investigated the effect of broccoli powder extract (BPE) in goat meat nuggets at three different concentrations 1, 1.5 and 2% and compared with control and BHT (100 ppm). Addition of 1.5 and 2% BPE decreased (P b 0.05) the pH value of the meat nuggets. Total phenolics in product with 2% BPE was similar to BHT nuggets. Chroma value of products with 1.5 and 2% BPE was lower (P b 0.05) than control and BHT nuggets. TBARS value of BPE nuggets was lower (P b 0.05) than control throughout the storage (Banerjee et al., 2012). Antioxidant activities of 70% ethanolic extracts of ten leafy green vegetables were determined and applied in raw beef patties. The extracts and BHT (positive control) were separately added to patties at 0.1% and 0.5% (w/w) concentrations and the patties were stored at 4 °C for 12 days. The addition of extracts and BHT resulted in concentration dependent decreases in TBARS values in the beef patties and also improved meat color stability. The fatsia extract had more effective antioxidant than the chamnamul (Kim, Cho, et al., 2013). In another study, the antioxidant efficacy of 70% ethanol and water extract of 10 leafy edible plants was evaluated in ground beef patties. Plant extracts (butterbur and broccoli extracts) and BHT were separately added to the patties at 0.1% and 0.5%

(w/w) concentrations and stored at refrigerated conditions for 12 days. TBARS values were significantly lower ($P \leq 0.05$) in the samples containing plant extracts or BHT than the non-treated control. In addition, the beef patties formulated with the selected plant extracts showed signifi- cantly ($P \leq 0.05$) better color stability than those without antioxidants (Kim, Min, et al., 2013).

Table: Plant sources used as natural antioxidants in meat and meat products

Natural sources	Scientific name	Dose in meat	Meat type	Effect on oxidation	References
Oregano + sage leaves	*Rosmarinus officinalis*	0.2% w/w each	Chicken breast and thigh	SDL	Sampaio et al., (2012)
Black currant extracts	*Ribes nigrum*	5, 10 or 20 g/kg	Pork patties	SDLP	Jia et al (2012)
Rosemary extract	*Rosmarinus officinalis*	200 ppm	Pork patties	SDL	Nissen et al. (2004)
Rosemary extracts	*Rosmarinus officinalis*	0.1%	Porcine liver patties	SDP	Estevez et al., (2006)
Rosemary extracts	*Rosmarinus officinalis*	250, 500, 750 mg/kg	Porcine liver patties	SDL	Doolaege et al. (2012)
Herbal extracts (Marjoram, sage)	*Origanum majorana, Salvia officinalis*	0.04% v/w	Ground beef	SDL	Mohameda, et al., (2011)
Broccoli leaf extract	*Brassica oleracea*	0.1% and 0.5% w/w	Ground beef patties	SDL	Kim et al., (2013)
Curry leaf extracts (Murrayakoenigii L.) Mint leaf extract (Menthaspicata)	*Murraya koenigii, Mentha spicata*	5 mL extract/500 g	Pork meat	SDL	Biswas etal., (2012)
Grape seed extract	*Vitis vinifera*	0.1%	Mutton slices	SDL	Reddy et al. (2013)
Grape seed extracts	*Vitis vinifera var. Monastrell*	1.0%	Cooked beef	SDL	Ahna et al., (2007)
Grape seed extracts	*Vitis vinifera*	400 and 1000 µg/g	Pork patties	SDL	Carpenter et al., (2007)
Pine bark extracts	*Pinus maritima*	1.0%	Cooked beef	SDL	Ahna et al., (2007)
Avocado seed extract	*Persea americana*	50 g extracts/700 g	Porcine patties	SDLP	Rodriguez-et al., (2011)
Butterbur leaf extract	*Petasites hybridus*	0.1% and 0.5% w/w	Ground beef patties	SDL	Kim, Cho, et al. (2013)
Broccoli powder extracts	*Brassica oleracea*	1.5 and 2%	Goat meat nugget	SDL	Banerjee et al. (2012)
Cocoa leaf extract	*Theobroma cacao*	200 mg/kg	Deboned Chicken meat	SDL	Hassan and Fan (2005)
Green tea leaf extract	*Camellia sinensis*	200 mg/kg	Deboned Chicken meat	SDL	Hassan and Fan (2005)
Ginkgo biloba leaf extract	*Adiantum species*	0.05%	Meat dumplings	SDL	Kobus-Cisowska, et al., (2010)

Hypericum perforatum L. extract	*Hypericum perforatum L.*	0.0005% 0.001%	Pork meat	SDL	Sanchez-Muniz et al. (2012)
Rosemary	*Rosmarinus officinalis*	0.1%-0.3%	beef meatballs	SDL	Fernandez-Lopez et al. (2003)
Nettle	*Urtica dioica*	10%	beef patties	SDL	Akarpat et al. (2008), Alp and Aksu (2010)
Pomegranate peel extract (PPE)	*Punica granatum*	250 mg/kg	ground beef	SDL	Tayel and El-Tras (2012)
Ginger(Ginger rhizomes)	*Zingiber officinale*	500 ppm	beef patties	SDL	Mansour and Khalil (2000)
Mint	*Mentha spicata*	0.1%	Radiation processed lamb meat	SDL	Kanatt et al. (2007), Kanatt, Chander, and Sharma (2008)
White peony extract	*Radix Paeoniae Alba*	0.5–2%	Raw and cooked goat meat patties	SDL	Han and Rhee (2005)
Nettle extract	*Urtica dioica L.*	300, 600 ppm	Sucuk (lamb meat)	SDL	Karabacak and Bozkurt (2008)
Carob fruit extracts (Liposterine and Exxenterol)	*Ceratonia siliqua L.*	3 g/ 100 g	Cooked pork	SDL	Bastida et al. (2009)
Cinnamon stick extract	*Cinnamomum verum*	100 mL/25 g	Aerobically packaged raw pork	SDL	Shan et al. (2009)
Nettle extract	*Urtica dioica*	200, 500 ppm	Ground beef	SDL	Alp and Aksu (2010)
Kinnow rind extract	*Citrus reticulata*	10 mL/500 g	Cooked goat meat patties	SDL	Devatkal et al. (2010)
Olive leaf extract		100, 200 μg/g meat	Raw beef patties	SDL	Hayes et al., (2010)
Pomegranate peel extract	*Punica granatum*	1%	Ground goat meat and nuggets	SDLP	Devatkal et al. (2012)
Ginger, onion, garlic extract	*Zingiber officinale, Allium cepa, Allium sativum*	5, 10%	Stewed pork	SDL	Cao et al. (2013)
Rosemary leaf extract (Carnosic acid)	*Rosmarinus officinalis*	22.5 ppm, 130 ppm	Raw and cooked ground buffalo meat patties	SDL	Naveena et al. (2013)
grape seed and Acacia catechu	*Vitis vinifera & Acacia catechu*	0.10%	Pork Frankfurters	SDL	Wagh R. V. et al 2015
green tea	*Camellia sinensis*	0.03%	Pork Frankfurters	SDL	Wagh R. V. et al 2015

Sea buckthorn seeds		0.3 %	Pork patties	SDL	Kumar et al., 2015

- SDL = significantly decrease lipid oxidation, SDP = significantly decrease protein oxidation, SDPL = significantly decrease lipid and protein oxidation.

Conclusion:

Natural compounds enjoy positive consumer image and have application in development of novel functional healthy meat products. Antioxidants are nature's defense against the damaging effects of free radicals for health and to extend shelf life of food products. Still there is various natures' gift for the mankind need to be explored. Phyto-ingredients are an excellent source of natural antioxidants that can improve meat shelf-life and quality mainly by retarding lipid oxidation and microbial growth. Functional food development is a multi stage process that requires input from commercial, researcher scientist and regulatory interest, with a critical need to achieve acceptance by consumers. Development of function meat products can be successfully achieved with the help of such novel Phyto-ingredients. This area has great potential to expand in a near future due to the increased consumer desire to improve health through food.

Applications of Artificial Intelligence in Quality Meat Production and Processing

Amandeep Singh, Parkash Singh Brar, Nitin Mehta and Gurpreet Kour
Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana, Punjab, India 141004.

Introduction

Whenever there is surge in population, the need for sustaining the population increases. The first need which comes to mind is food. With increase in population, there is need to shift paradigms to smarter food production and processing methods. The smarter methods shall be competent to make optimal use of land, water, labour, energy and other production resources. One of such smarter technique is Artificial Intelligence i.e. AI. Thinking about livestock sector, AI has always been a buzz word when expanded to artificial insemination. But with change of times and progress in technology, the time has come that stakeholder involved in livestock sector must know about other major abbreviation of AI i.e. Artificial Intelligence. AI has the potential to revolutionize livestock sector through its various applications like machine learning, deep learning, natural language processing, artificial neural networks, cloud computing, blockchain technology, internet of things, precision farming, sensor based systems, robotics, so on and so forth. It is also said that AI will give birth to 'fourth industrial revolution' on the planet and it will be a digital revolution. We might have heard about robots long back, but do we know it is also an application of artificial intelligence? On the other extreme lies the information technology which can be called as mother of AI. The multidimensional approaches sprouting from IT leads to the development of ICT i.e. Information & Communication Technologies. So, there are various subsets of technologies which are present in livestock domain as well. According to NASSCOM (2017), the present share of AI in case of Agriculture and Allied Sectors in India is only 5 per cent but it is estimated that by 2030, it will be doubled. There are so many ways by which AI can be used for farmers like development of learning simulations for the farmers who want to switch to livestock farming, deriving algorithms for ascertaining the animal production, deriving algorithms to understand the pattern and the amount of losses due to animal diseases and mortality, development of AI-Based Livestock Expert Systems, AI based

meat production and processing systems, camera based meat scoring systems, intelligent body scoring, etc. Although, AI has both pros and cons but it is also a true saying that robots cannot replace humans. Humans are blessed with the power of creativity which will always be lacking in robots. In this chapter, we will be discussing the major applications of AI in meat production and processing. This chapter will give only a brief and elementary description of the AI used in various studies related to meat production and processing. For more detailed information a reader is advised to address the literature specialized in description and mathematical concepts of AI.

