Meat Factory Cell: Assisting meat processors address sustainability in meat production

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***Abstract*— This paper briefly provides a brief overview of the novel Meat Factory Cell and discusses its concept in the context of increasing sustainability in the meat sector. Job quality, environment, health risks, industrial development and education are discussed as sustainability goals that can be mapped against some of the United Nations sustainable development goals (SDG).**

I. Introduction

The meat sector has often been put under the spotlight in recent times. Opponents often emphasise the poor green credentials of the sector (i.e., high carbon footprint, high waste), the poor working conditions and the male dominance in, particularly, primary processing lines. Furthermore, for small- and medium-scale processors, access to the latest innovations in respect of automation are economically impractical. Even for large-scale processors, investment in new technology is a decision that will affect their business operation for decades, limiting flexibility and expansion of production volumes.

Macro-scale meat consumption continues to increase and is expected to continue to do so at least for the next decade. The meat industry must therefore be proactive in adapting whilst acting responsibly and sustainably – in part that means supporting and utilising innovative automation technologies. The authors are engaged in the development of one such technology, the so-called *Meat Factory Cell* (MFC), which aims to consider the options for future abattoirs, where automation could be accessible to a broad range of meat processors, and not only the elite few with extremely high production capacity [1].

In this paper a brief overview of the MFC concept is provided and is discussed in terms of five key sustainability goals including job quality, environment, health risks, industry development and education and are mapped against some of the 17 Sustainable Development Goals (SDGs) being driven by the United Nations campaign for action to address the global challenges faced by the world [2].

II. Meat Factory Cell Concept

The RoBUTCHER concept enables an autonomous MFC. The main emphasis of the project is research into AI and cognitive systems, which will provide the necessary understanding for the cell to interact with raw material (e.g., a carcass) through physical tasks like cutting, grasping and lifting. The AI must be aware of the carcass anatomy, combining this knowledge with real-time 3D imagery and training input from expert human operators, to predict cutting trajectories. In order to test the AI, physical tools have been created for both cutting and grasping, both of which are challenging areas given the heterogenous and flexible nature of the material.

An overview of the RoBUTCHER MFC infrastructure already developed at NMBU in Norway is shown in Figure 1. The MFC consists of two robotic arms ABB IRB4600-40/2,55 for up to 40 kg payload and 2.5m reach and IRB4600-60/2,05 with up to 60kg payload and 2.05m reach. A gripping tool is attached to the IRB4600-60 to provide manipulation and grasping of meat parts such as limbs, for example, whilst the second IRB4600-40 has a cutting tool and together they are planned to work autonomously and in unison to complete the primal cuts of a red meat carcass that is supported on the Carcass Handling Unit (CHU).

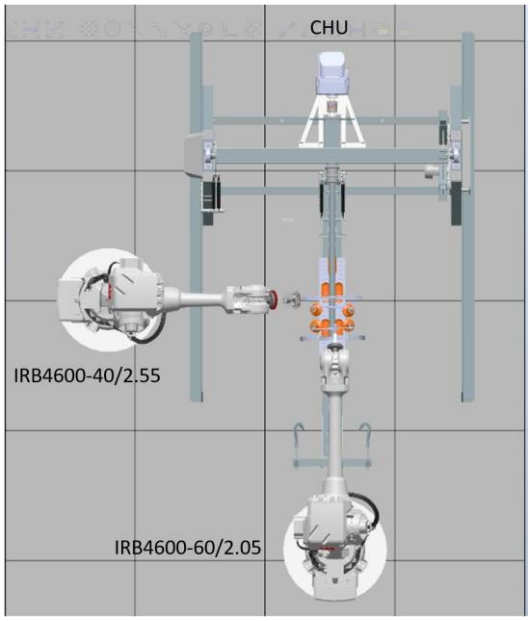

Figure 1. RobotStudio plan of RoBUTCHER Meat Factory Cell (MFC) showing cutting robot IRB4600-40/2.5, gripping and manipulating robot IRB4600-60/2.05 and carcass handling unit (CHU). Image by Steven Ross, NMBU.

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To this existing infrastructure bespoke computer vision systems have been fitted and will eventually replace the physical and cognitive functions of a human operator currently used for machine training.

III. Sustainability Goals

The MFC can be discussed in terms of sustainability goals, particularly those noted below:

A. Job quality

Workers in slaughter houses and cutting halls perform repetitive precision functions involving the preparation of meat – typically cutting, trimming, lifting and stretching. The concentration of the meat processing industry has led to de-skilling and harder working conditions with more repetitive and dangerous work tasks. This leads to a high rate of absenteeism at meat processing facilities, and over time has reduced the availability of workers for the sector.

