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Techno Economics Analysis of Industrial Scale Chicken Bone by-products: A Case Study Evidence in Pakistan

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ABSTRACT
The research studied the chicken bone by-product case evidence from Pakistan. I have solved the environmental problem by getting calcium, phosphate, and phosphorus from chicken bones and have also produced pet food, fertilizer, and chalk. I have taken primary (marriage halls and questionnaires) and secondary data (FAO reports, Pakistan poultry association). The methodology used in this study was Technoeconomic Analysis (TE) and calculated costs such as grinder costs, building costs, equipment costs, etc. The model used in this study is SWOT. The conclusion is that it was beneficial for developing countries because the cost of collecting bone was low, the revenue from chicken power was high, and it also generated employment and increased economic growth (GDP).

Keywords: *Techno Economics, Industrial Scale, Chicken Bone, By-products, Pakistan.*

1. Introduction

As an important source of human food supply, the poultry industry has provided adequate meat and eggs for humanity. Poultry product consumption around the world has been increasing dramatically during the past several decades (Zhang et al., 2023). Agblevor et al. (2010) stated that the fast growth of the poultry industry has greatly promoted agricultural economic growth and made a significant contribution to social employment and the living conditions of residents.

The poultry industry plays a distinct role in the global food market. Global production of poultry products in 2015 was around 74 million tons which rose to 123 million tons in the year 2018 and still remains the most consumed meat in the world. It further grew in an upward trend during 2018- 2028 (Ali et al., 2020). In Pakistan per capita monthly consumption of chicken meat is 0.36 Kg (MNFSR,2016). The poultry sector is a critical component of the livestock industry, providing employment opportunities to over 1.5 million people in Pakistan. With a substantial investment of more than Rs 1,056 billion, this industry has experienced impressive growth, averaging a remarkable 7.3 percent annual growth rate over the past decade. This expansion has led to Pakistan becoming the eleventh largest poultry producer in the world, with vast potential for future growth and advancement (PES,2022-23). There are over 15000 poultry farms spread deep into the rural areas across the country from Karachi to Peshawar. The capacity of farms ranges from 5,000 to 500,000 broilers. 40-45% of the total meat consumption is being procured from poultry products.

The poultry sector contributes 1.3% of the total national GDP of Pakistan (Samad et al., 2022). Chicken meat and bones meal is a waste produced from poultry slaughterhouses or rendering industries consisting of a mixture of small pieces of bones, fat, and residual fractions of meat. Meat and bones meal is widely used as a low-cost pet food formulation, because of their high protein content, but the nutritional properties vary dramatically, and in some cases, further processing is required(Hicks et al., 2016). Although Meat and bone meal can be seen as waste from slaughterhouse operations, this material becomes much more valuable after processing (Sarrion et al., 2023). With the expected rise in worldwide consumption of animal protein products, so too will there be an increase in associated waste. In a world with finite resources, the minimization, recovery, and utilization of by-products becomes increasingly important (Fallows and Wheelock, 1982).According to Krishnamoorthy et al. (2021) Meat and bone meal is generally rich in nutrients, especially phosphorus, which is a scarce mineral used as fertilizer. Phosphorus is an essential nutrient for all living organisms and the world food industry is highly dependent on phosphorous fertilizer, the supply of phosphorus from phosphate rocks will decline after an increase in population so other sources like chicken bone by-products must be used to produce phosphorus (Vikman et al., 2017). The chicken bones damped into thrash require too much time to decompose itself attracting pesticides and creating an environmental problem but after the by-products of bones, it will be used as fertilizer and help to decrease bone waste that causes environmental damage(Citizen,2023). The remaining unused bones of chicken and used cooking oil also can be converted into biodiesel using a catalyst converter (Farooq et al., 2015). Efficient utilization of by- products will lead to a direct impact on the economy and the environmental pollution of any country, or Non-utilization of by-products will lead to an increase in disposal cost and aesthetic environmental problems (Jayathilakan et al., 2012). Techno-economic analysis (TEA) has been considered an important tool to evaluate the economic performance of industrial processes. Recently, the application of TEA has been observed to have exponential growth due to the increasing competition among businesses across various industries. is a type of method to analyze the economic performance of processes in industries. TEA is conducted through a methodology consisting of a series of holistic analyses that must be

completed consecutively (process design, process modeling, equipment sizing, capital cost estimation, operating cost estimation, and cash flow analysis). The complexity of the problems demands a wide coverage of economic indicators (e.g., plant operation, plant design, transport, market behavior, etc.). TEA is usually addressed with various modeling approaches at manageable scopes depending on the level of perspectives; (Micro) biorefinery process model using ASPEN Plus (Ng and Sadhukhan, 2011) (Meso), plant design selection with fuzzy optimization (Wan et al., 2016), and (Macro) supply-chain model with mixed-integer linear programming optimization (How and Lam, 2018) for the estimation of various financial and technical values. As such, TEA is essential to evaluating the feasibility of upscaling or industrialization of various processes and technologies (i.e., biorefinery (Ng and Sadhukhan, 2011), as well as process the integration of carbon capture (Ng et al., 2013) and smart energy environment (Sheha et al., 2021).

1.1 Statement of the Problem

Chicken meat, about 10-20% is bone of an animal's body that is being discarded with zero income or a problem for environmental management (S.Irshad et al ., 2021). Chicken bones are rich sources of proteins such as gelatin and collagen where it is also a good source of minerals including calcium, phosphorus, and magnesium. This rich resource is being damped with no further use. In Pakistan this nutritious waste has no end use, it is simply dumped and wasted. It can provide a profitable business alternative, especially in developing countries.