Let's Understand Some Terms

- Artificial learning (AL) is a specific field of computer engineering that focuses on creating systems capable of gathering data and making decisions and solving problems.
- Artificial intelligence (AI) is usually defined as the science of making computers do things that require intelligence when done by humans.
- Machine learning (ML) is the process by which an AI uses algorithms to perform artificial intelligence functions.
- Deep learning (DL) is what happens when a neural network gets to work, as the layer process data, the AI gains a basic understanding.
- Natural language processing (NLP) is the process when an AI is trained to interpret human communication. E.g. chatbots like Alexa and Siri.
- Transfer learning or inductive transfer is a research problem in machine learning that focuses on storing knowledge gained while solving one problem and applying it to a different but related problem.
- Turing test was developed by Alan Turing in 1950, is a test of a machine's ability to exhibit intelligent behaviour equivalent to, or indistinguishable from, that of a human.
- Big data usually includes data sets with sizes beyond the ability of commonly used software tools to capture, curate, manage, and process data within a tolerable elapsed time.
- Internet of things (IoT) is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors,

actuators and connectivity which enables these objects to connect and exchange data.

- Cloud computing is an information technology (IT) paradigm that enables ubiquitous access to shared pools of configurable system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the internet.

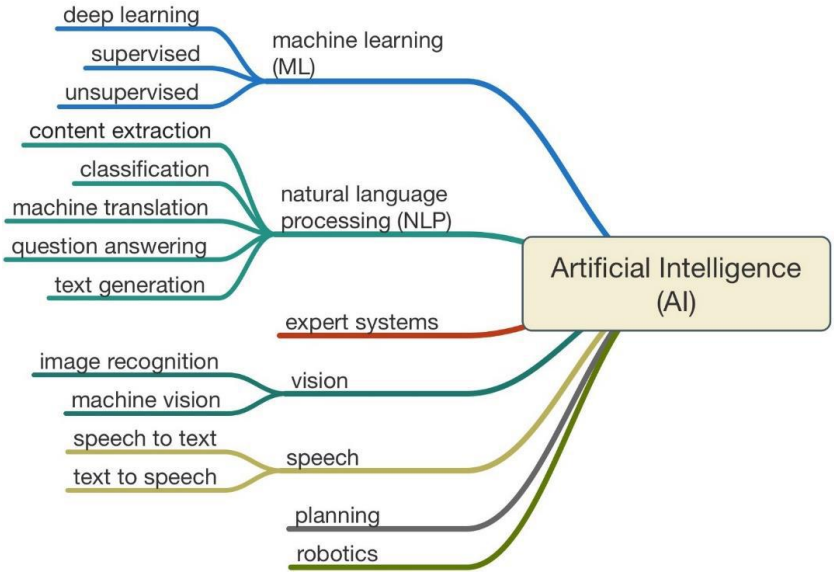


Figure 1: Different fields of artificial intelligence

Sector-wise Breakup of Artificial Intelligence in India

In South-Asia, China dominates the AI market, however the present day government is opening doors for new start-ups in this sector. Government of India has allocated $480 million to promote artificial intelligence, machine learning and IoT in the country, but India badly lags behind its neighbouring country China. Nearly 14.42 per cent and 85.58 per cent of research is done by the industry and universities respectively on artificial intelligence. As per Scopus Analysis, about 70 per cent of the AI research is at non-Indian companies' headquartered in India. Google and IBM have published almost 62 per cent of all industry research publications, while there is only one Indian company in the top 10 – TCS with 13 per cent of all publications (Sinha, 2018).

In terms of the number of engineers graduating every year, India is among the top countries. But sadly, the engineering talent in India is largely focused on IT and not research and innovation. The Scopus analysis shows that, out of 129 deemed universities, 67 public institutions, 700 degree-granting institutions, 35,539 affiliated

colleges, there are only 15 universities that contribute to almost 42 per cent of all research publications. IIT Kharagpur, the research hub of the Indian IT sector contributes to just 2.86 per cent of research publication related to the subject which according to Scopus Analysis, India's research is not matching the world's trend. The country produced less than 600 papers on AI in 2016, which is likely due to the complexity of research and lack of financial support from the government but an exponential growth in Computer Vision research. Additionally, the average citation of a top researcher in the world and Indian researcher in India is almost same (Sinha, 2018).

According to a report by National Software and Services Association (NASSCOM, 2017), the retail sector of the country employs highest number of start-ups related to AI. The agriculture sector on which 48 per cent of our population depends have market share of only 5 per cent. The following pie-chart shows the per cent share of the sectors in India related to AI ventures.

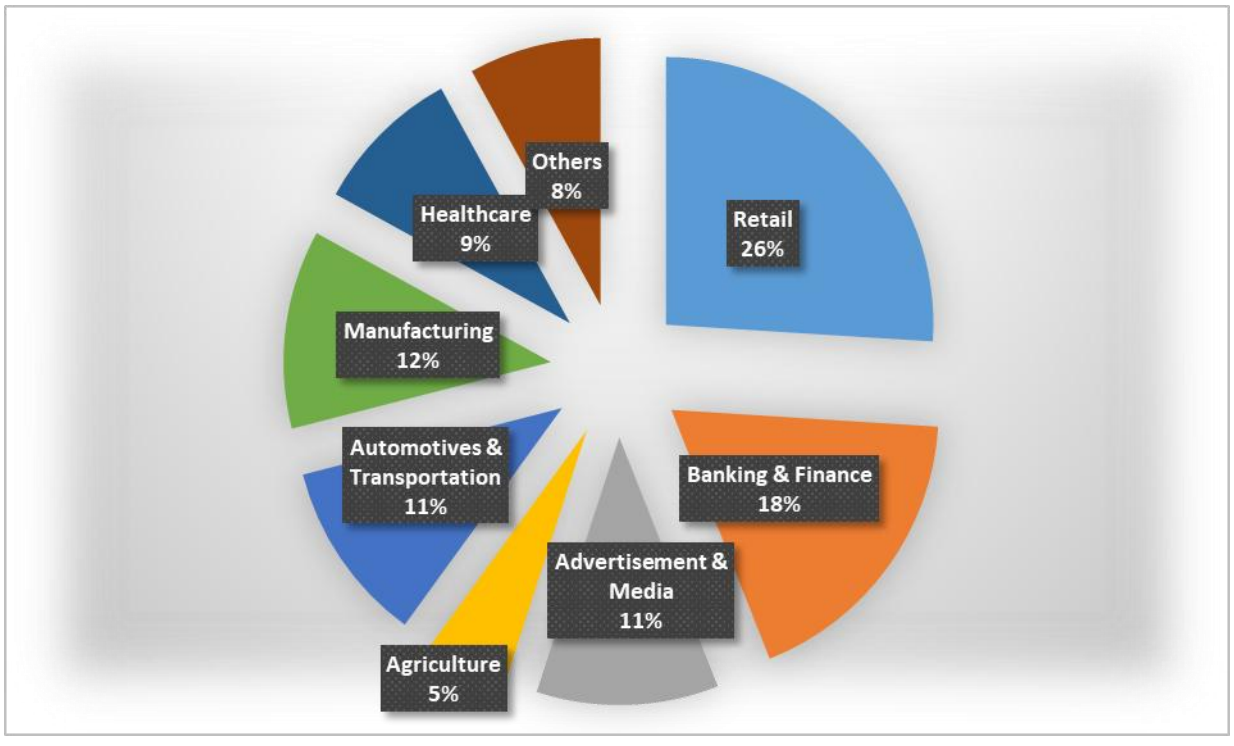


Figure 2: Sector wise breakup of Artificial Intelligence in India (Source: NASSCOM, 2017)

Challenges for AI Development in India

Vempati (2016) has commented that AI-based applications to date have been driven largely by the private sector and have been focused primarily in consumer goods. The emergent scale and implications of the technology make it imperative for policymakers in government to take notice. India should consider early lessons of AI success in the United States, China, South Korea, and elsewhere offer public and private funding models. The sequential system of education and work is outdated in today's economic environment as the nature of jobs shifts rapidly and skills become valuable and obsolete in a matter of years. Therefore, India needs to build plethora of skills based on AI for the young demographic resource of India. All the mentioned challenges can be overcome by adopting a policy based on extension of AI among all the sectors of the country through a national policy or national mission. Familiarity of students in early years of education and upgrading the skills of IT professionals can tackle these challenges.

Novel Methods for Ascertaining Meat Quality

Meat quality is a very complex term and it comprises various aspects which can differ according to the user's standpoint *i.e.* different factors or properties are important for producer, meat processor or consumer. From the animal production perspective the quality mainly refers to lean meat content on which the payment to the farmer is based. Processing industry on the other hand is interested in meat technological quality (suitability for further processing) and factors affecting consumer's choice. The consumer is sensitive about meat appearance (colour, lean to fat ratio), its sensory quality, nutritional value (macro and micro nutrients) and safety (presence/absence of toxic compounds, drugs, and pathogen or spoilage micro flora). Other factors like the way meat is produced (animal welfare, ecology) can also affect consumer's choice. In meat production and processing, different properties can play an important role in quality classification of meat for different purposes or can be critically appraised by consumers (often their basis for meat selection or rejection). In pork for example, water-holding capacity of meat has big significance, whereas in beef, tenderness is an important attribute. Spoilage detection or meat shelf-life is also an important issue in meat sector. In the last decades, the methods used in meat evaluation, meat quality control, or inspection have undergone important developments with the application of novel technologies like computer (machine) vision, spectral imaging, spectroscopy, electronic nose or bio-sensing technologies.