In 2013 there were ca. 3.1 million non-fatal accidents with at least 4 days of absence and 3,674 fatal accidents recorded across the EU-28. The incidence rates per 100,000 workers ranged from less than 1 in Sweden, Greece, the UK and the Netherlands to over 4 in Latvia, Malta, Portugal and Lithuania. In addition to these accident rates, 7.4% of the workforce suffered from work-related health problems. In most countries musculoskeletal disorders were the most prominent of all health problems [3].

In 2011, Europe spent 2.1% of GDP on work-related incapacity benefits, and specifically on the direct costs of musculoskeletal disorders, with back pain and rheumatoid arthritis in the European workforce costing over €12 billion and €45 billion per year, respectively. At national level, the UK estimates the financial impact of workplace injuries and illnesses to be £14 billion. In the Netherlands, the direct financial impact of workplace injuries and illness resulted in medical costs of €76 million, with absenteeism leading to another €200 million loss [4]. In some parts of Norway, health related issues account for ca. 8% absenteeism in slaughter houses and can be as high as 20% in deboning rooms.

The RoBUTCHER project focuses on the meat industry for which recent (2018) occupational reports reveal a great potential for workplace amelioration [5]. In most EU countries, the industry increasingly employs mainly male meat processors of foreign origin. Companies are also increasingly employing workers on temporary contracts with low levels of employment protection, retaining skilled workers only for special tasks such as supervision, operation of highly automated machines or quality control.

Covid-19 has increased this pressure by reducing the possibility for migration (e.g., within Europe), which many in the sector rely upon. Three elements that determine job quality are as follows:

- *Earnings quality:* This reflects how salaries contribute to worker well-being and includes the level of an individual's earnings as well as the equity of wage distribution across the workforce (i.e. the social comparison). RoBUTCHER seeks to ensure that meat producers across Europe can retain skilled workers who will naturally have higher earnings, since they not only have knowledge of the cutting or slaughtering process, but also be able to interact with equipment via teleoperation.
- *Labour market security:* This reflects the probability and economic cost of job loss, which comprises risk and expected duration of unemployment. By developing systems that will encourage workers to have highly developed and variable skill sets, the RoBUTCHER MFC will improve workers chances of retaining employment. Furthermore, with the burden of repetitive tasks being taken on by the robotic systems within the cell, the project will reduce the number of EU workers who must give up work for health or disability reasons which are derived from the working environment. This figure can exceed 30% of the overall workforce in some EU countries.
- *Quality of the working environment:* This to how the characteristics of work impact on worker wellbeing and satisfaction and is measured based on the balance between job demand and job resources. This is an area where RoBUTCHER will make a significant contribution, as the MFC concept alleviates many of the pressures faced by workers in the meat sector today by providing greater autonomous resource. It is envisaged also that the workers can develop environments which can be characterised as trusting and inclusive, where they can work together with the robotic systems rather than competing with them. The MFC concept ensures a two-way relationship; on the one hand the MFC can request assistance where its AI raises uncertainty, and on the other the human operator can teach the AI how to adapt to the situation in which that uncertainty arose. This is a marked difference to the situation today, where workers feel under pressure to compete with the automation systems to ensure efficiency.

Systems like the MFC will have a positive impact on job quality since it will necessitate improved skill-levels of workers in meat processers, reducing the need for repetitive tasks and increasing their earning potential. As highlighted earlier, the meat sector, particularly in slaughter and deboning, is male dominated – one report suggests that of all workers in butchery, less than 1% are female [6]. RoBUTCHER, through its human–robot interface (teleoperation) approach, will open the meat sector to greater inclusivity and create a working environment that is equitable regardless of gender. In terms of the United Nations SDG's, the MFC can support positive action against SDG 03 Good Health and Wellbeing, SDG 05 Gender Equality SDG and SDG08 Decent work and economic growth, it can also be argued that SDG 01 No poverty, could be included in this.

B. Environment

In the EU, around 88 million tonnes of food waste is generated annually, with ca. 17 million tonnes of total food waste are associated with processing. Pig meat waste due to processing attributes 6%, equating to 948,000t [7]. In meat processing, such waste is often associated with events including:

- *Line stops:* The present line approach to meat production is intolerant to faults. Therefore, if the line is halted (e.g. due to mechanical failure, injury or quality issue), all production throughout the line is impacted. The sensitivity of the raw material to spoilage can, in the worst case, result in significant product loss as waste.

The MFC concept ensures that a producer with multiple cells operating in parallel would be able to continue production at a lower capacity if one of the cells stops operating, while the cause of failure is sought and rectified.