1.2 Objectives of the study

1. Based on the idea of the waste to resource approach, following are the key objectives of the current study:
2. To estimate the cost required to collect bones from meat industries, grinding cost, autoclave cost, and the cost required for new plant and measure their capacity, labor and machinery, and all other expenses on grinding like 1ton bones.
3. Create an awareness and set a pioneer approach in Pakistan for the usability of chicken bones

To provide a technoeconomic analysis of the chicken bone powder production in the setting of Pakistan

1.3 Organization of the study

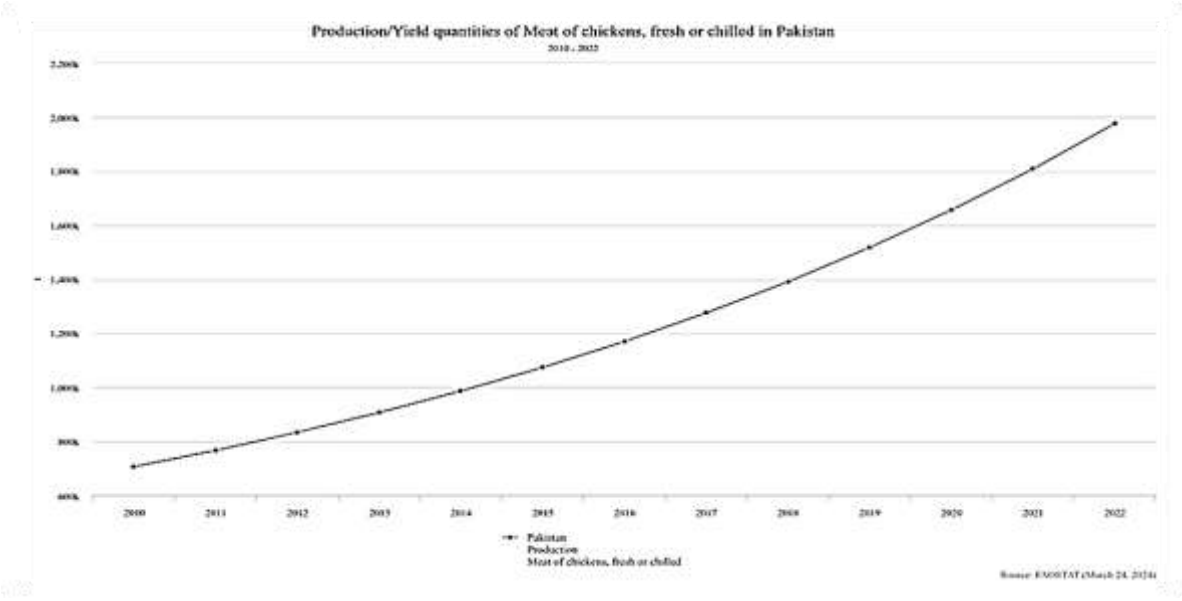
This research paper will contain and divide into four parts. The first part will be consisting of introduction of techno economics analysis of industrial scale chicken bone by-product (1), statement of problem (1.1) and also discuss the objective of our study (1.2). Second part will be consisting of review of literature. Third part will be consisting of model and methodology. Furthermore the findings and the conclusion of the study. Also some policy recommendations will add to the study Last part of our research is consisting and adding the references relate to our research topic

2. Review of literature

2.1.1. Chicken meat production in Pakistan

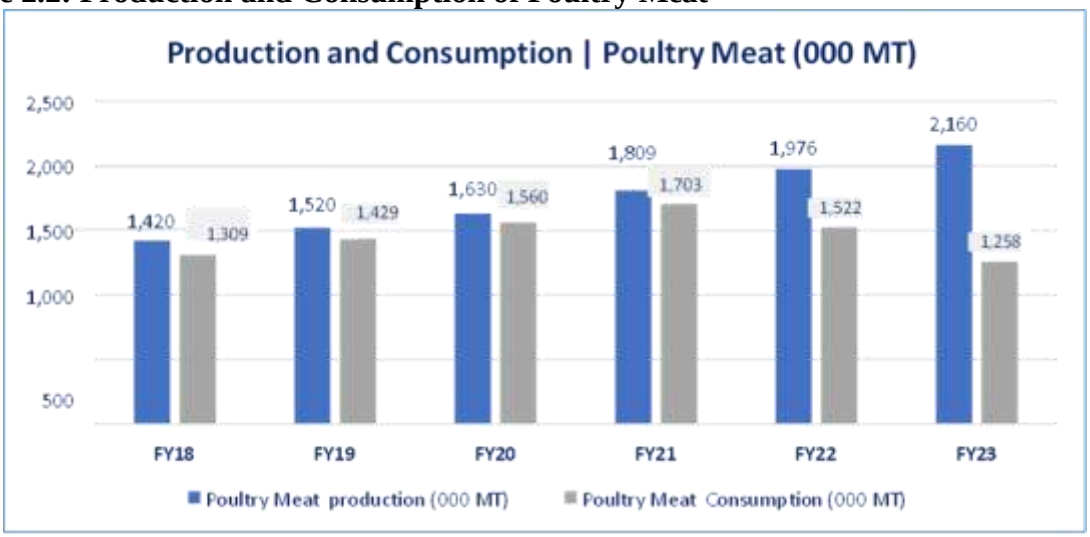
The Data show on FAO from 2010 to 2022 shows the increasing trend of production of chicken meat in Pakistan. It leads to a strong industry in Pakistan and this industry socially or economically important for Pakistan (Figure 2.1 and 2.2).

Figure 2.1: Production of Chicken meat in Pakistan



Source: FAO Report

Figure 2.2: Production and Consumption of Poultry Meat



Source: PES,PPA

Global production of Chicken meat (Table 2.1)

Over the past two decades, poultry has become the most widely consumed animal product in the world. When it comes to poultry meat consumption, the USA is once again at the top with around 18 million tonnes, with no major changes in the last three years. China comes in second with consumption of around 14 million tons. Recently, poultry consumption in China has declined due to a shift in demand for other meat products and an accompanying economic slowdown. Population growth, rising incomes in developing countries and urbanization have led to an increase in global poultry consumption. Poultry meat consumption in Pakistan is expected to reach around 2 million tonnes in CY23, similar to CY22 and CY21.

		CY21		CY22		CY23*	
Sr.	**Country**	**Amount**	**% Share of World Market**	**Amount**	**% Share of World Market**	**Amount**	**% Share of World Market**
1	USA	20	20%	23	23%	21	21%
2	China	15	15%	14	14%	14	14%
3	Brazil	14	14%	14	14%	15	14%
4	European Union	13	12%	11	11%	11	11%
5	Russia	5	5%	5	5%	4	4%
6	India	4	4%	4	4%	4	4%
7	Mexico	4	4%	4	4%	4	4%
8	Thailand	3	3%	3	3%	3	3%
9	Turkey	2	2%	2	2%	3	3%
10	Argentina	2	2%	2	2%	2	2%
11	Pakistan	2	2%	2	2%	2	2%
12	Others	18	19%	16	16%	21	18%
Total		**102**	**100%**	**101**	**100%**	**104**	**100%**

Source: Pakistan Credit Rating Agency (PACRA) Research on Poultry

2.2.Recent literature search on chicken meat and bones

Zhang et al. (2023) have discussed that the demand for products in the poultry industry has been increasing day by day like the demand for eggs and meat. The problem is that in the past year the waste material of poultry these are not in used, burned and decomposed. In this paper modeling and simulation studies on poultry waste-to-wealth, or emerging technological processes for poultry waste-to-wealth are described: anaerobic digestion, pyrolysis, gasification, hydrolysis, enzymatic treatment, and microbial conversion. For further research, we suggest a

focus on the poultry waste- to-wealth projects in different regions, the behavior strategy of different stakeholders, and policy- making for the commercialized application of poultry waste-to-wealth technologies.