As far as AI is concerned, it is catching the attention of businesses across many disciplines and sectors with Food Processing and Handling (FP&H) being one of them. Today, the FP&H industry is capped at a whopping $100 billion and will continue to grow at a CAGR of 5% at least till 2021.

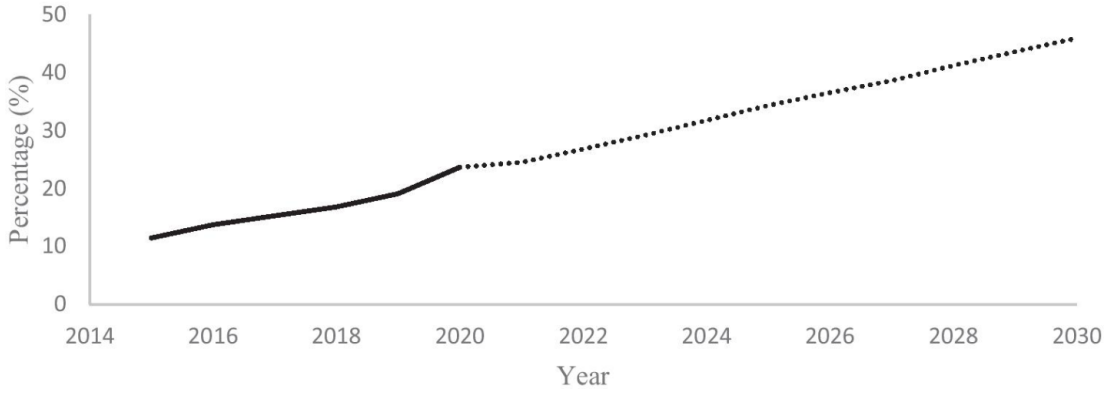


Figure 3: Line chart highlighting the application of AI in food industry

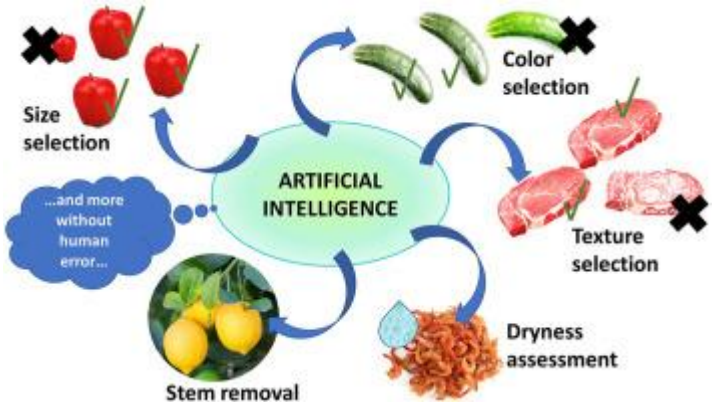


Figure 4: Applications of Artificial Intelligence in Food Production and Processing

Major Applications of AI in Meat Production & Processing

However, AI is used at an increasing rate in food industry but for meat sector, the application can be categorized into following types:

1. Meat Sorting
2. Meat Packaging
3. Food Safety Compliance
4. Maintaining Cleanliness
5. Developing Products
6. Helping Customers with Decision Making

The comprehensive explanation regarding the same are provided hereunder.

Robotic Hide Puller

Robotic hide puller is a new addition to meat industry which is based on the principle of automation, artificial intelligence and reduction of human touch. This machine as the name suggests, is used to remove hides from the body of slaughtered animals in a downward pulling motion. It pulls the hide from the tail area down along the back and finally over the head. The main operations of the machine are controlled using metered hydraulic pedals. Automatic hide puller is equipped with stainless steel stand with built-in apron washes, knives/whizzers, sterilizers, drip trays and drainage system. It reduces the human touch and enhance the quality of meat. The principle of clean meat production can be actuated using automatic hide puller. As of now, hide pullers are operated using electricity whereas research is underway to reduce the power consumption. The machine is made up of rust-resistant GI steel. Further, the motion cameras and intelligent cameras analyse the quality of meat and ensure safe consumption.

E-Nose or E-Tongue

Electronic nose or electronic tongue is also known as electronic sensing or e-sensing. It is a complex array of sensors which are linked to create a detection system for taste, odour and flavours. An e-nose or e-tongue is combination of gas sensors or chemical sensors which mimics human nose or human tongue. Gas sensor arrays are defined as ‘electronic nose (e-nose),’ while chemical sensor arrays are referred to as ‘electronic tongue (e-tongue)’ (Orlandi et al., 2019). Depending on the sensing materials, gas sensors can be classified into several types including, conducting polymers (CP), metal-oxide semiconductor (MOS), quartz crystal microbalance (QCM), and surface acoustic wave (SAW) sensors.The chemical sensors commonly employed for an e-tongue include electrochemical sensors, biosensors, and optical mass sensors.Typically, rapid sensing can be achieved by those sensor arrays, and the price of a sensor array is relatively lower than the standard analytical equipment, such as gas chromatography–mass spectrometry (GC–MS), laser scatting analyzer, and high-performance liquid chromatography (HPLC). Sensor arrays have broad applications in determining food quality-related properties, such as sensory attributes, microbiological properties, and processing quality (Matindoust et al., 2016). Those applications are achieved with the help of sensor arrays combined with corresponding data pattern recognition approaches and classification algorithms. The data collected

after using these sensors can be analysed for ascertaining meat quality through artificial neural networks.

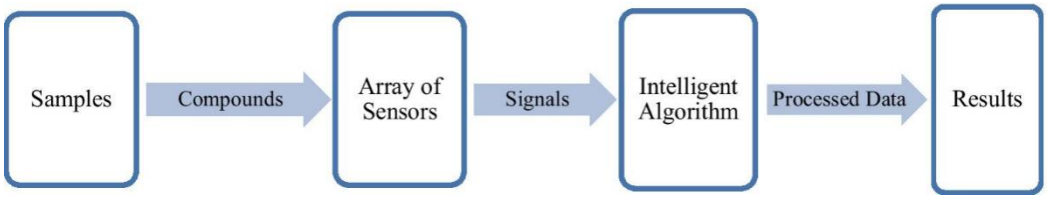


Figure 5: Line diagram of electronic sensor based meat evaluation

Smart Packaging

Officially called the AMP Cortex system, the robot is nicknamed Clarke, named after science fiction author and futurist Sir Arthur C. Clarke. Cortex system is comprised of a camera, much like the one on a typical smartphone, to scan materials as they pass through a conveyor belt on the recycling line. It uses AI that learns from experience to be able to identify the thousands of food and beverage cartons from the other materials on the line. Cortex is also able to identify the different kinds of carton packaging, from knowing the difference between gable-top and aseptic cartons to being able to differentiate a broth or almond milk carton to knowing a package is not a carton and should therefore not be sorted with them. In fact, Cortex has learned to identify more than 150 carton variations and is constantly learning more (Brown & Horowitz, 2017).

Production of Minced Meat Using Process Control Computer (PCC)

Modern trends in the development of meat processing equipment include the use of highly precise methods for meat raw material analysis and high-calibre control of raw meat processing. In the traditional technology for minced meat production, using batch-operated technological units, finished product quality, to a large extent, depends on the operator. The new technology, realised on the proposed automatic line, envisages complete automation of the technological process with the use of the PCC which is an Intelligent Control System (ICS); that is, control is conducted according to the principle of an unmanned operation based on artificial intelligence (Figure 1). This will allow finished products of guaranteed high quality to be obtained by computer control both of each technological operation and the whole technological process in realtime (Kapovsky et al., 2017).

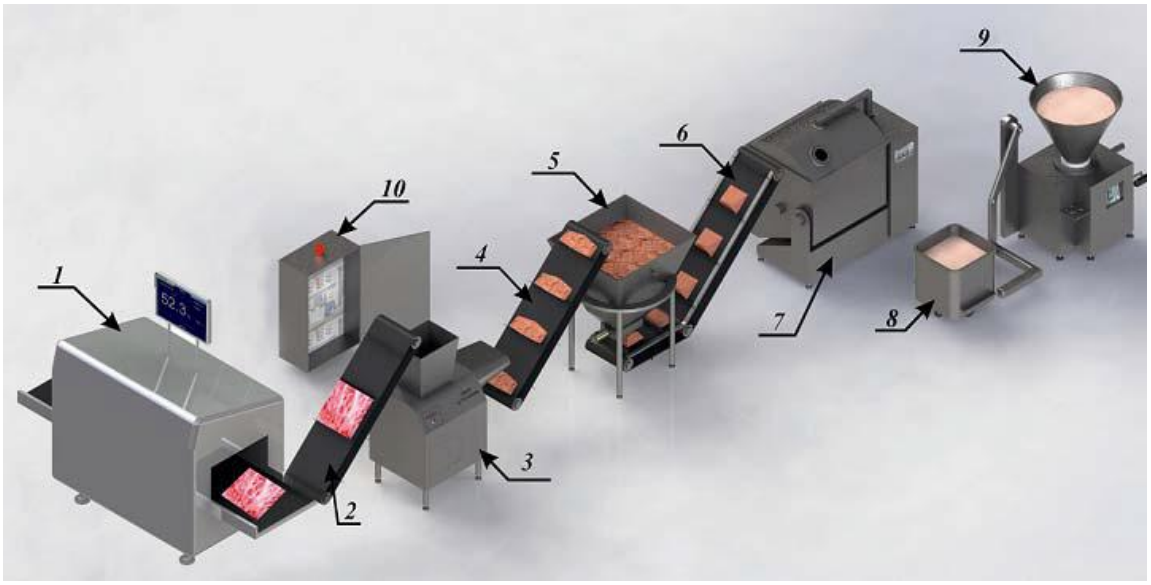


Figure 6: Design of the automatic line for minced meat production: 1 – input control unit for processed raw material; 2, 4, 6 – conveyers; 3 – milling cutter; 5 – hopper for minced raw material; 7 – minced meat mixer; 8 – elevator with a buggy; 9 – stuffer; 10 – process control computer (PCC).