- *Product damage and consistency:* The use of low-skill manual labour in most slaughter houses and cutting halls leads to varying levels of consistency in end-product quality and yield. Typical examples can include poor cutting consistency (e.g., fat or muscle separation varies from operation to operation), over or under trimming and floor waste (i.e., dropping parts). This is compounded by the physical and tiring nature of the work, where workers are under pressure to perform several hundred operations per hour.
- *Environment for continuous development:* The investments in line-organised plants comes with great risk. The chosen solutions are basically expected to last for 20-30 years. When a line has been installed, only incremental improvement can take place and often just to overcome shortages with the solutions. Cell organisation creates a unique opportunity for constant development of processes with a significant degree of freedom for adaptation and faster implementation of new technology. New approaches can be tested and validated in a cell and then rolled out when a solution is documented with supreme functionality and productivity.

Systems like the MFC will provide the benefits of robust automation, providing parallel processing opportunities (as opposed to today's linear processing). Furthermore, robotics systems couple with artificial intelligence offer possibilities for greater consistency, while specially adapted tools will reduce food damage. The flexibility of the advanced robotic systems will enable process- and product-development.

Improvements made in waste reduction will help reduce the amount of pig meat required for production and conversely improve carbon emissions from both the production and waste disposal. Further to this MFC approach has resulted in a new way of slaughter. This method combines some actions from slaughter and primary cutting in comparison with the industry practise today which have significant implications for cooling requirements. Current practise for most producers is to cool split carcasses after grading these weigh ca. 30-50kg, and therefore take hours to cool. With the combined MFC approach, the output from the cell comprises much smaller parts, with the heaviest most likely being the ham (in pork production), which weights ca. 15-20kg, Smaller parts take significantly less time to cool, and there are also discussions that such parts could go directly for further processing, eliminating mass cooling entirely [8]. Refrigeration in meat processing accounts for 16% of energy consumption in the European meat sector, thus the innovative RoBUTCHER approach reduces the environmental impact of meat production [9]. Therefore, the MFC approach coupled to savings made from meat cooling practices shows great potential towards positive actions against United Nations SDG 13 Climate action. Furthermore, it could be argued that a reduction in food waste would also generate positive action towards SDG 02 Zero Hunger.

C. Health risks

The unavoidable systematic weaknesses of the slaughter process, combined with slaughterer non-compliance to hygienic procedures and the HACCP system, are the main reason for contamination. People are also a source of contamination, and its spread. Furthermore, the current conditions and layouts of meat processing plants in conjunction with working processes have led to large scale COVID-19 infection rates that has resulted plant closures across the UK [10], Germany [11], Ireland [12] and Norway [13] too name but a few. Since the beginning of the pandemic the robotics community has developed solutions to help preventing, treating and monitoring its effects [14].

With the MFC approach and automation, the industry would have better tools to manage microbial spread, quality and hygiene more effectively, reducing exposure and recalls. The impact of recalls in the industry can be severe and costly. In some instances, millions of kilos of meat must be recalled for consumer protection. Automation reduces the risk of contamination and cross contamination that is caused by people working in processing areas, including the slaughter house and cutting halls. Alvseike et al [1] performed a comparative assessment and showed that, in principle, meat inspection in the MFC approach can be significantly improved compared to procedures in conventional slaughter houses.

Planned changes to the working environment, layout and procedures that will be implemented by the MFC align with positive actions against SDG02 MFC is a driver towards food security which contributes towards the zero-hunger goal. SDG 03 Good health and Wellbeing through improved working conditions and processes reductions in process related infection spreading both across product and between workforces can be realised.

D. Industry development

The inaccessibility of widespread automation to most producers across Europe puts food security at risk and creates an ever-widening division in the sector that impacts productivity and competition. With the MFC approach and automation, the sector is presented with greater opportunities for robust, flexible and scalable automation, which will suit the

needs of processors regardless of volume. Not only will this increase competitiveness, but it will also offer prospects for new business models which can better optimise aspects of commercial aspects such as logistics and proximity of processing plants to farms, as well as equipment leasing models rather than outright ownership.