According to Sarrion et al. (2023), chicken bone is also important and generally rich in nutrients, especially phosphorus. Chicken meat and bone meal is a waste produced from poultry slaughterhouses or rendering industries. Chicken meat and bone waste is treated through a sequence of stages including hydrothermal treatment, nutrient recovery, and anaerobic digestion, with the aim of evaluating their potential synergy as a circular economy approach. These methods prove that after processing the chicken bone it can obtain highly value-added products (Bio- fertilizer, Bio-oil, Biogas).

Leng et al. (2019) in the last past years the worldwide use of phosphorus in fertilizer and demand for phosphorus has increased day by day. Phosphorus is generally generated from chicken bone and it rich source of nutrients the high demand of phosphorus is used in agriculture fertilizer, animal feed, and also in detergents. The ash of meat bone is collected through a UK industrial-scale of incinerator in a power plant. The incineration ash from the combustion of meat and bone meal is used as "synthetic phosphate rock" due to its high phosphorus content or and low hazardous elements contents.

Hick & Verbeek (2016) worldwide utilization of meat items established an enormous and constantly growing industry. By-products created from this industry have a high biological oxygen demand, and if they are not treated properly, then they can have serious implications for the environment. Meat items, such as fish, chicken, beef, sheep, and pork all result is comparative waste products. These include carcasses, intestines, feathers, fish bones and scales, as well as blood although these can be seen as waste from the meat producer, they become much more valuable after rendering. These are mainly used as animal feed supplements because of their high protein content.

Vikman et al. (2017) In the poultry industry a large amount of bones are generated by products of the deboning of chickens. These by-products are potential sources of valuable components such as proteins and nutrients. Enzymatic hydrolysis of animal by-products can be used to produce protein hydrolyzes resulting in the formation of rich in phosphorus and nitrogen. They used hydrothermal treatment to evaluate the nutrients.

Kong et al. (2024) stated that the efficient use of chicken bones in food is associated with technological and nutritional challenges due to their low content bio-availability and technical functionality. Animal bone is usually solid waste and it can't be discarded without any utilization it also creates a huge environmental problem. Animal bone consists of calcium and protein thus it is used as a nutritional supplement for body growth and skeletal development. Bone powder is usually used as a nutrition-fortified product. In this, they used steam treatment and the impact of steam explosion to make smaller size of particles of chicken bone powder with time and saved energy compared with treatments The SE improved bio-availability in chicken meat bone powder which has higher protein digestibility, calcium content, and main amino acids. The results indicated that steam explosion was an effective process for the preparation of bone powder with improved technical functionality and noticeable bioavailability.

Wang et al. (2024) say that in China there is a lot of high-strength byproducts/wastes are discharged from slaughterhouses of the meat industry and if it is not properly treated serious environmental pollution occurs. These wastes are rich in protein and lipid and could potentially be utilized for effective recovery of energy and nutrients. They used three treatment scenarios of slaughterhouse wastes, namely anaerobic digestion (AD), composting, and rendering also the greenhouse gas was calculated and compared. The results showed that 23.1Teregram of slaughterhouse byproducts and 679.7 Mm3 of wastewater were estimated to be released in 2020, potentially producing 2743 Mm3 of bio-methane in anaerobic digestion, 316 Gg nitrogen, and 660 Gg of phosphorus nutrients during composting or 5.4Tg of rendering products during rendering. Anaerobic digestion of SBP resulted in a high Greenhouse gas reduction (approximately 17.88 Tg CO2-eq). This integration of bioenergy/by-product productions into animal processing can potentially increase the environmental sustainability meat industry in China in the future.

Singh et al. (2018) Poultry industry is one of the fastest growing markets and it also produces large amounts of solid waste. Poultry waste is a serious environmental pollution problem through offensive odor and fly propagation. If it is utilized properly The appropriate use of its waste or by- products increases money production and protects against its unwanted side effects. Inadequate approach and carelessness in the management of poultry slaughterhouse wastes will lead to a constant threat of disease in poultry farms and this results in direct losses in the form of death and reduced productivity. Therefore, timely waste disposal in a well-organized method is an important poultry waste management tool to increase healthy and profitable poultry operations.

Kowalski et al. (2007) say that every year Europe produces 18 million tons of waste in the meat industry. Meat industry waste is very harmful to human health because it produces dangerous diseases. The best solution for meat industry waste management is with the help of cleaner production methods and it involves reducing pollution and diseases and getting energy, and protein from the wastage of the meat industry. The thermal process is not good for meat wastage because when the bones burnt start then phosphoric raw material is produced. As we know phosphoric creates dangerous diseases and pollution. Cleaner Technologies- to prevent the Meat Waste Formation method are used for handling the waste of the meat industry and this method is very useful for producing biofuel, pet food, medicine, and fertilizer.

Iskakov & Sugirbay (2023) stated that animal waste is used as a raw material source for feed preparation and also after appropriate processing, as fuel, fertilizer, biogas, and other useful products. Animal waste recycling is a feature of the circular economy that leads to environmental sustainability. Many scientific researches showed that animal byproducts are desirable for use in combination with vegetable protein sources use in combination with vegetable protein sources. Current scientific publications identify 15 relevant types of animal waste and 13 feed origins. Technological equipment for drying, grinding, and mixing is discussed, along with processing waste into animal-derived products.

