final report

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Stage 2 Upscaling 3D Printed Meat

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Abstract

To maximize carcass value, low value meat trimmings are emulsified and turned into low cost/low value products such as hot dogs and dog food. Until now production options have been limited as emulsified meat has no texture and no binding properties. RS3Dprint has changed that. Through 3D printing, RS3Dprint has created a method and machine to turn low value emulsified meat trimmings into high value meat products in an economically scalable way. This method of high volume continuous 3D printing creates meat pieces with the bite/mouth feel and visual texture of butchered meat.

Based on market research, RS3Dprint believes that we can turn the meat used in low value products sold at roughly $9 US a kilo into products sold at $61 US a kilo. Through printing of meat or meat/veggie/fruit combinations not currently seen in the market, RS3Dprint has built a prototype that in the next phase we believe can take 1,576 kg of meat sold at $14,184 US and create a product that can be sold for $96,136 US; a $81,952 US difference.

With support from of Meat Livestock Australia, RS3Dprint took on a second phase of our 3D printing project to create high value meat products from low value meats through high volume continues 3D printing. This new technology has many advantages for the Australian beef industry and RS3Dprint believes that with a partner interested in scaling technology we can increase the printer head count, increase extrusion rate and other factors to print at an industrial level.

Executive summary

Executive Summary

To maximize carcass value, low value meat trimmings are emulsified and turned into low cost/low value products such as hot dogs and dog food. Until now production options have been limited as emulsified meat is a simple paste with no texture and no binding properties. RS3Dprint has changed that and created a method and machine to turn low value emulsified meat trimmings into high value meat products. This method of high volume continuous 3D printing of emulsified meat creates meat pieces with the visual, bite feel and mouth texture of butchered meat in an economically scalable way.

RS3Dprint with support from Meat livestock Australia has finished a second round of product development with the goal of turning low value meat into high value meat products. The key to the upscaling 3D printed meat project is to show that meat can be printed not as one off specialty pieces but continuously and at high volumes in order to produce products at economies of scale.

In phase one of our work with the MLA, RS3Dprint built a 3D printer that could print meat slurry into high quality meat pieces with the look, bite texture and mouth feel of butchered meat. These meat pieces were printed similar to the way other 3D food is printed; one piece at a time. The first phase was a success with the end result a high quality 3D printed meat piece similar to sliced butchered meat. This result led us to the second phase of our partnership with the MLA: upscale the printing process to continuously print meat products with the same quality as the first phase.

The process of feeding emulsified meat into the 3D printer is equivalent to feeding emulsified meat into a hotdog skin. In the production of a hot dog, the emulsifying of raw meat allows a wide use of input meats to be put into a hotdog machine which is then extruded into a skin. In RS3Dprint's process this same meat is extruded through a tube onto a moving conveyor belt and turned into textured meat sheets. While hotdogs are sold at $4 US a pound and dog food is sold at an even lower costs, based on market research of equivalent products, the meat snacks RS3Dprint produces can be sold at the higher snack rate of $28 US a pound.

Additionally the 3D printing process also allows for the combination of multiple ingredients. While varied meats such as beef and lamb can be slurried together and printed, RS3Dprint has also successfully printed beef/veggie and beef/fruit combinations. This combination of meat and fruit/veggies mass produced into texture snacks opens new markets for Australian meat producers.

For the recently completed phase 2 of our project, RS3Dprint built a single nozzle printer connected to a 25 cl syringe that prints on a continuously moving base. The injector system has capacity to hold eight syringes of any volume therefore allowing us to multiply the amount of product to whatever levels we desired. For this phase we also printed at an infusion rate of 1ml/min.

Based on partners interest and texture requirements RS3Dprint would like to build a higher single unit extruder machine connected to a multi head printer. The projected machine would occupy an area roughly a meter squared and include ten heads and increased flow rate.

The rate of 3D printing is slower than producing a hot dog but the return on volume and variety of products are exponentially higher. With the current flow rate of 1 ml/min on a ten head printer, RS3D can print 60 CL an hour. At comparable snack food prices this is equivalent to a $42 US product. With

input material and processing being equal or lower than a hotdog which sells at $4 US a pound, potential revenue from 3D printed meat snacks is significantly higher.