- *Robustness:* A failure, blockage, maintenance operator or some other delay at any point on a production reduces productivity by 100% for the entire duration of the event. This leads to waste, but the effect it has on productivity across the whole value chain is also important. With the MFC, failure of a single cell reduces production only within that cell, and parallel cells can continue working – therefore the risk of total productivity loss is significantly reduced. Planned maintenance is also easier with a cell structure, so the likelihood of failure can be reduced.
- *Flexibility:* Production lines offer low flexibility to change production from one species to another. While work today, including in RoBUTCHER, focuses on application for the pork sector, the MFC concept is applicable to others including lamb, beef and poultry. Furthermore, line production offers little flexibility in productivity level, arising from low production volumes, seasonal variations, etc. The MFC would enable producers to adjust productivity to suit the flow of raw material, using only those resources required to meet demand. The cell approach offers flexibility for process development and reduced risk of investment. Also, the investment can be taken gradually as old and new technology in principle can work in parallel.
- *Scalability:* A major hurdle for small and medium producers is their ability to expand their business, because expanding a production line requires significant investment in space, perhaps more so than in the equipment itself. This means that up-scaling of production cannot be incremental – large (often >50%) increases in productivity are required for expansion to be financially viable. That requires not only that the meat producer has the will and capacity, but it also requires the surrounding value chain to respond in kind to provide significantly more raw material and buy significantly more product. The RoBUTCHER approach enables more incremental scaling, thus placing less demand on the value chain to adjust in such an acute manner.
- *Quality and yield:* Automation, like that proposed in ROBUTCHER, provides opportunities for greater consistency in production, especially given the pressures on today's meat sector workforces. This will potentially improve quality traits (e.g., tenderness, colour, shape, visual appeal), in addition to overall yield.
- *Competitiveness:* The widening division between the highest volume producers and the rest of the meat sector restricts competitiveness both within and outside of Europe. Close to a third of the growth of the overall industrial output in Europe is already due to the uptake of digital technologies. Broader access to automation will enable greater levels of competitiveness (consumer benefit) in addition to enabling the European meat sector to compete with others for market share beyond its borders. The challenge ahead is for the European industry to seize fully and swiftly on new opportunities to secure medium to long term competitiveness. RoBUTCHER offers modularity which even smaller market players in limited markets (such as Hungary and Norway) could apply to the MFC concept successfully. This is in line with the ICT call document [15] which states: "The Digitising European Industry … should enable all sector and application areas to adapt, transform and benefit from digitisation, notably by allowing also smaller players to capture value."
- *New business models:* The current model for the meat supply chain is to transport animals from farms to slaughter houses. In some countries, Norway for example, this poses a logistics challenge as the transit distances can be large. Furthermore, in the winter months where temperatures are sub-zero, those journeys pose a risk to animal welfare and must be postponed. In other countries (e.g., Finland), transport trucks are insulated and heated which increases transport costs. With a cell approach, there becomes a possibility for new business models, whereby the slaughterhouse travels to the farm, in a container for example, and performs the slaughter on-site. This would significantly reduce animal welfare issues related to transport. Furthermore, to explore the idea of new business models further, many small and medium scale producers could benefit from models where the MFC is rented or leased when necessary. It can be installed at the producer's premises only for the duration of animal slaughter and meat cutting and taken away by the equipment owner to other users or to the storage. For meat producers it will eliminate the need to perform costly maintenance of the equipment. In turn, it will create a new business – renting out robots and automated MFCs to meat producers. The industrial innovation and development of the MFC will positively impact the following three United Nations sustainable development goals, SDG 08 Decent work and economic growth, SDG 09 Industry innovation and infrastructure, SDG 12 Responsible Consumption and Production.

E. Education

RoBUTCHER, an international collaboration set up to develop the MFC, seeks to generate new knowledge, which will generate impact for academia in several ways. This will lead to high-impact publications and dissemination of the knowledge gained, spin-out commercial activities, as well as formulation of new ideas and concepts. Post-project, the pilot system is envisaged as a research platform for the purposes of continued development – it will be an advanced "one of a kind"

system. This will attract new research projects, MSc and PhD students, and generate the next wave of Early Stage Researchers (ESRs) and continue knowledge generation. NMBU and OBUDAUNI also practise "research integrated teaching", so the cutting-edge research will feed into existing or new taught undergraduate and master's level programmes, seeding interest and competence in the Robotics Core Technology areas at the earliest opportunity. The Consortium will continue cooperating after the project completes, and it is anticipated to set up a framework of exchange to further enhance the relation, and to broaden the training and opportunities for students and generate interest for more women to join the field. The knowledge dissemination and workshops generated by the RoBUTCHER MFC project generates positive impact towards SDG 04 Quality Education. It will also open up opportunities for women both in industry and academia and so, SDG 05 Gender Equality is positively impacted. Finally, since the RoBUTCHER MFC has only been made possible through a successful truly international collaboration of many partners then the impact towards SDG 17 Partnerships for the Goals is obvious.

IV. Conclusion

This paper provides a brief overview of some of the sustainability benefits related to new technologies, such as the MFC approach in meat processing. It is likely that advanced automation systems will realise further sustainability, however those noted here are viewed as those with highest impact potential and can be mapped against having some positive impact towards 10 of the 17 United Nations Sustainable Development Goals (SDG).

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