Staron et al. (2016) say that meat industry waste increases due to more consumption of meat day by day. Waste from meat industries is very harmful to human health because it is an

environmental problem. As we know meat bones and other wastes include calcium, magnesium, and phosphorus and these elements are valuable because we can get fertilizer, medicine, and pet food and also get more calcium from bones with the help of Thermal treatment of waste from the meat industry in high scale rotary kiln method and conclusion of this research was it can neutralize hazardous waste materials, and it provides a product that can be used as fertilizer.
McGauran et al. (2021), explores the potential of using poultry waste as a sustainable and cost-effective polymer additive.This paper presents a techno-economic analysis to determine the feasibility of using three abundant poultry waste materials, bones, meal and feathers, within the polymer industry, quantifying the energy, cost and carbon implications compared to conventional polymers and the potential oil savings compared to using them as a feedstock bioenergy. Given the complexity of such an approach, the relevant assumptions have been described in detail. In parallel, compositional analysis provided a detailed breakdown of each material that was used to determine their potential as fillers in polymer processing. The calculations concluded that the use as a polymer filler in the filling up to 40% wt. for bone and meal and 60% wt. for feathers, has provided high energy, carbon and cost savings in both the polymer and poultry industries. Oil savings were 5 times higher than when used as a bioenergy source, showing the potential of poultry waste streams as polymer additives.
Macavei et al. (2024),in this research paper the potential of thermochemical processes such as pyrolysis and gasification for the recovery of chicken bone waste. The thermochemical conversion of chicken bones through pyrolysis and gasification creates a new opportunity to valorize this type of waste by reintroducing valuable by-products into the economy and thus achieving sustainable waste management objectives. The results of this study showcase the multiple applications of the pyrolysis of chicken bone waste products and the necessity of a better exploration of the gasification process of chicken bone waste. Therefore, this study explores the properties of animal- derived waste and discusses the pyrolysis and gasification of chicken bone waste, the influence of process conditions on product yields, and the catalytic enhancement of these thermochemical processes.
Deydier et al. (2005) investigate the potential of using meat and bone meal (MBM) incineration residues as a valuable resource rather than a simply waste.Management of MBM waste is increasingly important due to environmental and health regulations restricting landfilling practices.The efforts are increasingly focused on investigating alternative waste management strategies such as incineration and resource recovery.Thermogravimetric analysis (TGA) was used to monitor the thermal behavior of raw meat and bone meal and inorganic residues were obtained. Particle size distribution, powder X-ray diffraction (XRD), specific surface area (BET), scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX) were used to characterize the resulting ash. The elements that were found in the sample were calcium and phosphate, two key components of bone. TGA, XRD and specific surface measurements were used to investigate the effect of combustion temperature on ash composition. As the calcium phosphate crystallized, we saw a significant reduction in the surface area of the ash. This paper contributes to this field by investigating the potential of MBM combustion residues as a raw material in construction applications.

According to shahzad et al. (2017) residual animal material is considered waste from slaughterhouses. Waste usually has no market value, rather it requires additional investment to be managed in accordance with strict environmental regulations.This area of research explores the potential of slaughterhouse waste as a raw material for biopolyesters, a valuable bioplastic with increasing market demand.The use of industrial waste streams as input materials for bio-mediated production processes represents the current goal of research and development not only to reduce process costs on the input side, but also to minimize hazardous emissions into the environment.This paper provides a detailed economic analysis of polyhydroxyalkanoate (PHA) production from this waste bio-refinery concept, involving the use of low quality bio-diesel, offal and meat and bone meal (MBM).

Ling bee et al. (2019) food industry by-products, particularly chicken bones, are typically seen as trash and thrown away before being used to their full potential. Seen from a waste-to-riches perspective, this by-product has the potential to be a very valuable biological resource for the hydroxyapatite synthesis process at a low cost. In order to create hydroxyapatite, heat treatment was applied to the remaining chicken bones in relation to various calcination temperatures. The characteristics of the calcined samples were assessed by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), and X-ray fluorescence spectrometry (XRF). The following phenomena will occur when the calcination temperature is raised an increase in crystallinity, a decrease in the association of organic ash, and a reduction in the carbonate content

1. Model and Methodology

1.1. Introduction

In which we will use primary data and collect data from different sources like the economic survey of Pakistan, local websites, the Department of Food and Agriculture in Pakistan, and FAO reports and we will get most of the data from the Poultry Association of Pakistan after the collection of data we will estimate the cost of making products by bone with the help of techno economics analysis. Some taken economic factors of production like land(building) labor (workers, staff) capital (types of machinery like a grinder, tools, computers, etc.), and entrepreneur for techno economics analysis (TE). We will also calculate the cost of chicken bones like (collect bones from marriage halls chicken factories and garbage). All the prices of raw material equipment and land will be used and provided according to the Pakistani market.

1.2. Theoretical Framework & Model Specification

1.2.1. Preparation of chicken bone powder

The equipment and machinery used in the processing of chicken bone by-products can be grouped into the preparation stage, the processing stage, and the packaging and labeling stage. In the preparation stage, the chicken bone input is weighed to specified quantities using a digital weighing balance. The groundnut oil is then measured and poured into the steam boiler up to a level just below the exit valve. Once this is done, the machine is switched on, and the heater is turned on for steam production. Also in the preparation stage, the boiler, which is the source of steam, is started up and the water level is checked. Water is added if necessary. Groundnut oil is drained from the cylindrical tank into the steam boiler, and then the machine is operated to

check for any mechanical problems. In the processing stage, the bones are conveyed into the milling machine through a conveyor belt for grinding into bone paste. The steam from the boiler is used in the cooking of the bone. The semi-automatic bone paste filling machine is used to fill the bone paste into the plastic containers. This occurs following the addition of additives and preservatives. In the packaging and labeling stage, the containers are labeled and packaged into large cartons for storage in the cold room. The rinsing machine is used to wash the containers, after which a drier is used to dry them. Also, the labeled containers are fixed into the rotary round table, and the pasted date stamps are glued onto them (Irshad et al ., 2021).

The cold storage room is used to store the packaged products to prevent the growth of pathogenic microorganisms. This is maintained at a temperature of between 0°C and 5°C with a relative humidity of about 90-95 percent. This is essential in maintaining the quality of the bone paste product. The conveyors and machines are usually connected through a small programmable logic controller (PLC) system, which is automatically controlled by the inputs from different types of sensors that are used to detect either the bone level in the hopper or the labeling of containers. The use of a PLC reduces the over-reliance on manual labor and helps in improving the overall efficiency in terms of production. Every machine is installed with emergency buttons that can immediately terminate any operation if there is any problem. These machines are safe to use and require minimum supervision. Digital temperature recorders are placed in the cold storage room for the monitoring of the temperature. Also, a temperature indicator is installed to display the current temperature inside the room. (Irshad et al., 2024)