Additionally while we currently print single layer pieces of meat good for snack foods, RS3Dprint has previously demonstrated (in phase 1) the ability to print multi layer pieces of meat through cryolithography. Cryolithography is the process of stacking multiple layers of biological material while freezing the pieces together. This has two distinct advantages, the first being the preservation of the biological material from spoilage while the second directing all fibers in a single direction to create a continuous piece of meat. Combining the technique of cryolithography and mass production of single layer 3D printed meat, RS3D can give meat producers even higher value meat products from low value meat.

Consumers are looking for new healthy, high protein low fat snacks and products and 3D printing is a way to give consumers what they want. There have been multiple developments in the field of 3D printed food. BeeHex, Foodini and Jet-Eats all print single item foods such as pizza, chocolate and breads. There is an annual 3D food printing conference in The Netherlands called the “3D food printing conference” where manufacturers of 3D printers go to show their latest printed desserts. Recently an academic book titled “Fundamentals of 3D Food Printing and Applications” by Professor Bhesh Bhandari of the University of Queensland was published. As the title suggests, this book discusses current applications and processes of 3D printing food. RS3Dprint very proud to have our work mentioned in the final chapter “Future Outlook of 3D Food printing” which covers upcoming innovations in the field.

While other companies are 3D printing food, RS3Dprint is the only company that is focused on the mass production of high value meat products. With support from the MLA RS3Dprint took on the next phase of upscaling of printed meat project and set out to complete the two main project components:

The first component was to enable continuous printing of sheets of meat. These sheets would then be turned into meat floss; a fried, fluffy meat snack popular in Asian cultures.

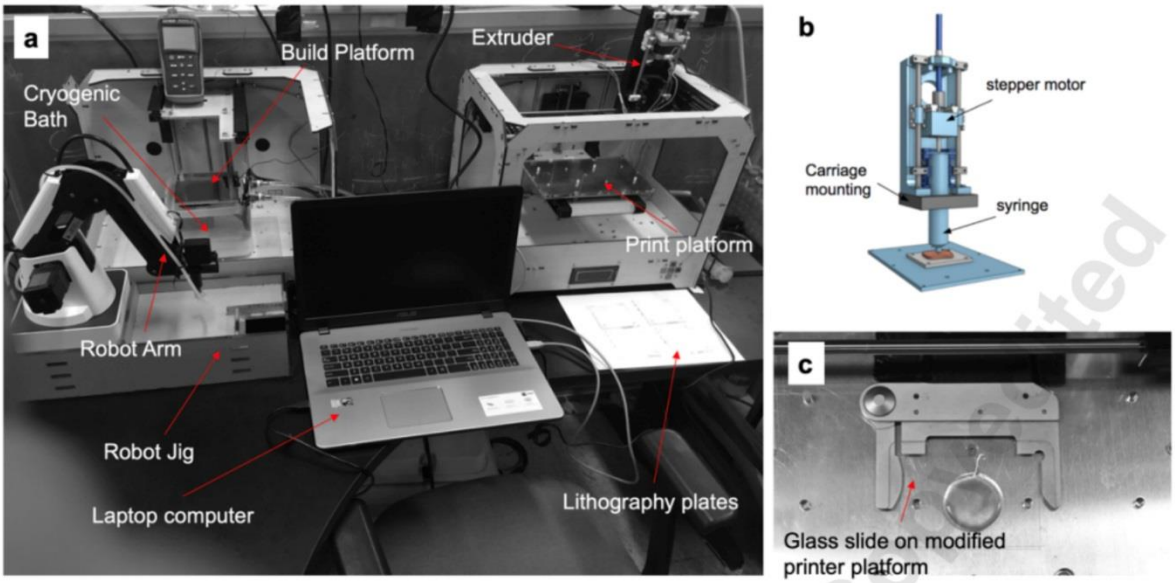
The second component was a market research report around the opportunity and acceptance of 3D printed meat snacks.

The final results reached the goals set forth by this project: continuous printing of high volumes of meat and market research that has shown a large market, product acceptance and opportunities for 3D printed meat snacks.