Meat Quality Evaluation using Computer Vision

Imaging technique or computer vision (CV) technology has received huge attention as a rapid and non-destructive technique throughout the world for measuring quality attributes of agricultural products including meat and meat products. Computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. The application of computer vision in the industry, where information is extracted for the purpose of supporting a manufacturing process, is called machine vision. Like ultrasonography provides the reflection signature about the inner structure of the medium, similarly computer vision provides details about the meat structure. Classical methods of meat quality assessment, however, have some disadvantages like they are expensive and time-consuming, whereas CV has several advantages over the traditional methods. It is non-destructive, easy, and quick, hence, more efficient in meat quality assessments. In CV, spectral imaging or spectral analysis is done based on the principle component of meat color i.e. myoglobin. The CV presents the color simulation results of meat samples based on data on the content of various forms of myoglobin in different proportions after subsequent analysis.

Even pictures taken from a simple camera can be analysed for ascertaining meat quality. After standardization and calibration of CV for meat quality, the prediction accuracy can be increased for meat color, pH, DL, crude protein and ash content of the sample.

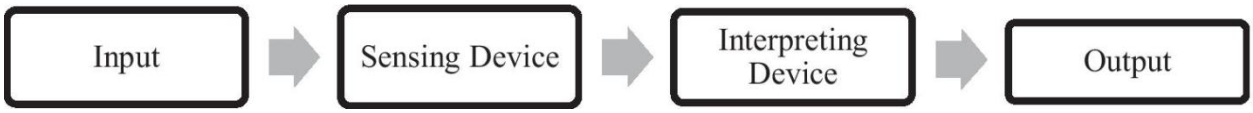


Figure 7: Working diagram of computer vision system

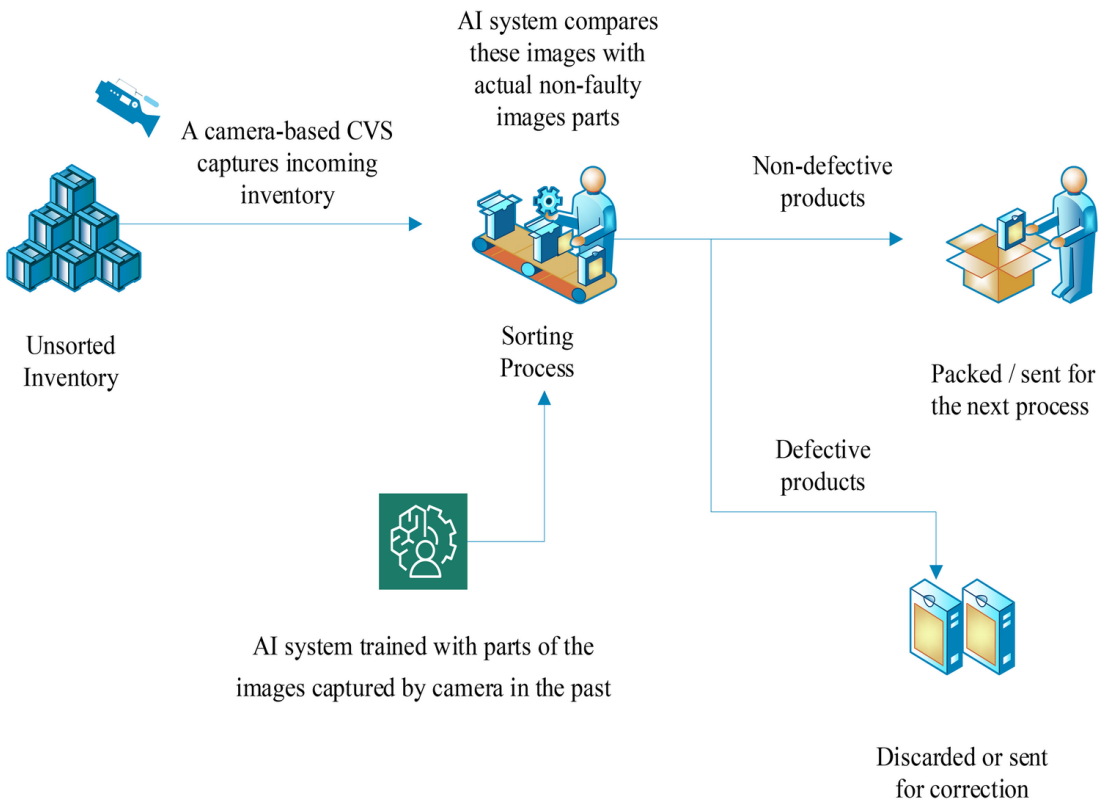


Figure 8: Computer vision based quality control process

Near Infra-Red Spectroscopy for Meat Freshness

Increasing concerns about adulterated meat encouraged industry looking for new non-invasive methods for rapid accurate meat quality assessment. Main meat chromophores (myoglobin, oxy-myoglobin, fat, water, collagen) are characterized by close comparable absorption in visible to near-infrared (NIR) spectral region. Therefore, structural and compositional variations in meat may lead to relative differences in the absorption of light. Utilizing typical fiber-optic probes and integrating sphere, the degradation of meat samples freshness can be observed at room temperature referring to the relative changes in absorbance of main meat

chromophores. The data obtained after NIRS can be subjected to principal component analysis (PCA) for obtaining the stage of freshness which is not observed by the conventional analysis of the reflectance spectra. This approach is highly precise for assessing meat quality and monitoring relative absorbance alternation of oxymyoglobin and myoglobin in visible, and fat, water, collagen in NIR spectral ranges (Peyvasteh et al., 2020). As far as PCA is concerned, PCA is an advanced analysis technique for reducing the dimensionality of datasets which increase interpretability but at the same time minimizing information loss. It does so by creating new uncorrelated variables that successively maximize variance (Jolliffe and Cadima, 2016).

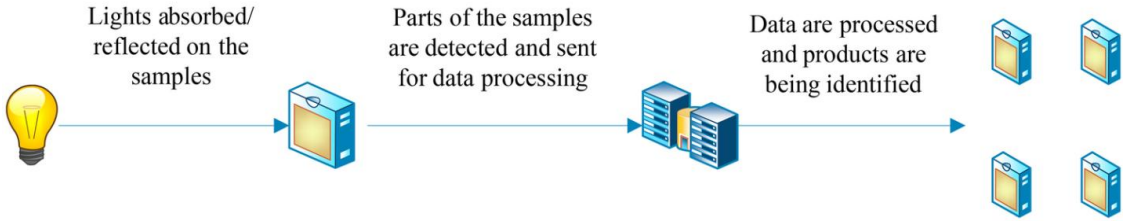


Figure 9: Basic working principle of NIRS

Bio-sensing Technology

The meat industry associated with the health hazards like deadly pathogens, veterinary drugs, pesticide residues, toxins and heavy metals is in need of a tool to tackle the awful situation and ensure safer product to consumer. The growth in the industry, global trade scenario, stringent laws and consumer awareness has placed an extra onus on the meat industry to meet out the expectations and demands. Biosensors are the latest tool of detection in the fast growing industries including the food industry (Singh et al., 2016).Biosensors can be defined as an analytical device, which converts a biological response into an electrical signal and consists of two main components: a bioreceptor or biorecognition element, which recognizes the target analyte and a transducer, which converts the recognition event into a measurable electrical signal (Velusamy et al. 2010). Bio-sensing technology combines a sensitive biological element (e.g. enzymes, microorganisms, antibodies, *etc*.) with a physicochemical detector of an analyte (optical, piezoelectric, and electrochemical). The physicochemical detector transforms the interaction of the analyte with the biological element into a signal which can be measured and quantified. The results are

displayed in a user-friendly way. Biosensors are rapid method of meat quality assessment and can be used for bulk meat testing.

AI Based Meat Sorter

Untill the end of 20th Century, when meat was sorted by human touch in developed countries as well is now shifted to AI based solution. Unlike other food sorting machines which only sort poor quality fruits and veggies from the good ones, AI Based Meat Sorter, uses X-ray, NIR (Near Infra-Red) spectroscopy, LASER, cameras and a unique machine-learning algorithm to analyze different aspects of a meat package for sorting. Both quality and quantity of meat is ascertained with this feature. The anomalies in meat are also detected and the samples having anomalies are sorted out.

CNN based Meat Identification

The Convolutional Neural Network (CNN) is a popular deep learning tool, which has been used widely in classification problems. The most significant advantage of CNN is its automatic learning ability from an input image without feature extraction, but CNN requires a larger image data set to train the model from the scratch (Krizhevsky et al., 2017). CNN can be used in identification of meat cuts, meats of different species, fresh/spoiled meat, marbling, etc. In 2016, the Google^{TM} Brain team released a new deep learning neural network open-source software package called TensorFlow (Abadi et al., 2016). This free, open-source deep learning algorithm library provides an effective, fast, and accurate source of artificial intelligence for industry applications by which CNN can be used.