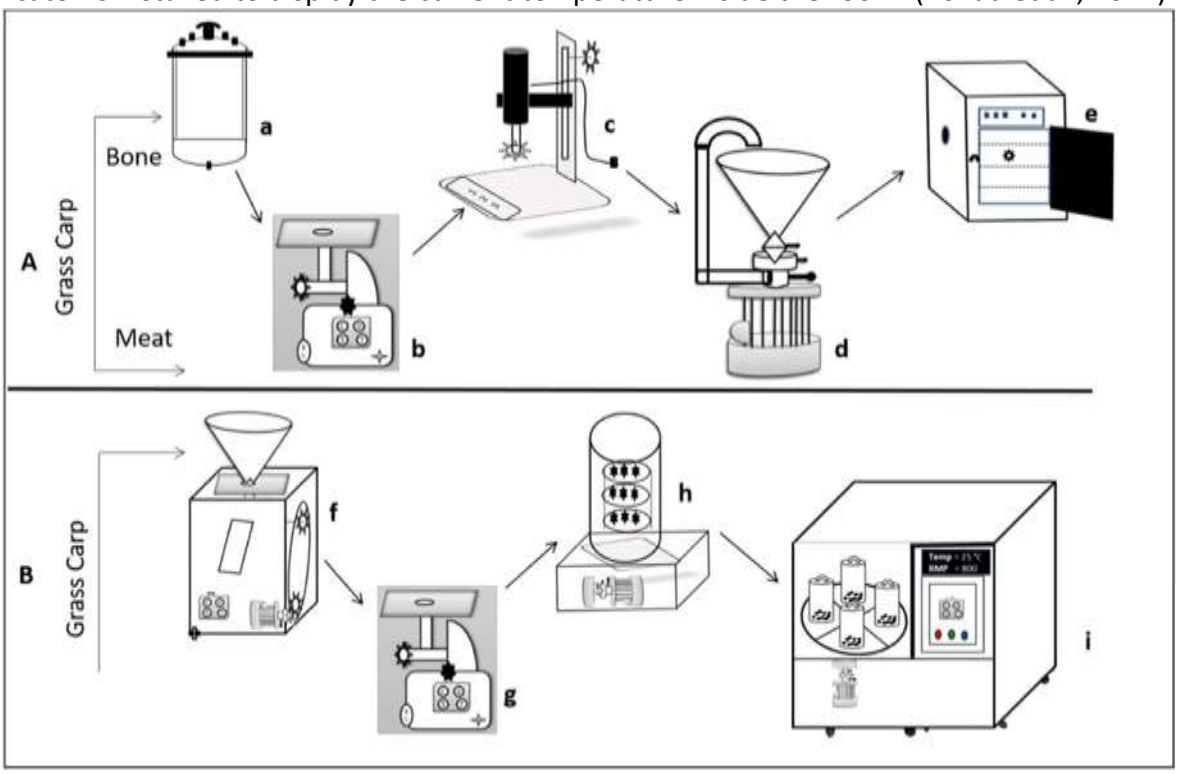


Fig. 2. Schematic diagram of chicken bone and powder engineering. Fig. 1A is chicken bone powder: a) autoclave, b) commercial meat mincer, c) high-speed disperser, d) colloidal mil and

e) hot air oven. Fig. 1B represents the whole chicken powder steps: f) high-speed pilot scale miner, g) commercial meat mincer to mince in more small size, h) freeze dryer and i) stone ball media milling with controlled temperature to avoid protein denaturation.(S.Irshad et al.,2023)

3.2.2 Nutrition of bone powder

Nutrition in Chicken Bones *	**Percentage**
Fats	9.5%
proteins	15.6%
minerals	14.7%
moistures	57.7%
total	97.5%
*Cansu, Ü., & Boran, G. (2015). Optimization of a multi-step procedure for the isolation of chicken bone collagen. *Korean Journal for Food Science of Animal Resources*, *35*(4), 431.	

3.3 Variable Description and Data Source

The primary and secondary data were collected through research and survey methods (Gangrade 1082). The primary research mainly included the collection of direct information with the help of surveys and observations. Data from 4 different marriage halls were collected. Through observations, it was noted that most of the marriage halls in Lahore are not using the waste of chicken bone as a by-product, and also operatives are throwing away the chicken bones as a waste material. The secondary data were collected from the published reports of different government and private sector organizations, such as the Economic Survey of Pakistan, Planning and Development Department, etc., and existing literature including industry profiles, trade association reports, technical bulletins, company component literature, journals, and any other relevant information from the internet. The review of existing literature and data from the internet and libraries, especially good scientific journals, was an effective way to validate the results from primary research, and it also provided deeper knowledge in establishing the chicken bone by- product industry. However, the challenging task was to get the consent of people for the interview and also to access a lot of articles and journals from the internet and to read them, and understand them for extracting relevant information. . The questionnaire and location of data collection is given below in appendix section.

3.4. Econometric Methodology

Techno-economics analysis, model used in the current study, is very important for economic growth because. It is a method used for producing technical products and innovation. In techno economics analysis also includes cost and benefits. It also involves economic factors such as investment, capital cost, labor cost, maintenance cost and opportunity costs etc. It is very helpful for developing countries because developing countries can get more benefits from useless things and it is also a source of employment. Techno-economics analysis was used first time in the United States. Dr. Kal Renganathan Sharma PE, West Virginia University (process model and techno economics analysis).

Techno economics analysis is used in every field such as energy, Telecommunications, and infrastructure development and economics. It helps to calculate the cost and benefits of using technologies within the sector. Techno economics analysis using some kinds of software for example Microsoft excel, or a process of simulator. Three of the most effective tools that economists use are the scientific method, graphs, and economic models. The objective of techno economics analysis is to guide investment for technology development, to Qualification of R&D performance target and priority, to identify the data gab, to increase national income (Ng 2013). Techno-economics analysis are used in various research papers such as Techno-economic analysis of biomass fast pyrolysis to transportation fuels (wright et al., 2010). A comprehensive techno- economic analysis of income-generating sources on the conversion of real sheep slaughterhouse waste stream into valorized by-products (Yetilmezsoy et al., 2022). Value-added materials recovered from waste bone biomass: technologies and applications (Hart et al., 2022).The bone industry in the Capsian and Neolithic contexts of Eastern Maghreb: A technological and functional approach (Petrullo et al., 2016)Environmental and economic sustainability of poultry litter gasification for electricity and heat generation (Kumar Jeswani et al., 2019).Utilization of rice husk and poultry wastes for renewable energy potential in Pakistan: An economic perspective (Ali et al., 2016). Techno-Economic Optimisation to Enhance the Sustainability of Agro-Industrial Clusters: A Focus on Livestock Systems (Raziq et al., 2023).

3.5. SWOT Anaylsis

SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or business venture. It involves specifying the objective of the venture or project and identifying the internal and external factors that are favorable and unfavorable to achieve that objective.