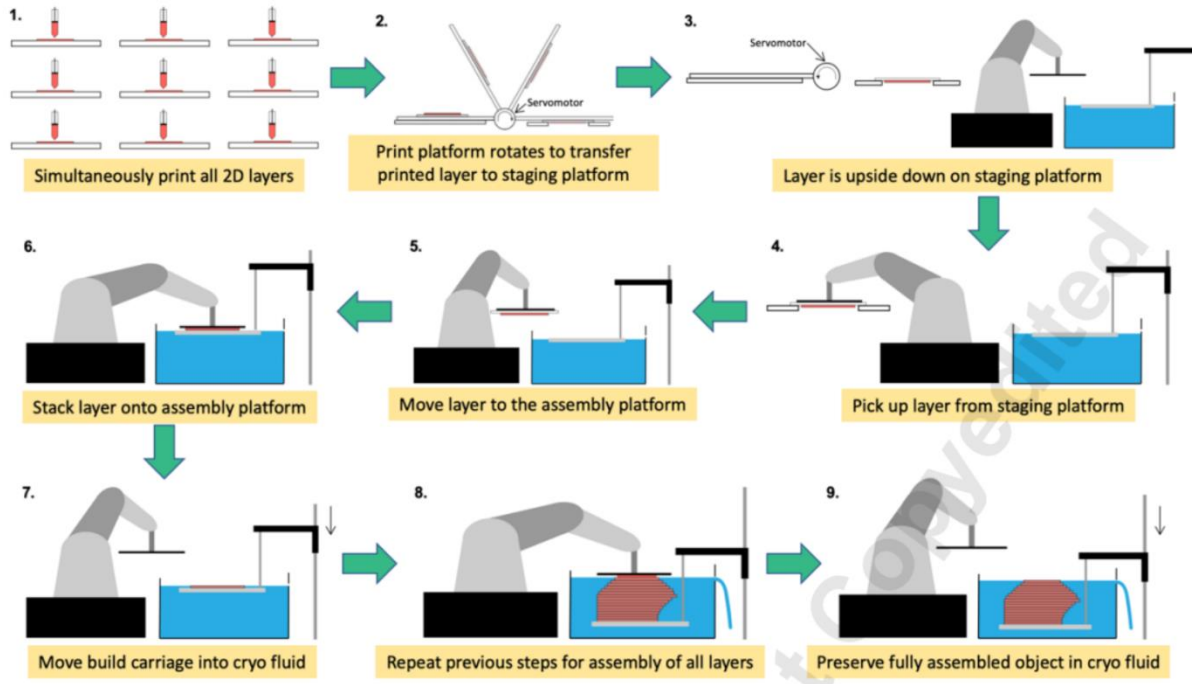
Table of contents

1 Background

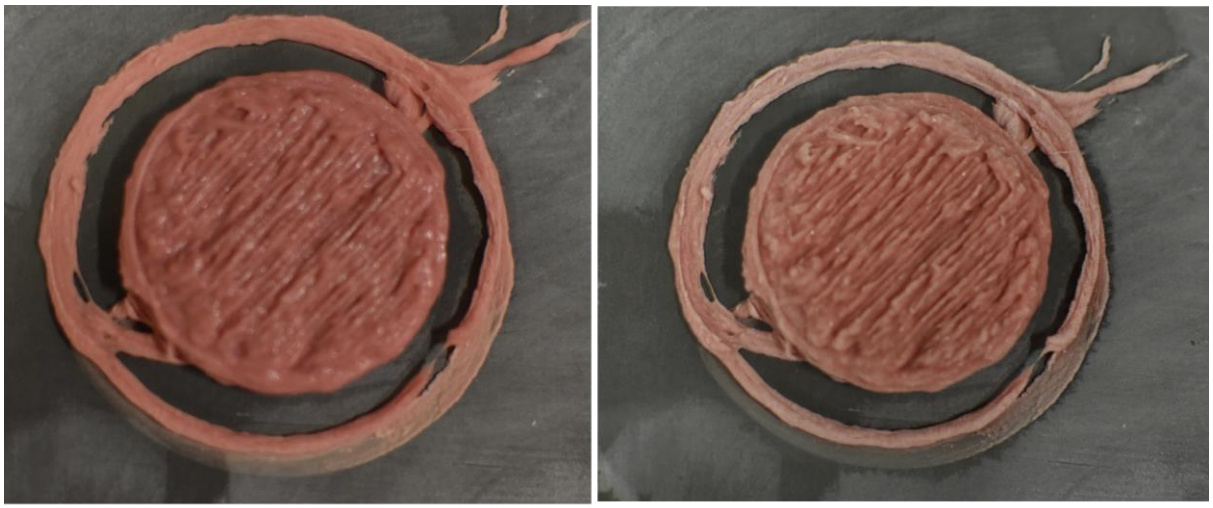
In phase one of our work with Meat Livestock Australia, RS3D built a 3D printer that could print emulsified meat into pieces of meat with the look and mouth texture of butchered meat. These meat pieces were printed similar to the way other 3D food is printed; one piece at a time. This is a slow process with multiple manual steps. In the original project the volume of printing was also limited to the extruder used. This extruder being less than 10 cl meant that the size of the printed meat was small. To show the development of large scale products we introduced a robotic arm to layer subsequent printed meat pieces one atop the other. Through a process of cryolithography we were able to freeze one layer of meat onto the next create a multi layer piece of meat with the same properties as butchered meat.