Ascertaining Carcass Quality or Classification

Meat industry is interested in lean and conformed carcasses which provide high meat yields. The so called carcass grading or classification (used for pig, bovine, lamb carcasses) is performed at the end of the slaughter line and represents a basis for the payment to the farmer. Another example is in poultry, where the carcasses are inspected at the slaughter line for the wholesomeness and those with an abnormal aspect (tumorous, bruised, skin-torn, septicemic, cadaver, air-sacculitis) are discarded. The mentioned procedures are mostly based on the visual appraisal and thus subjected to human limitations (speed, error, fatigue). This can be achieved by the use of convolutional neural networks wherein by the use of image analysis, one can ascertain the carcass quality and also classify carcass on various grades. Even the computer vision can also be used in this context.

Spoilage Identification/Storage Time Assessment

Meat and meat products are highly susceptible to spoilage or contamination, affecting the quality and safety of the products. Many of the methods used for the detection of spoiled or contaminated meat are based on immunological or nucleic acid based procedures which are time consuming, laborious and demand trained personnel. At present no method is available for a real-time, non-destructive, reagentless, quantitative and relatively inexpensive monitoring. According to Ellis & Goodacre (2001) interesting analytical approaches include biosensors, electronic noses, infrared spectroscopy upgraded with machine learning methods like ANN, CNN, etc.

AI Based Cameras for Food Safety Compliance

Safety is a massive concern in the meat processing business. Even the smallest contamination in meat can to widespread consequences. Although traditions HACCP systems have reduced the contamination of meat at a larger scale but the accountability is questioned when a product exits a production line and enters a retail or a food chain. To ascertain the food safety at factories, eateries and restaurants, AI-based cameras have been installed to detect whether an employee is wearing a proper costume or not. The AI-enabled cameras helped restaurant managers to keep a watch on the restaurant workers as to whether or not they are wearing proper food protection gears as per food safety regulations. It helps them to detect any indiscipline in real-time through alerts on their gadgets.

Intelligent Cleaning Systems

Maintaining cleanliness is a massive concern in meat handling and production factories, slaughter houses, abattoirs, butcheries, etc. Many companies claim to be as clean as ice because their every process automated and untouched by human hands. What if the machines and pieces of equipment are contaminated? Customers have also become intelligent, and they know that having every process automated does not mean the product will be safe to eat. According to the University of Nottingham, equipment cleaning accounts for almost 30 per cent of energy and water supplies of a food processing plant. They claim that their AI-based sensor technology is capable of saving nearly $133 million per year and also save time (by 50%), energy, and water to clean the equipment. Traditional cleaning systems did not include any sensors which resulted in residual of meat particle in vessels of equipment. The system was unable to clean small food particles which the new self-optimizing cleaning system could. It uses optical fluorescence imaging and ultrasonic sensing technologies to deliver data to the

machine learning algorithm, which will help to monitor the microbial debris and food particles in the equipment.

Development of Meat Products

There are hundreds of meat products present in the current times with varied ingredients, processing protocols and likelihood by the customers. One company produces several hundred meat products at a time. There is always uncertainty to maintain the original flavor if humans are involved. AI through machine learning algorithms plays a key role in precisely adding to the ingredients in a meat product, maintaining temperature and conditions for its processing. The customer acceptance can be studied by collecting field based data and then after predictive analytics and deep learning, the companies can increase the supply of certain meat products as per their likelihood and demand. The customers purchasing online can also be studied for developing need-based products. AI assisted market research can help a company to increase its share of profits over a time by development of required products.

Meat Supply Chain Optimization

Algorithms based on Artificial Neural Networks can monitor and check the process of meat delivery and goods tracking at every step, making it safer and providing transparency. A perfect balance is established using ANN for meat supply from the place of production to place of consumption, thus reducing the demand-supply gap. Also, it makes forecasts regarding demand, supply, pricing and inventory, which prevents extra costs.

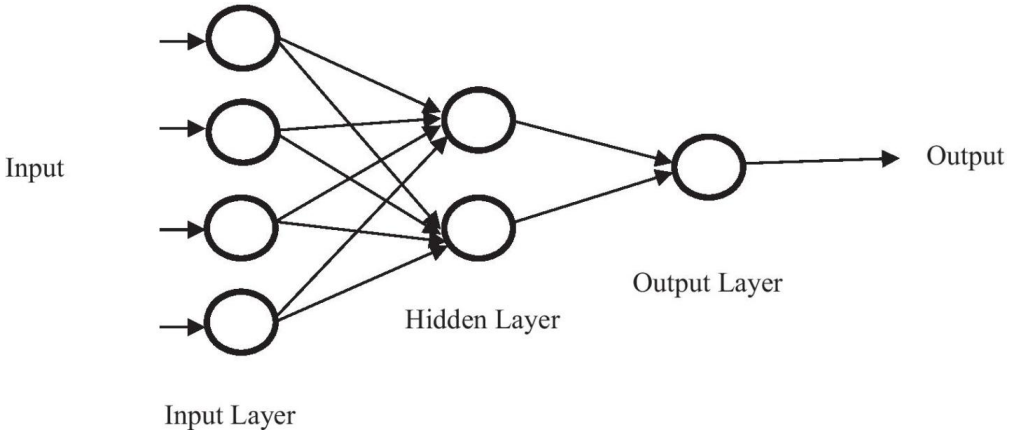


Figure 10: A typical ANN Model

Predictive Maintenance, Remote Monitoring and Condition Monitoring of Meat Plant Equipment

Production and processing of enormous amounts of meat and its products demand large, complicated, and intricately constructed mechanisms. The maintenance of such machines can be rather costly without predictive maintenance – figuring out the time-to-repair and cost-to-repair indicators through categorizing issues and making predictive alerts. Timely repairs can save up to 50 per cent maintenance time and reduce the costs needed for it by almost 10 per cent. To perform remote monitoring on complicated mechanisms, digital twin of the machine can be made that shows the performance data on parameters and manufacturing processes and boost the throughput. Machine Learning also allows the identifications of factors that affect the quality of the manufacturing process with Root Cause Analysis (eliminating the problem at its very source). With condition monitoring, the equipment's health can be monitored in real-time to reach high overall equipment effectiveness (OEE). With condition monitoring the disruption in the production cycle of products can be prevented.

Next Generation Sequencing

Next Generation Sequencing (NGS) could replace DNA methods in the meat safety testing area very soon. Automated processes and workflows make data capturing and the preparation of laboratory samples much faster and more precise than ever. The reason for implementing NGS in organizations like the CDC and the FDA lies in finding out about dangerous trends more quickly. NGS can even prevent some disease outbreaks before they harm masses of people. The data obtained after NGS can be analysed using various application of AI.

Self-Ordering AI-based Kiosks

Artificial Intelligence-based self-ordering machines can contribute to enhanced customer experience by reducing their waiting time, and the need to stand in line for making payment. Such machines can take consumer order, and enable them to make payments directly without human assistance through integrated card readers.

Figure 11: McDonalds self-ordering kiosk

Other AI Based Applications

1. Matching customer tastes with your business strategy
2. Introducing new recipes
3. Analytical solutions for a better customer experience
4. Identification of food-selling sites
5. Meat revenue prediction using deep neural networks
6. AI based food delivery based on best routes
7. Serving robots

Figure 12: Serving robots

AI Based Start-ups in Food Industry

There are many companies and organizations that already incorporate machine learning, deep learning, and AI into food and beverage products and services. Some of the examples are provided hereunder:

1. **Gastrograph AI** uses machine learning and AI to understand consumer's sensory perception of flavor and predict consumer preference of food and beverages (Gastrograph AI About, 2019).
2. **Whisk** uses deep learning and natural language processing to map the world's food ingredients, properties (nutrition, perishability, flavour, categories) and food purchase options in order to provide hyper-relevant advertising and customized personalizations (Whisk FAQ, 2019).
3. **Tastry** uses AI, machine learning, analytical chemistry, flavor preferences to provide consumer product recommendations. The company provides retailers with science-based suggestions for product development, inventory purchase and direct-to-consumer recommendation (Tastry Press, 2018).
4. **Edamam** uses natural language processing for extraction of food entities from unstructured text in order to provide nutritional analysis (Edamam Developer Documentation, 2019).
5. **Pingwell** is exploring the use of computer vision and machine learning algorithms to deliver the contextual information to consumers and retailers in the grocery/pharmacy space (Pingwell, 2019).
6. **Sure** is applying natural language processing and machine learning to better understand user's needs and navigate them to the right businesses in the overcrowded food scene (Sure Blog, 2016).
7. **Instacart** uses machine learning to predict real-time availability of grocery items. It also uses machine learning, representation learning and image similarity search to sort items for users to "buy again" and recommend items for users while they shop (Instacart Blog, 2018).