3.5.1.1. Strengths

This project can create bone powder which will lead to the creation of by-products of chicken bone such as a rich source of calcium phosphorous and the calcium used in poultry feed. The high intake of calcium leads to better growth of bones and production of eggs. This feed also used for live stock to produce extra milk. The primary strength of this project is the awailbility of low cost raw materials and it leads to high margin profit. It can produce such as glue, fertilzers, pet food, chalk and oil production. In the real world, it can be very helpful from an economical point of view because It can generate employment and increase income per capita and lead to increasing the share of ploutry industry.

3.5.1.2. Weakness

limited consumer awareness about by products of bones that can be utilize as a substite. Lack of government awareness reguarding this project and also a absence of already exisiting market

3.5.1.3. Opportunities

Pakistan, having an agro-based economy and an abundance of poultry and livestock sector in the country, chicken bones can contribute a significant share to the economy and its stakeholders. The poultry and livestock sector contributes 11% to GDP and employs 30-35 million people in the country, making a valuable contribution to national economic development. Although this sector has been badly affected by the recent economic turmoil and has faced stiff competition from

more viable substitute products. This case study has shown that the poultry by-product industry in Pakistan can change the scenario which is grappling the poultry and livestock sector for the last many years. The study has pointed out towards the excellent true cost economics of the fertilizer value of bone and chicken and its potential to save foreign exchange on imports of around 13.9 million US$ and 153.8 million US$ spent on fertilizer and chicken feed ingredients respectively. Its estimated net savings are 167.69 million US$, which is a good saving for the national economy (Nushad et al .,2021).

3.5.1.4. Threats

The issue of environmental regulations being a barrier or a brainstorm for chicken bone projects is a complex one. The enforcement of regulations to control industrial pollution are minimal at present and so could be viewed as an opportunity as it gives time for the industry to develop. In general a cost of cleaner production methodology is only justified for products that have a large market, a high margin and a medium to long term sustainable production run. This would not be the case for most higher value chicken bone projects and any regulations which increase the cost of production would be deterrent. However, it is very likely that as global awareness of environmental issues increases, the more stringent regulations will be enforced. This could be the case in the EU and USA where most of the potential customers for chicken bone byproducts reside. The switch to cleaner poultry slaughter technologies will mean that the availability of raw material will reduce and the cost of mopping up remaining dirty material from traditional slaughterhouses may be too high. If such time that there are no poultry slaughterhouses operating with low emissions, Pakistan would have to import raw material to meet demand for bone meal and other byproducts. This would make the provision of byproducts less competitive.

4. Results and Discussions

4.4. Amount of annual bone collection

After conduct the interview of these marriage halls I was calculate that how much I can get chicken bones from halls. In daily basis I can get 42kg bones out of 125kg chicken. If I get chicken bones in monthly basis, then it will be 1260kg bones from these halls. But I want to calculate how much I can get chicken bone from these marriages' hall in annually. Annually, I can get 15120kg bones. It can be very beneficial if I used chicken bones for making powder such pet food, fertilizer; and get calcium. I also estimate that before grinding, if I wash 30kg bones then I have to bear 2% loss in weight after drying. I also estimate that before grinding, if I wash 20kg bones then I have to bear 1.5% loss in weight after drying. I also estimate that before grinding, if I wash 40kg bones then I have to bear 2.5% loss in weight after drying.

Table 4.1: Primary data collection form marriage halls located in the vicinity of Lahore

Marriage hall Name	Chicken use	Daily *	Monthly	Annual	Washing loss (20%) **
Five star	30kg	6kg	180kg	2160kg	2116.8kg
Noor mahal	20kg	4kg	120kg	1440kg	1418.4kg
Topaz complex	40kg	16kg	480kg	5760kg	5616.8kg
Anmol	40kg	16kg	480kg	5760kg	5616.8kg
Total	125kg	42kg	1260kg	15120kg	14767kg

* Latshaw, J. D., & Bishop, B. L. (2001). Estimating body weight and body composition of chickens by using noninvasive measurements. *Poultry science*, *80*(7), 868-873.

**Irshad, S., Nawaz, A., Walayat, N., Khan, M. R., Ahmad, N., Khalifa, I., ... & Luo, X. (2024). Insights into the engineering parameters and Ca-peptide chelation of whole fish: Chemistry, structure and in vitro digestibility characteristics. *Journal of Food Engineering*, *365*, 111826.

4.2. Techno-Economic Analysis

In techno economics analysis we have taken price according to Pakistani rupees (pkr). The cost of building (based on rental) is 5000 because in developing area we take easily 10 Marla place for business in 50000 rupees. The cost of grinder, autoclave, gloves, stationary, etc are include in equipment cost and this equipment are very important in chicken bone process according to USD the price of grinder is 1450 dollar and 1450 dollar equal to pkr is 400000 (1450 usd = 400000 pkr).

In Pakistan price of autoclave machine is 25500 pkr. Other equipment cost is around about 60 to 70 thousand and equipment cost approximately 500000 pkr. In commercial area if we use water on daily base such us wash bones before grinder and other uses that's why cost of water very month will 10000 (bill amount per month). In Pakistan the unit price of electrify is 65 rupees at the commercial area. In techno, economic analysis, we will keep 10 workers for this purpose busses and their monthly.

Chicken Bone Powder		
Items	**Cost Pkr**	**Cost (%)**
Cost of building (rental base)	50000	5.370569
Equipment cost	500000	53.70569
Maintenance cost (10 %)	50000	5.370569
Cost of water	10000	1.074114
cost of chicken bone (per 40kg)	1000	0.107411
cost of chicken	0	0
power cost (per 1000 unit)	65000	6.98174
Labor cost (per month -10 employees)	250000	26.85285
Transportation cost	5000	0.537057
Total cost with one time land and equipment	**931000**	

Total cost without one time land and equipment	**271065**	

wages /daily wages will be (30000 or 1000) and the wages of workers also included in the cost.
In techno economics analysis transport costs are also included because we collect bone from the marriage halls and after grinding bone (preparing bone powder) toward the market for sale. The transportation cost will be 5000 due high price of petrol.
Now we find the benefit cost of the preparation of powder of 40kg chicken bone. Let's suppose we have taken 40kg of bones from a marriage hall in 500 because bones are a waste for the owner of marriage halls that's why the price of bones is low. Also, we assume the industry has a 10- kilometer distance to marriage halls and its transportation cost will be 10000. Water costs are also required to wash bone before grinding according to Pakistan if we use water only 30 liters for washing 40 kg of bone its water will be 300.
as we know we only grinding the 40kg bone for approximately 10 minutes will use a grinder for prepare the powder and if we use only a 10-minute grinder its cost will be 100-200. If we use only 3 laborers for this process cost will be 1500-2000. And we include building cost (rental base on one day) it will be 5000. After the preparation of chicken bone powder, we also required bags for packing so also included a packing cost of 2000. The total cost will be 20000.
After washing the bone, the weight of the bone also decreases by approximately 2kg weight loss out of 40kg. So, assume we will have 38kg of bone powder. Now will see the benefit, The price of 1kg bone powder is 1000 rupees in Pakistan. If we prepare 38 kg bone powder its price will be 38000. And we have already calculated the cost of 20000. It will be beneficial because which cost will be low and the profit is high.