(image of printer and robotic arm. Robotic arm would take a printed layer of meat and submerge it into a liquid nitrogen bath to freeze layer upon layer)



(Multi layer meat printing process)



RAW STEAK

FROZEN STEAK

(Multi layer raw and frozen steak – This steak was frozen on a cold plate)

While the end results of the project were successful, unless we could figure a way to increase the volume and speed of the printed meat, this project would not be a viable option for Australian beef and lamb producers.

Based on the results of the first phase a second phase of the project was introduced. The overarching aim of this project was to design and build a 3D printing machine that could turns the tonnes of low value meat trimmings the Australia meat industry creates every year into high value meat products. Technically this meant RS3Dprint had to upscale the printing process to continuously print high volumes of meat products with the same quality as the first phase.

The second part of phase 2 was to create research exploring the size, opportunities and acceptance of the 3D printed meat market. This could lead Australian meat producers to understand that with the

3D printer RS3Dprint designed, could open new market for the meat trimmings most commonly reserved for low value meat products.

2 Project objectives

1. Validate the market opportunity for (Australian origin) Beef Floss

2. Design and deliver CAD drawings for 3D meat floss printer that builds on the CryoLithography design from stage 1 (V.RMH.0001)

3. Demonstrate meat floss printer working (minimum target 1-2 pounds at a time) – video footage, along with capability to be cooked and flossed.

4. Complete preliminary product specifications (including photos) and bills of material yields and costings plus cook-up assessments of proof of concept printed meat floss

5. Send a sample bag of printed meat floss to MLA's Washington and/or North Sydney Australia office

6. Submit progress and final report to MLA.

3 Results

3.1 Engineering results

The basis of RS3D and MLA working together has been the goal of turning low value meat into high value meat products. The first product agreed upon was meat floss. Meat floss is a stringy and fluffy meat snack similar in texture to cotton candy. Meat is boiled, smashed, fried after which the fibres are pulled apart.

RS3D hit a road block early on in our experiments. The meat printed by RS3D is very thin and while it has the macro texture of butchered meat, RS3D has not been able to get down to the microstructure of butchered meat. That microstructure of extremely fine fibres is what we believe is needed for meat floss.

This drawback was reported to MLA early in the process and in a conversation on December 19, 2018 in an e-mail exchange titled "Meat Printing Update and Feedback Request" we jointly signed off that RS3D could not produce meat floss but would instead revert to snack concepts that included meat, meat and veggie and meat and fruit.

RS3D quickly focused our engineering research on two main parts needed for a scalable continuous meat printing machine: A continuous surface area to print emulsified meat and providing a continuous supply of slurry.

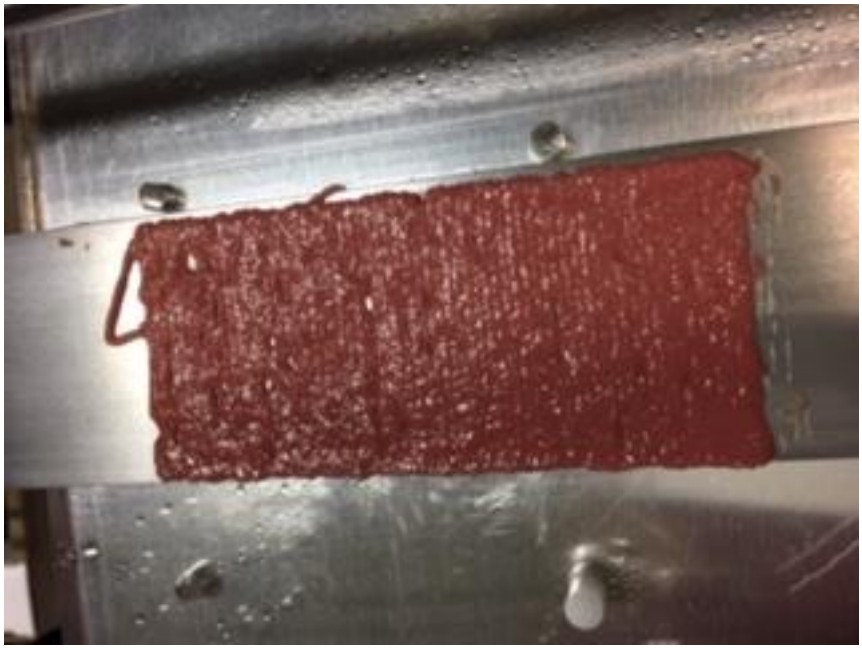
The continuous printing machine has two key parts to it that allow us to continuously print meat. The first part we focused on was the conveyor belt. Currently 3D printing is done on an X,Y,Z plain where a printer prints a base and then prints one layer upon the other. With the conveyor belt, the 3D printer is only printing on an X plain with the conveyor belt creating the Y plain. In short, it's like a