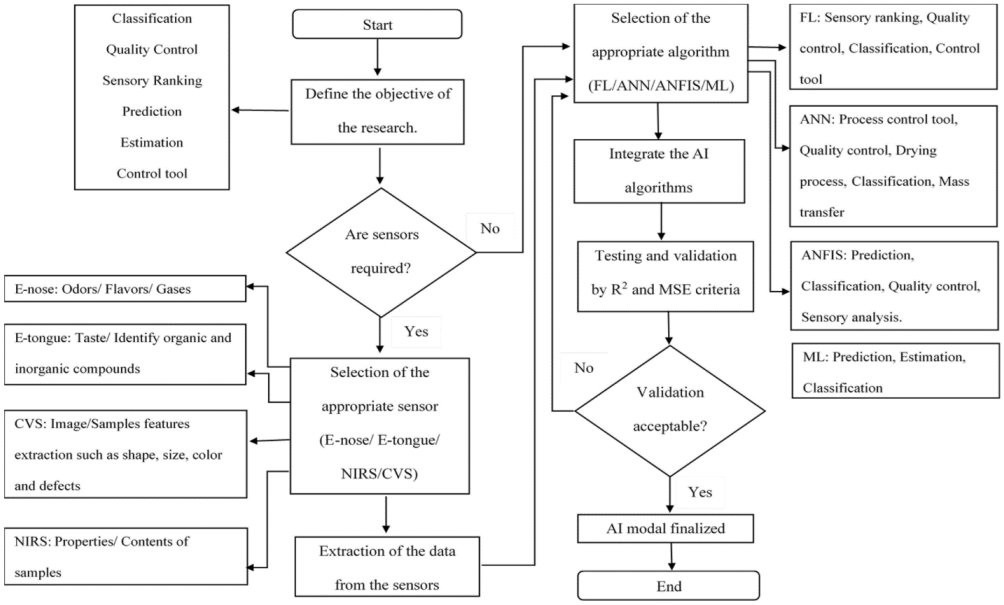


Figure 13: Flowchart for developing AI based model

Conclusion

Despite being at its initial stage, AI is reshaping the meat production and processing handling business. In upcoming years it is going to revolutionize the meat sector forever. AI will help meat-based companies to increase their revenue by speeding up the production process, reducing maintenance time and hence the production downtime, decreasing the chances of failure by automating almost every process and eventually delivering an excellent customer experience by predicting their likes, dislikes, and desires. It will further add-on to enable fewer human errors and less waste of abundant products; lowering costs for storage/delivery and transportation; and creating happier customers, quicker service, voice searching, and more personalized orders. Robotics is still quite a subtle thing to introduce, even for big processing plants, but it will occupy its niche very soon, bringing an obvious benefit in the long run.

Pulsed Electric Field in meat processing

Dr Yogesh K.

Scientist, Livestock Products Technology

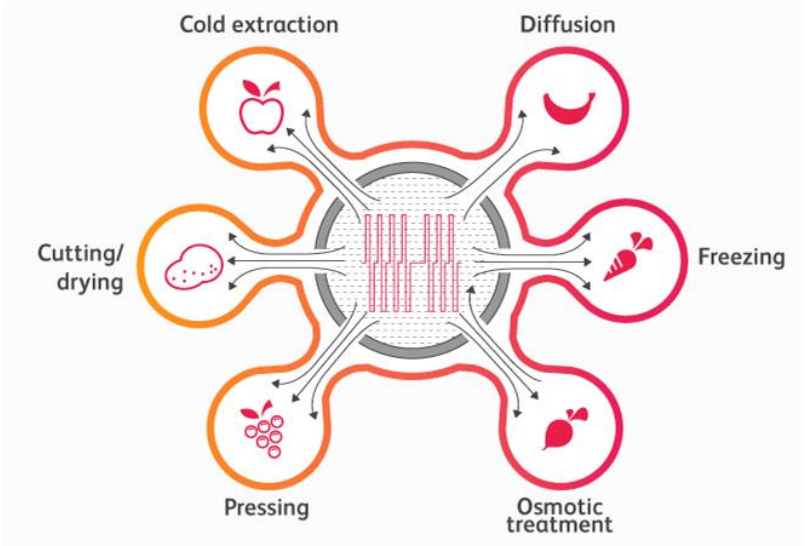
ICAR-CIPHET

The demand for high-quality foods with a marked degree of user convenience is increased. Natural freshness and flavour are highly valued, particularly in foods that are ready-to-eat and thermo-sensitive. The food manufacturer will have to try to meet consumer preferences in order to maintain their sustainability in profit. These have helped to determine the need for more hygienic means of producing primary products and improved hygiene during processing. Thermal processing results in deterioration of nutritional and sensorial properties of thermosensitive food items. Bioactive compounds, vitamins are destroyed during heat treatment up to a considerable level. Thus, milder processing and preservation treatments are required, and food safety and shelf-life cannot be compromised. It is in this situation that new non-thermal preservation strategies are urgently needed. The pathogenic micro-organisms that are potentially present on fruit and vegetables are presented in Table 1. Many pathogens, including bacteria, parasites and viruses, are involved in outbreaks of food-borne illness that are attributed to fresh fruit and vegetables, and an increasing number of outbreaks associated with fresh produce is being reported. It is clear that the newer consumer demands require different preservation strategies to ensure that the foods in question remain safe and have an acceptable shelf-life. The application of pulsed electric fields is one of the technologies that would be suitable, at least for some of the consumer products considered here.

PEF: background, definition and scope

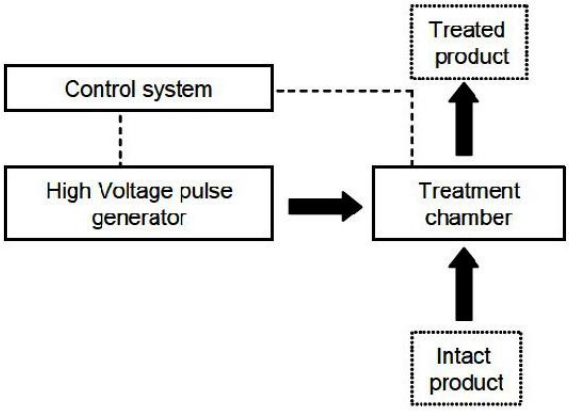
The German engineer Heinz Doevenspeck reported pioneering experiments into the application of pulsed electric fields in food processing, resulting in a patent in 1960 describing the application of pulsed electric fields for disruption of cells in food material to improve phase separation. The technology was conceived almost 100 years ago, but was not pursued seriously until the 1960s. In the 1980s, however, when consumers started to question the quality of canned and other foods preserved by thermal methods, novel preservation technologies gradually received more attention from several research groups. Early results tempted Maxwell Technologies in the USA (through a subsidiary named ‘PurePulse Technologies’) to market PEF

equipment for the preservation of food. However, the inactivation of microorganisms by PEF was more complex than expected and results of pilot plant studies were disappointing and Maxwell closed down PurePulse Technologies in 2002. However, attempting to meet consumer demands in Europe and military requirements in the USA, governments supported further research in collaboration with the food industry. In the Netherlands, a large research and development consortium was established, consisting of several research institutes and R&D departments of multinational food companies. They worked in co-operation with engineers from the High-Voltage Laboratory of the Technological University of Delft, who were to deal with the electrotechnical challenges involved in PEF preservation of food. The project resulted in the development and testing of a fairly large scale pilot plant and the establishment of rules for scale-up to production size. The commercialisation of a PEF pasteurization treatment was achieved in 2005. At present, techniques to employ PEF as a pre-treatment in fruit and vegetable processing and meat processing are in the process of being commercialised.



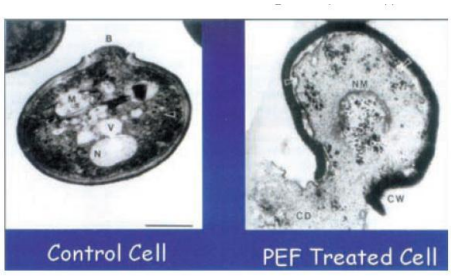
PEF processing involves the application of very short, high-voltage electrical pulses to a food item, which is placed between or passed through two electrodes. Usually, some pulses of 20 – 1000 μs duration with several thousand electric field strength (kV/cm) between some specialized electrodes are required for an effective PEF treatment. PEF is also been applied for pre-treatment of fruit and vegetable tissue prior to extraction, drying or juice winning enhancement of mass transport rates in fish and meat tissue treatment of waste and processing water. Food product held between two electrodes inside a chamber, is capable of transferring electricity because

of the presence of several ions, giving the food product certain degree of electrical conductivity. The applied high voltage results in an electric field that causes microbial inactivation by cellular and molecular damage. In this technique the electric field may be applied in the form of exponentially decaying, square wave, bipolar, or oscillatory pulses at ambient, sub-ambient, or slightly above-ambient temperature. After treatment, food is aseptically packaged and stored under refrigeration.

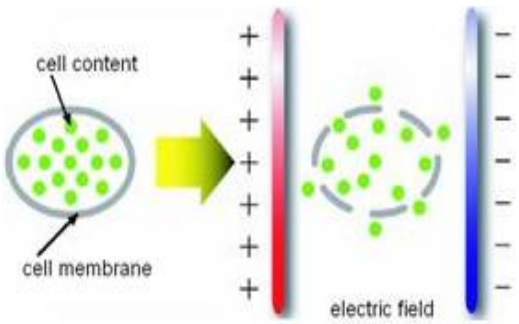


Mechanism of action

Two mechanisms have been proposed for the mode of PEF action on microbial membrane: electroporation and electrical breakdown; however, both mechanisms are in fact referring to a phenomenon starting by electroporation resulting in electrical breakdown by which the cell wall is perforated and cytoplasm contents leak out resulting in cell death. The electroporation theory suggests that the main effect of an electric field on microbial cells is to increase the membrane permeability due to membrane compression and poration, and cell inactivation results from osmotic imbalance across the cell membrane. High electric field leads to dielectric breakdown of the microbial cell membranes as well as interaction with the charged molecules of food. Hence, PEF technology has been suggested for the pasteurization of food such as juices, milk, yogurt, soups, and liquid eggs.