Conclusion:

This study provides strong evidence that chicken bone by-products, which are often treated as waste in Pakistan, can instead be transformed into profitable industrial resources. By processing bones into value-added products such as bone powder, fertilizer, chalk, and pet food, industries can create an entirely new revenue stream. The techno-economic analysis revealed that the cost of collection and processing is relatively low compared to the market value of the outputs, ensuring substantial profit margins. Moreover, the utilization of chicken bones reduces the environmental burden associated with improper waste disposal, such as pollution and health hazards from landfill dumping. At the same time, the industry has the potential to generate employment across different stages of the value chain—collection, processing, packaging, and distribution—contributing to both local livelihoods and national economic growth.
From a macroeconomic perspective, the integration of poultry by-products into formal industries contributes to GDP growth, enhances resource efficiency, and supports sustainable development. The study therefore, highlights the dual benefits of such initiatives: environmental sustainability through waste minimization and economic advancement through industrial diversification. Ultimately, chicken bone by-products can serve as a model for waste-to-resource strategies in developing countries, proving that environmental challenges can be turned into economic opportunities when supported by proper technology and policy frameworks.

Policy Recommendation:

- ❖ Promote Waste-to-Resource Policies – The government should encourage poultry waste utilization through subsidies, tax incentives, and integration into national waste management strategies.
- ❖ Awareness & Training Programs – Campaigns should raise awareness among poultry businesses, marriage halls, and local communities about the economic value of chicken bone by-products.
- ❖ Support Industrial Scaling – Investment in machinery, cold storage, and transport infrastructure should be facilitated to ensure the large-scale adoption of bone by-product industries.
- ❖ Research & Innovation – Encourage R&D in advanced processing technologies (e.g., hydrothermal, enzymatic, or thermochemical conversion) to diversify the product range and improve efficiency.
- ❖ Regulatory Framework – Develop environmental and food safety regulations to standardize quality, ensure consumer trust, and align with international export standards

REFERENCES

A.Ali, K.Gulraiz, M.Munir (2020). POULTRY WASTE MANAGEMENT OPTIONS AND OPPORTUNITIES:

A SHORT REVIEW. *Journal of Natural and Applied Sciences Pakistan, Vol 2 (2), 2020 pp 472-484*

Agblevor, F. A., Beis, S., Kim, S. S., Tarrant, R., & Mante, N. O. (2010). Biocrude oils from the fast pyrolysis of poultry litter and hardwood. *Waste ma.nagement*, *30*(2), 298-307.

Bee, S. L., Mariatti, M., Ahmad, N., Yahaya, B. H., & Hamid, Z. A. (2019). Effect of the calcination temperature on the properties of natural hydroxyapatite derived from chicken bone wastes. Materials Today: Proceedings, 16, 1876-1885.

Can You Compost Chicken Bones? A Complete Guide - GreenCitizen

Deydier, E., Guilet, R., Sarda, S., & Sharrock, P. (2005). Physical and chemical characterisation of crude meat and bone meal combustion residue:“waste or raw material?”. Journal of hazardous materials, 121(1-3), 141-148.

Farooq, M., Ramli, A., & Naeem, A. (2015). Biodiesel production from low FFA waste cooking oil using heterogeneous catalyst derived from chicken bones. *Renewable Energy*, *76*, 362-368.

Gangrade, K. D. (1982). Methods of data collection: Questionnaire and schedule. *Journal of the Indian Law Institute*, *24*(4), 713-722

Hicks, T. M., & Verbeek, C. J. R. (2016). Meat industry protein by-products: sources and characteristics.

In *Protein byproducts* (pp. 37-61). Academic Press.

Irshad, S., Nawaz, A., Walayat, N., Khan, M. R., Ahmad, N., Khalifa, I., ... & Luo, X. (2024). Insights into the engineering parameters and Ca-peptide chelation of whole fish: Chemistry, structure and in vitro digestibility characteristics. *Journal of Food Engineering*, *365*, 111826.

Iskakov, R., & Sugirbay, A. (2023). Technologies for the Rational Use of Animal Waste: A Review. *Sustainability*, *15*(3), 2278.

Jayathilakan, K., Sultana, K., Radhakrishna, K., & Bawa, A. S. (2012). Utilization of byproducts and waste materials from meat, poultry and fish processing industries: a review. *Journal of food science and technology*, *49*, 278-293.

Khan, N., Naushad, M., Fahad, S., Faisal, S., Shehzad, F., & Khan, U. Poultry Farming Industry Contribution in the World Economy.

Kong, X., Qiu, X., Li, P., Li, Y., Zhang, Y., Guo, X., & Kong, F. (2024). Enhancement of nutrient bioaccessibility and functional property of chicken bone powder through steam explosion. *Journal of Agriculture and Food Research*, *15*, 100941.

Kowalski, Z., & Krupa-Żuczek, K. (2007). A model of the meat waste management. *Polish Journal of Chemical Technology*, *9*(4), 91-97.

Kowalski, Z., Muradin, M., Kulczycka, J., & Makara, A. (2021). Comparative analysis of meat bone meal and meat bone combustion using the life cycle assessment method.

Energies, 14(11), 3292.

Leng, L., Zhang, J., Xu, S., **ong, Q., Xu, X., Li, J., & Huang, H. (2019). Meat & bone meal (MBM) incineration ash for phosphate removal from wastewater and afterward phosphorus recovery. Journal of Cleaner Production, 238, 117960.

Macavei, M. G., Gheorghe, V. C., Ionescu, G., Volceanov, A., Pătrașcu, R., Mărculescu, C., & Magdziarz,

A. (2024). Thermochemical Conversion of Animal-Derived Waste: A Mini-Review with a Focus on Chicken Bone Waste. Processes, 12(2), 358.

McGauran, T., Dunne, N., Smyth, B. M., & Cunningham, E. (2021). Feasibility of the use of poultry waste as polymer additives and implications for energy, cost and carbon. *Journal of cleaner production*, *291*, 125948.