piece of paper going through a paper printer; the ink jet goes back and forth while the paper moves forward.

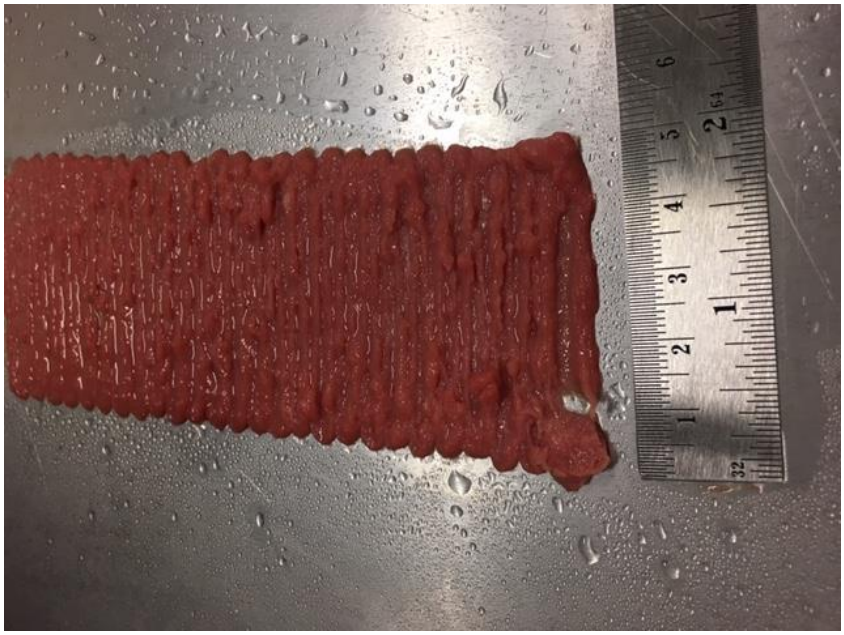
After moving away from the printing of meat floss and instead focusing on the printing of meat pieces, we moved from a small printer head to one with a 2mm nozzle. There was little difference in the appearance of the original printed meat and the new 2mm nozzle printed meat. However the speed of extrusion was significantly higher.

Through testing different extrusion, nozzle and conveyor belt rates we found that different consistencies were created. The extrusion rate, the print rate and the conveyor belt rate all must work together to achieve the consistency and texture desired.

Eventually we determined an optimal printing and conveyor belt speed as well as the optimal extrusion rate to consistently print a sheet of meat with graining similar to butchered meat. Not only were we able to produce on a continuous level but we were able to print a piece of meat that did not break apart and maintained its structure and texture. Our printing process solved for the major problem mentioned in MLA's 'Review of market acceptance and value proposition for 3D printed meat', that of "using a liquid form of raw material and controlling the liquid coming out of the extruder".



(3D printed meat)



(3D printed meat wet from cross linker)

We cooked it in several ways

Such as pan fried, oven baked, boiled and microwaved.

The boiled and microwaved versions had an unpleasant look to them. The fried meat was tasty, gave a good mouth feel similar to eating a thin piece of steak. At the end the oven dried process was the real winner.

(Boiled 3D printed meat)

(Microwaved 3D printed meat)

(Pan fried 3D printed meat)

(Oven dried 3D printed meat chips)

The meat was baked in an almost oven drying method for roughly five minutes. The meat chips came out crunchy, with great meat flavour and addictive.