Picture 1 - Comparing a reference cell (Saccharomyces cerevisiae) with a PEF-treated cell, showing the damage to the cell membrane.
Source: Washington State University, Harrison et al 1996



PEF: Efficiency and factors

Factors	Parameters
Treatment parameters	Electric field strength
	Treatment time
	Temperature
	Pulse width
	Pulse shape
Product parameters	Electrical conductivity
	Density
	pH
	water activity
	viscosity
Microbial/Cell parameters	size
	Growth stage
	Gram +ve/-ve

PEF efficiency is directly proportional to Electric field, Pulse duration (pulse width x pulse number) and larger cells easily damaged. Square wave pulses are more efficient than exponential wave and bipolar are more efficient than monopolar wave pulse. If pH and conductivity of medium is more then PEF efficiency is less.

PEF: application with other technologies

The application of non-thermal hurdle combinations has the potential to allow for the production of safe, stable products while also maintaining the desired organoleptic characteristics of a minimally processed product. Palgan et al. (2011) applied non-thermal hurdles such as ultraviolet light (UV) (5.3 J/cm2), high intensity light pulses (HILP) (3.3 J/cm2), PEF (34 kV/cm, 18 Hz, 93 μs) or manothermosonication (MTS) (4 bar, 43°C, 750 W, 20 kHz) to inactivate Escherichia coli and Pichia fermentans inoculated in a fresh blend of apple and cranberry juice. In this study, combinations of non-thermal hurdles consisting of UV or HILP followed by either PEF or MTS resulted in comparable reductions for both microorganisms to those observed in thermally pasteurised samples (approx. 6 log cfu/ml). Thermally pasteurised samples

had a shelf life exceeding 35 days, while that of UV+PEF and HILP+PEF treated samples was 14 and 21 days, respectively. In another study (Munoz et al., 2012), inactivation of Escherichia coli and Listeria innocua by combinations of HILP, Ultrasound (US) and PEF and sub-lethal concentrations of nisin (2.5 mg/L) or lactic acid (500 mg/L) was investigated in two different buffer systems (pH 4 for E. coli and pH 7 for L. innocua). Individually, HILP (3.3 J/cm2), US (126 s residence time, 500 W, 40°C) and PEF (24 kV/cm, 18 Hz and 1 μs of pulse width) did not induce a microbial reduction of greater than 2.7 or 3.6 log units, for L. innocua and E. coli, respectively.

Combined treatment using HILP+PEF sufficiently inactivated E. coli without antimicrobial addition. This confirms the potential of combination of non-thermal technologies for microbial inactivation. Palgan et al. (2012) reported PEF or MTS treatment conditions for inactivation of Listeria innocua in a milk based smoothie. These authors observed combinations of PEF and MTS processing resulted in maximum inactivation effect. Another most important observation of these researchers is the sequence in which the MTS and PEF were applied, as it was found that MTS followed by PEF was the most effective in inactivating L. innocua achieving a mean reduction of 5.6 log cfu/ml, thereby exceeding the 5 log cycles minimum requirement specified by the United States Food and Drug Administration. Significantly lower reductions of 4.2 log cfu/ml were achieved when the PEF+MTS sequence combination was applied. Halpin et al. (2013) reported the efficacy of MTS (20 kHz, 27.9 mm, 225 kPa) at two temperatures (37˚C or 55˚C), before being immediately treated with PEF (32 kV/cm, 10 ms, 320 Hz) in homogenized milk samples and it was observed that milks treated with MTS/PEF at 37˚C and 55˚C contained lower microbial levels than raw milk for a certain duration. Apart from inactivation of micro-organisms, combination of selected non-thermal techniques has

been shown to improve some physico-chemical properties of food products. For example, Caminiti et al. (2011) applied combination of a UV (5.3 J/cm2) or HILP (3.3 J/cm2) in combination with PEF (34 kV/cm, 18 Hz, 93 μs) or MTS (5 bar, 43˚C, 750 W, 20 kHz) on a blend of apple and cranberry juice and observed no significant changes in non-enzymatic browning, total phenolics and antioxidant activity of the juices. UV + PEF and HILP + PEF treatments did not affect the color of the product and HILP + PEF processing retained more monomeric anthocyanins than other combined treatment.

References

Caminiti IM, Noci F, Munoz A, Whyte P, Morgan DJ, Cronin DA, Lyng JG. (2011). Impact of selected combinations of non-thermal processing technologies on the quality of an apple and cranberry juice blend. Food Chem 124(4):1387-1392.

Halpin RM, Cregenzan-Alberti O, Whyte P, Lyng JG, Noci F. (2013). Combined treatment with mild heat, manothermosonication and pulsed electric fields reduces microbial growth in milk. Food Control 34(2):364-371.

Munoz A, Palgan I, Noci F, Cronin DA, Morgan DJ, Whyte P, Lyng JG. (2012). Combinations of selected non-thermal technologies and antimicrobials for microbial inactivation in a buffer system. Food Res Int 47(1):100-105.

Palgan I, Caminiti IM, Munoz A, Noci F, Whyte P, Morgan DJ, Cronin DA, Lyng JG. (2011). Combined effect of selected non-thermal technologies on Escherichia coli and Pichia fermentans inactivation in an apple and cranberry juice blend and on product shelf life. Int J Food Microbiol 151(1):1-6.

Palgan I, Munoz A, Noci F, Whyte P, Morgan DJ, Cronin DA, Lyng JG. (2012). Effectiveness of combined Pulsed Electric Field (PEF) and Manothermosonication (MTS) for the control of Listeria innocua in a smoothie type beverage. Food Control 25(2):621-625.

Avenues and prospects for developing processed meat sector in India

R. Thomas, Senior Scientist

ICAR-National Research Centre on Pig, Rani, Guwahati- 781 131, Assam

Introduction

The livestock sector is poised for revolution in developing countries where the major increase on meat and milk are anticipated. Livestock production is a vital activity in rural areas and has helped to provide employment and income generation for farmers, rural poor and weaker sections. The meat production and consumption has increased remarkably in recent years. The demand for quality meat and meat products is ever increasing due to growing awareness about nutritional and palatability characteristics of meat products as well as a sense of satiety arising from eating. Increasing purchasing power, changing socio-economic status and life stiles have also contributed for the enhanced consumption of processed and convenience meat products.

Meat processing refers to any treatment which brings about substantial physical and chemical changes in the natural state of meat. In broadest sense this includes grinding, curing, smoking cooking, canning freezing, fermentation, dehydration, production of intermediate moisture products and use of certain additives such as seasoning, chemicals and enzymes etc. In processing, properties of fresh meat have been modified, however, the inherent property of "being meat" must remain intact even after processing. Meat technology is the practice of any or all of the applied science that have practical values or industrial use. It is the application of all scientific or modern knowledge for the production of meat in easier methods which include slaughter, processing, transportation, storage and marketing etc. in such a way that has some practical value over traditional way of production. Thus, processing is a part of meat technology.

Importance of processed meat products

Processing aids to produce value added, variety and convenience meat products to meet life style requirements. It helps better utilization of different – carcasses, cuts and edible byproducts. It facilitates incorporation of non-meat ingredients for quality and economy. It helps preservation, transportation and distribution and marketing to over larger populations. It facilitates export and

competes imports and also promotes entrepreneur ventures & employment. Value added products are further processed products with increasing convenience to consumer through decreasing preparation time, minimizing preparation steps. It facilitates the use of specific parts, creation of products with different flavours and increases the shelf life of products. Value added products could be broadly classified based on processing, variety/convenience and function.

Demand for meat and meat products

Muscle foods play a major role in human diet as they contribute macro and micro nutrients required for the growth and maintenance of health. The rate of increase in per capita consumption of animal products was found to be higher in the developing countries compared to developed countries. The per capita animal protein consumption in India is about 10.4 grams per day compared to world average of 25 grams per day. Based on targeted minimum requirement of 20g per capita/ day for animal protein(from milk 10g, meat 4g, eggs 2g), the estimated demand for the present population would be:milk104mt, meat7.7mt, and egg 4.6mt (104 billion number) as against the present production of: milk 84mt, meat 6.04mt, fish 5.6mt and eggs 30 billion.

Prospects of meat products

We must aim at technologies and equipments to result in process efficiency for achieving lower production costs and higher yields, product diversification, byproducts utilization, improving shelf life, developing quality control and management systems and providing positive image to meat products. Product diversification is also necessary to minimize imports to the detriment of domestic industry. Small quantities of processed pork products are being produced which is meager in relation to enormous quantity of available pork at cheaper prices. Processing technology should also focus on global competitiveness, energy conservation and socio-ecological friendliness.

Meat processing is carried out both in organized and unorganized sectors. Organized processing under the supervision of professionals can make sure that the right kind of product is delivered to the consumers with safety and at affordable price. Meat based fast food industries have great potential in this country. Multinational food companies have already started their business in India. As quantitative restrictions have been removed, the imported meat and meat products may be available in cities and major towns. Globalization promises a wealth of product

choices and product value for the consumer. The demand for convenience meat based fast food is ever increasing due to rapid industrialization and urbanization, higher standards of living and increasing number of working women. Rising literacy and increasing health awareness also influence the purchasing pattern of the consumers. The shift in the food consumption pattern from cereals to dairy and meat products and such shift is more prominent is the growing middle class with high purchasing power.

Livestock products and sustainability

Pragmatic approaches for efficient livestock production and utilization are important to sustain livestock production activities.Sustainable animal production depends on: feed supplies and costs, production efficiency and optimum utilization of produce. They further depend on: hygienic production, value addition and diversification, better utilization of by products, cost efficient processing technology, creating sustained demand for the product, building positive image and innovative marketing approach.