Ministry of Finance, "Pakistan Economic Survey 2011-2012," Government of Pakistan, Islamabad, 2012. MNFSR (2016) Govt. of Pakistan, Ministry of National Food Security & Research.

Ng, K. S., & Sadhukhan, J. (2011). Techno-economic performance analysis of bio-oil based Fischer- Tropsch and CHP synthesis platform. *Biomass and Bioenergy*, *35*(7), 3218-3234.

Ng, K. S., Zhang, N., & Sadhukhan, J. (2013). Techno-economic analysis of polygeneration systems with carbon capture and storage and CO2 reuse. *Chemical engineering journal*, *219*, 96-108.

Pakistan Credit Rating Agency (PACRA)., *Poultry Sector Study*, September 2023 PPA (Pakistan Poultry Association) *Present Status of Poultry Sector*

Samad, Abdul & Hamza, Muhammad & Muazzam, Ayesha & Ahad, Abdul & Shah, Rabbya & Fatima, Tehreem & Liaqat, Nouman & Hanif, Muzamil & Husnain, Ali. (2022). POULTRY BUSINESS IN PAKISTAN, PROBLEMS AND THEIR POSSIBLE SOLUTIONS.

Sarrion, A., Ipiales, R. P., de la Rubia, M. A., Mohedano, A. F., & Diaz, E. (2023). Chicken meat and bone meal valorization by hydrothermal treatment and anaerobic digestion: Biofuel production and nutrient recovery. *Renewable Energy*, *204*, 652-660.

Shahzad, K., Narodoslawsky, M., Sagir, M., Ali, N., Ali, S., Rashid, M. I., ... & Koller, M. (2017). Techno- economic feasibility of waste biorefinery: Using slaughtering waste streams as starting material for biopolyester production. Waste management, 67, 73-85.

Sheha, M., Mohammadi, K., & Powell, K. (2021). Techno-economic analysis of the impact of dynamic electricity prices on solar penetration in a smart grid environment with distributed energy storage. *Applied Energy*, *282*, 116168.

shen How, B., & Lam, H. L. (2018). Sustainability evaluation for biomass supply chain synthesis: novel principal component analysis (PCA) aided optimisation approach. *Journal of Cleaner Production*, *189*, 941-961.

Singh, P., Mondal, T., Sharma, R., Mahalakshmi, N., & Gupta, M. (2018). Poultry waste management. *Int.*

J. Curr. Microbiol. App. Sci, *7*(8), 701-712.

Staroń, P., Kowalski, Z., Staroń, A., & Banach, M. (2017). Thermal treatment of waste from the meat industry in high scale rotary kiln. *International Journal of Environmental Science and Technology*, *14*, 1157-1168.

Vikman, M., Siipola, V., Kanerva, H., Slizyte, R., & Wikberg, H. (2017). Poultry by-products as potential source of nutrients. *Adv. Recycl. Waste Mang*, *2*, 1-5.

Wan, Y. K., Sadhukhan, J., Ng, K. S., & Ng, D. K. (2016). Techno-economic evaluations for feasibility of sago-based biorefinery, Part 1: Alternative energy systems. *Chemical Engineering Research and Design*, *107*, 263-279.

Wang, S., Wei, Z., & Wang, L. (2024). Improving slaughterhouse byproducts utilization via anaerobic digestion, composting, and rendering. *Renewable and Sustainable Energy Reviews*, *189*, 113881.

Wang, Y., Feng, T., Xia, Q., Zhou, C., & Cao, J. (2022). The Influence of comminuting methods on the structure, morphology, and calcium release of chicken bones. Frontiers in

Nutrition, 9, 910435.

Zhang, L., Ren, J., & Bai, W. (2023). A Review of Poultry Waste-to-Wealth: Technological Progress, Modeling and Simulation Studies, and Economic-Environmental and Social Sustainability. *Sustainability*, *15*(7), 5620.

APPENDIX

Five-star; near Samna bad

In Lahore there are lot of marriage halls but I have gone only four marriage halls because these marriage halls are very famous and most of chicken is made in these halls. Firstly, I have gone five-star hotel its location is near Samna bad and I have Took interview to manager of this marriage hall he said in this marriage hall arrange and cook 30kg chicken for 100 peoples.
According to scientist in hen 10-20% bones are in body so I can collect 6kg bones from this marriage hall. https://www.google.com.pk/search?sca_esv=100a8d72724cfbcd&q=five+star+marriage+hall+gulshan-e-ravi+lahore&tbm=isch&source=lnms&prmd=ivsnbz&sa=X&ved=2ahUKEwjCy-Hjy4qFAxXhefEDHQpaCCEQ0pQJegQIERAB&biw=1242&bih=583&dpr=1.1#imgrc=fJa7NzafwpkypM
Second day I was go to Noor mahal for conduct interview because I was want to know that in this marriage hall how much chicken is used for cooking. The owner os this hall said me that approximately every day 20kg chicken cook for 50 plus peoples. I can also get 4kg bones from this all.https://www.google.com.pk/search?sca_esv=100a8d72724cfbcd&hl=en-GB&q=noor+mahal+banquet+hall+lahore&tbm=isch&source=lnms&prmd=ivnsbz&sa=X&ved=2ahUKEwjOjfTRzoqFAxX1g_0HHa9hDiMQ0pQJegQIDhAB&biw=1242&bih=583&dpr=1.1#imgrc=k9bPaTAXnmLzyM

Noor mahal Near; Los
Topaz complex is near johar town I have go to this hall because in this place 40kg chicken are made for 120 plus peoples. I can get more bones from this hall approximately16kg bones can collect in low price.https://www.google.com.pk/search?sca_esv=100a8d72724cfbcd&hl=en-GB&q=topaz+complex&tbm=isch&source=lnms&prmd=ivsnbz&sa=X&ved=2ahUKEwjuv8qo0IqFAxXdSPEDHR8SALcQ0pQJegQIDBAB&biw=1242&bih=583&dpr=1.1
Topaz complex near; johar town.

Lastly I was go to Gulshan Ravi for conduct the interview of worker of Anmol marriage hall. Worker said that 40kg chicken are used for cooking different dishes. And worker also ready to sale bone in low price. Approximately I can get 16kg bones from this hall.
https://www.google.com.pk/search?sca_esv=100a8d72724cfbcd&hl=en-GB&q=anmol+shadi+hall&tbm=isch&source=lnms&prmd=ivsnbz&sa=X&ved=2ahUKEwjGoOH40oqFAxVihv0HHUlTBfMQ0pQJegQIDhAB&biw=1242&bih=583&dpr=1.1
Anmol marriage hall Near; Gulshan Ravi.