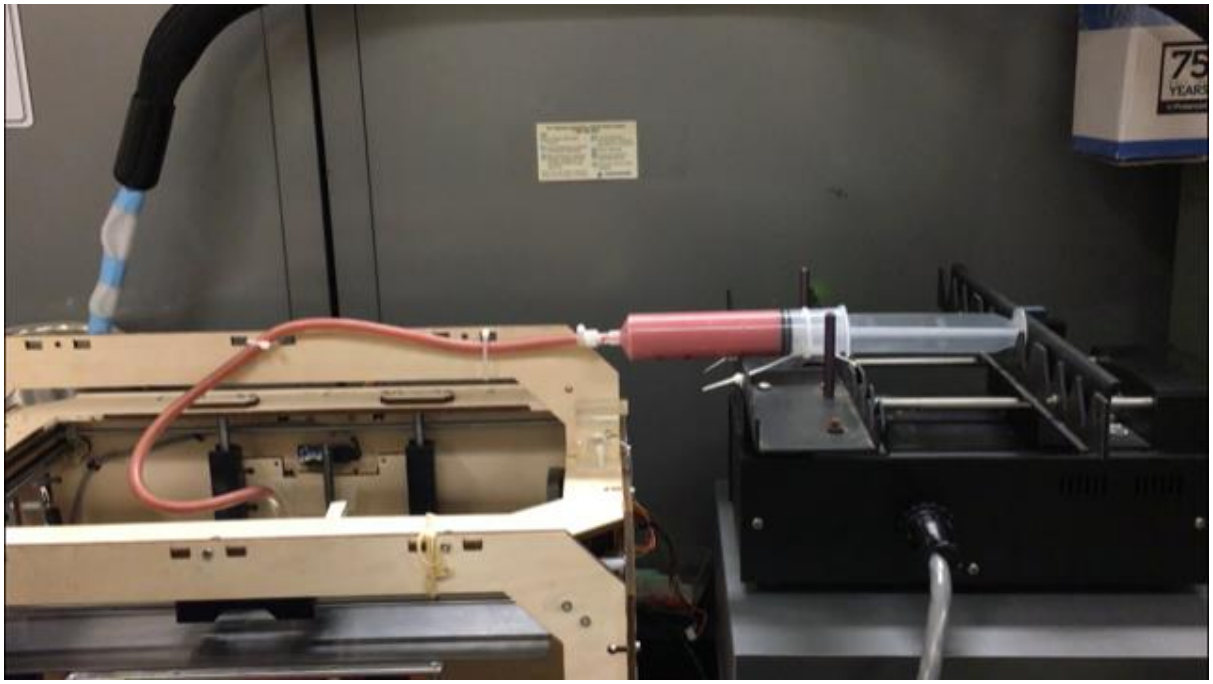
Notice the fine graining lines in the fried and baked chips (also somewhat visible on the boiled meat). These graining lines turn out to be very important for the cooking process as we later learned through an experiment.

In order to determine if the printing process was necessary or if we could simply take the meat slurry through the crosslinking process without printing, we ran a couple of experiments. We created an even layer of slurried meat and alginate and used the same cross linker in the printed version. We then proceeded to fry and bake the examples. The fried version was terrible. The results were squishy and unappetizing in every way. There was no butcher meat mouth texture or chew. The baked version did not cook consistently and gave an unsatisfying and uneven texture. Reflecting on this difference we determined that the ridges in the printed version allowed for a crunchiness to be created that could not happen when there was a uniformity to the texture.