Value addition of livestock products

Value addition is an import avenue for efficient utilization of livestock resources with increased demand and higher returns. Higher growth in demand for meat, eggs and milk in developing countries would be a positive attribute for Indian livestock sector with increased trade opportunities. Value added products are further processed products with increasing convenience to the consumer. The growth of products industry assures the farmers a regular off take of their produce at reasonable prices and provides variety to consumer. It involves a larger component of labour where India is at advantage with nearly lowest labour cost in the world. Employment potential would be substantial.

Advantages of meat processing

i. To change the form or characteristics of the products so as to make it easier to market and more attractive to the consumers
ii. Facilitates in incorporation of non-meat ingredients for quality and economy
iii. Helps in preservation, transportation and distribution to cover larger population (City life becomes easier)
iv. Helps in utilization of low quality meat and by-products
v. Development of different products with different recipe, thus varieties of value added and functional pork products can be produced

vi. Helps in fast food chain of food industries
vii. Inhibit climatic factors and destroy microorganisms that might cause deteriorative changes or spoilage
viii. Improves nutritive values

Requirements for meat processing

For successful processing of meat following infrastructures are required.

- Constant flow of healthy animals to feed the plant
- Scientific transportation of live animals
- Slaughter house with lairage and modern slaughter equipments
- Modern processing equipments
- Pork products to be developed with good recipe
- Scientific packaging, cold storage and marketing facilities
- By-products utilization facilities
- Technical manpower

Meat extension

A variety of non-meat food items are incorporated into products which are commonly referred as extenders, binders and fillers. Purpose of their incorporation in meat products are many and a few are mentioned here viz. to improve emulsion stability, to improve water binding capacity, to enhance flavours, to reduce shrinkage during cooking, to improve slicing characteristics and to reduce formulation cost. Common examples for a) fillers - soy products, potato, starch; b) extenders – wheat, rice, pea, corn flours and c) binders – milk powers, dried whey and sodium casinate.

Formulation of processed pork products

There are hundreds of processed pork products in the world. Some of the very common processed pork products are ham, bacon, salami, sausages, luncheon meat, pickles, patties, loaves, balls, nuggets, slices and pork snack products.

- The first goal of formulation of the product should be such that it maintains uniform appearance, taste, composition, nutritive value, physical properties. The product should be acceptable to the consumers.
- The second goal is that it must meet the quality standards.
- The third goal is that the proportion of meat ingredients like meat, fat and by-products to non meat ingredients like binders, extenders, fillers, spices salt etc. should be such that the products become stable and cost effective.

Value added products could be broadly classified based on processing, variety/ convenience and functions and are briefly discussed hereunder.

Comminuted pork products: Comminution is a process for meat particle size reduction and normally includes griding, flaking, chopping, milling etc. Pork is well suited for comminuted meat products. The processing techniques for high quality pork patties, sausages, loaves, blocks, nuggets and rolls as well as restructured products are available. Incorporation of back fat in these products formulations could improve the juiciness and palatability of the finished products. Further, several low value by-products such as pork rind (skin), head meat, heart meat etc. could also incorporate into these products without much adverse effect on sensory attributes of the products.

Restructured pork products: Restructuring is a processing technique used for developing convenience meat products with texture in between intact steaks and comminuted products. Some of the modern processing techniques viz. flaking and vacuum tumbling can be used to improve the product yield, binding, texture and sensory attributes of the products.

Enrobed pork products: Enrobing is a technique for coating the meat products with edible materials to improve their cooking yield and provide better protection against oxidative and microbiological deterioration.

Cured and smoked pork products: Curing is one of the oldest methods of preservation technique for pork and pork products and per se it is the addition of salt, sugar and nitrite/nitrate to meat for the purpose of preservation, flavour enhancement or colour development. In the applied concentrations most curing agents are bacteriostatic or fungistatic and more detrimental to gram negative organisms. There are different methods of curing viz. dry curing (ingredients will be rubbed on the meat), pickle curing (ingredients will be dissolved in water and applied either by immersion or injection methods), cold curing (at low temperature) and hot curing (at higher temperature to accelerate the penetration of curing ingredients). The entire curing process may be divided into four different stages viz. curing, salt equilibration/maturation, ageing and smoking. Curing and smoking contributes attractive colour, unique flavour along with shelf life extension of meat products, which makes them popular among consumers.

Shelf stable pork products: Production of thermally processed pork products either in cans or retort pouches with extended shelf life at room temperature promotes

distribution and marketing. Simple technology was standardized for developing shelf stable pork sausages using hurdle technology.

Intermediate moisture pork products: Pork products with 15-50% moisture content with moderate juiciness and texture, inhibit growth of bacteria, moulds and yeast, water activity between 0.6 to 0.85, self stable at ambient temperature for a considerable length of time are known as intermediate moisture pork products. A mixture of sodium chloride, glycerin, lactic acid and antioxidants are used in the formulations.

Fermented pork products: Fermented pork products can be prepared by using lactic acid producing specific microflora like Lactobacillus, Micrococcus and Pediococcus etc. The bacterial cultures create such an environment that other spoilage and harmful microorganisms can not grow. Based on the moisture contents, three types of fermented pork products can be manufactured e.g. dry, semi-dry and moist. Extension of storage life, safety of foods and improvement of sensory properties are the benefits.

Designer pork products: Pork can be effectively utilized to produce designer/ functional pork products. This is achieved by lowering fat, sodium and calories by incorporating fat replaces, fibers and natural antioxidants. A combination of hydrocolloid fat substitute, sodium alginate and carrageenan enhance the sensory attributes of low fat meat products. It is now tried to formulate designer pork products with bioactive peptides so as to use as disease preventing and health promoting food.

Clause 22 of the FSS Act, 2006explains the definition of functional food as - (1) ―foods for special dietary uses or functional foods or nutraceuticals or health supplements means:

(a) foods which are specially processed or formulated to satisfy particular dietary requirements which exist because of a particular physical or physiological condition or specific diseases and disorders and which are presented as such, wherein the composition of these foodstuffs must differ significantly from the composition of ordinary foods of comparable nature, if such ordinary foods exist, and may contain one or more of the following ingredients, namely:- (i) plants or botanicals or their parts in the form of powder, concentrate or extract in water, ethyl alcohol or hydro alcoholic extract, single or in combination; (ii) minerals or vitamins or proteins or metals or their compounds or amino acids (in amounts not exceeding the Recommended Daily Allowance for Indians) or enzymes (within permissible limits);

(iii) substances from animal origin; (iv) a dietary substance for use by human beings to supplement the diet by increasing the total dietary intake;

Traditional pork products: Indigenous meat products are very popular because of their ease of preparation and unique sensory attributes, in particular flavour profiles. Considerable progress has been made in standardization of product profile and mechanization of traditional meat products. However, much has to be done to meet the increasing requirements of traditional food products particularly meat products. The demand for traditional meat products is bound to increase further in the coming years due to rapid urbanization and industrialization. The rich heritage of India contributes to wide range of traditional foods and has a role to play in health foods. Indigenous pork products and much popular in North-Eastern Region and are unique in their spicy flavour, simplicity and ease of preparation. With many processing methods and tools offered by contemporary food technology along with scientific packaging, the quality and shelf life of traditional pork products can be raised to world class standards.

Constraints in development of processed meat sector

The developing processed meat sector is facing several constraints which includes limited availability and high cost of good quality meat, non availability of tested indigenous technology for commercial scale processing, batch processing-which takes more time and less production, high cost of imported meat processing equipments, lack of authenticinformation on many indigenous meat and poultry products, non availability of cold chains required for storage, distribution and marketing as meat products are perishable and lack of scientific approach for processing. Inadequate power supply and frequent power failures further detracts the entrepreneurs to enter into this sector.

Strategies for augmenting meat processing sector

The quality and palatability of meat can be further significantly improved by following some of the steps either during production of meat or processing of meat products to fetch higher profits.

1. Production of shelf stable meat products in retort pouches will facilitate their distribution and marketing in the absence of cold-storage network.
2. Appropriate technologies need to be further standardized for profitable utilization of edible offal's like tripe into snack products or incorporation into other comminuted meat products or pet foods.

3. Processing technologies need to be dynamic for economic survival, consumer needs and continued evolution market. Use of standardized low-cost processing technologies for several meat products can benefit entrepreneurs in producing better quality products.
4. Pragmatic long-term slaughter policy of meat animals by Govt. of India would help to attract private investments for production of wholesome meat, safe and nutritious meat products for developing sustainable meat industry.
5. Reduction of excise duties on processed meat products and further decrease of custom duties on imported meat processing equipments would encourage the growth of the sector.

Conclusions

Pig production is a vital activity in rural areas and has helped to provide employment and income generation for farmers, rural poor and weaker sections. The abundantly availabile and comparatively low priced pork has vast potential for production of several value added convenience meat products. The developed processing techniques for several products need to be evaluated at pilot scale and by large scale consumer acceptance trials for their techno-economic feasibility. Production of meat products with adequate process and quality control may find their entry into global markets and fetch higher returns. The future success of meat industry in India depends on how well industry partners and R & D Institutions join hands for meaningful partnership and alliance towards converting scientific knowledge into value added systems by improving linkages infrastructure, adjusting taxation and food laws as well as drawing clear plans which benefits producer, processor and consumers.

ISBN: 978-93-91668-41-9

Guru Angad Dev Veterinary and Animal Sciences University Ludhiana, Punjab
&
National Institute of Agricultural Extension Management, Hyderabad