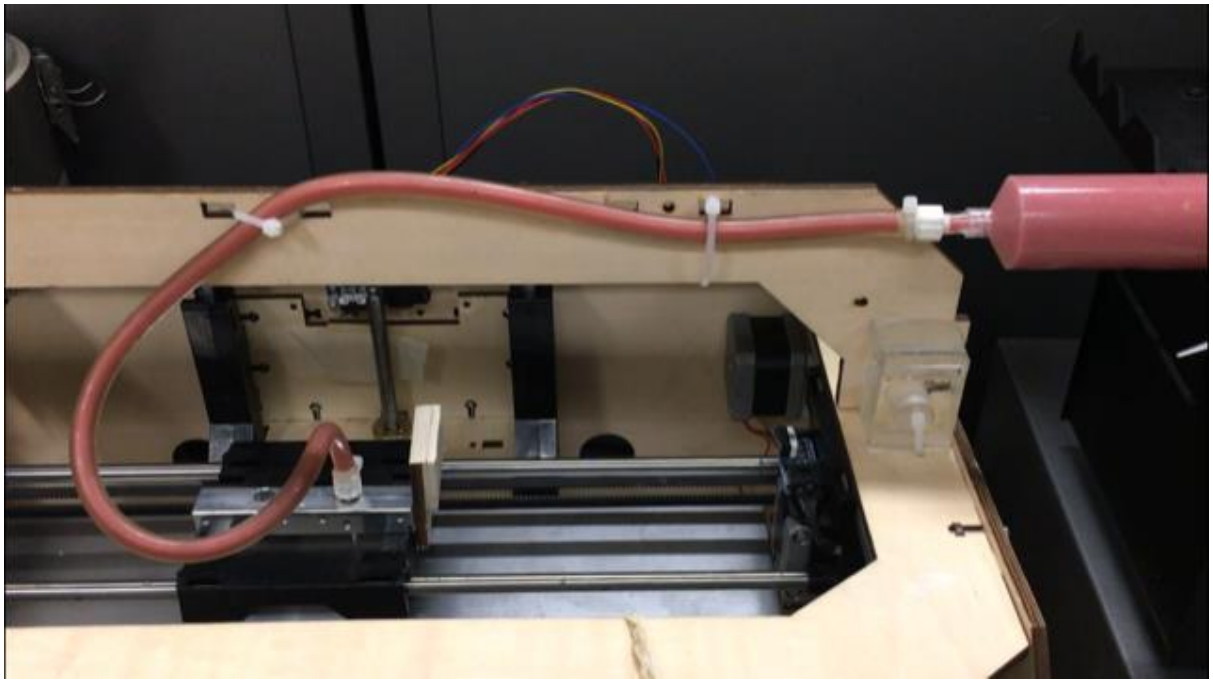
Upon discussion with the MLA another method of cooking was suggested but never tired; air cooking. We believe this method would have a very good outcome resulting in a evenly cooked piece of meat with great bite and mouth feel.

The second part of the project needed for continuous meat printing is the high volume extruder. For this part of the project we purchased a commercial grade syringe pusher. This syringe pusher can hold up to eight syringes of varying volumes. For our purposes we used a 25cl syringe but could have put eight 40 cl syringes and combined them.

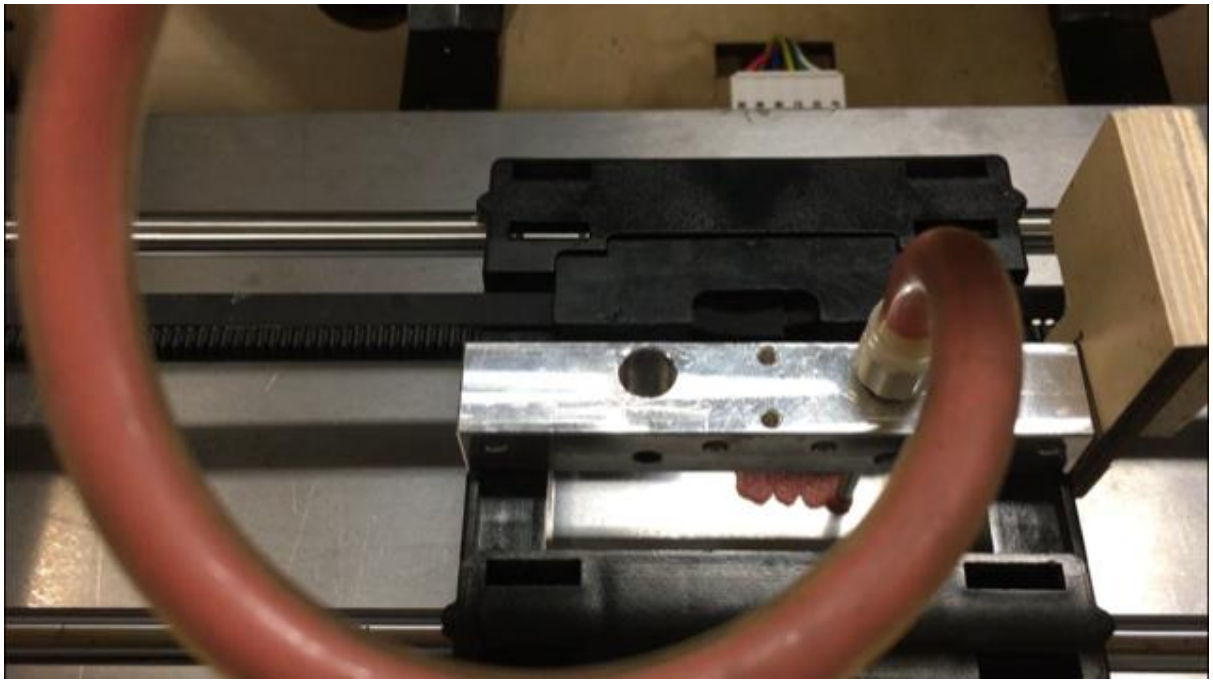
The syringe was attached to a tube that was then attached to the 2mm syringe head. We modified the printing apparatus by drilling a hole big enough for the syringe head to rest. The tube allowed for the printing apparatus to continuously travel back and forth on the X access while being fed through the tube which itself was being fed by the syringe. With the high volume of meat slurry available, the printing plate could run continuously.



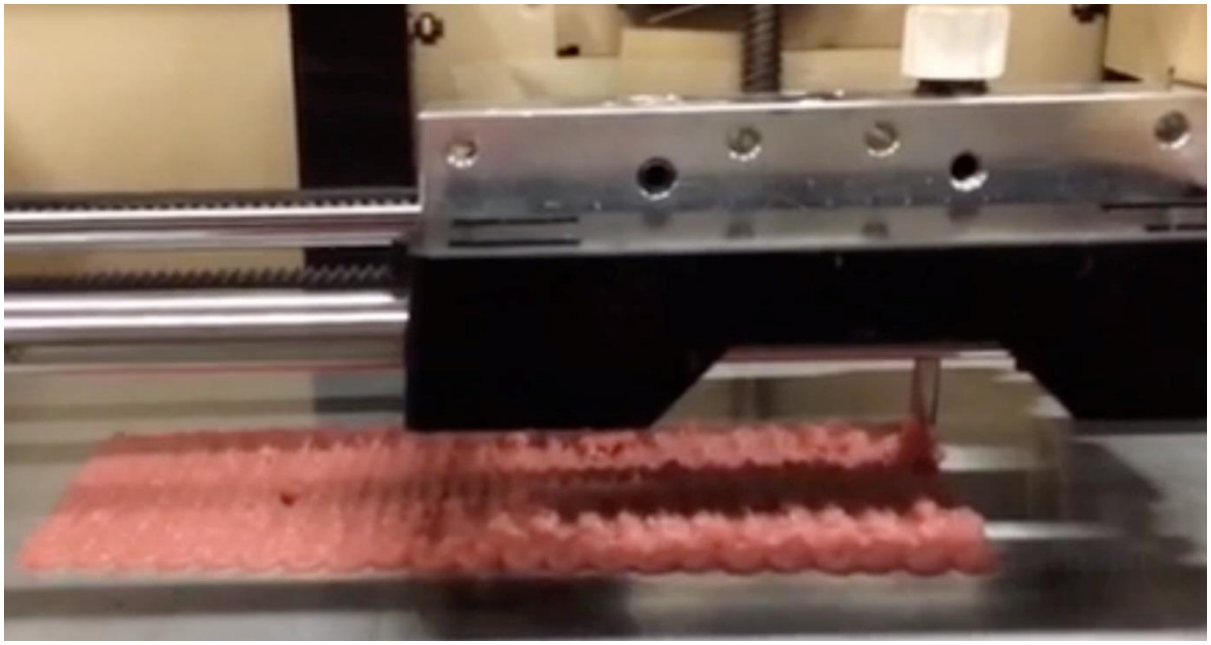
(Syringe in pusher attached to tubing)



(Syringe, Tubing and 3D printing Nozzle)



(3D printing nozzle extruding emulsified meat)



(Printing a layer of meat)

As previously discussed, RS3D shifted from focusing on meat floss to meat, meat and veggies and meat and fruit snacks (Meat +). Everything printed must first be turned into a slurry so for the fruit and veggies we used an already available fruit and veggie slurry: applesauce and baby food pouches. We mixed both apple sauce and a veggie/fruit sauce with our meat slurry and went through the printing process. The additives were mixed on a one to one ratio to the meat. The results were nearly identical to meat printing only.

(Store bought vegetable slurry)

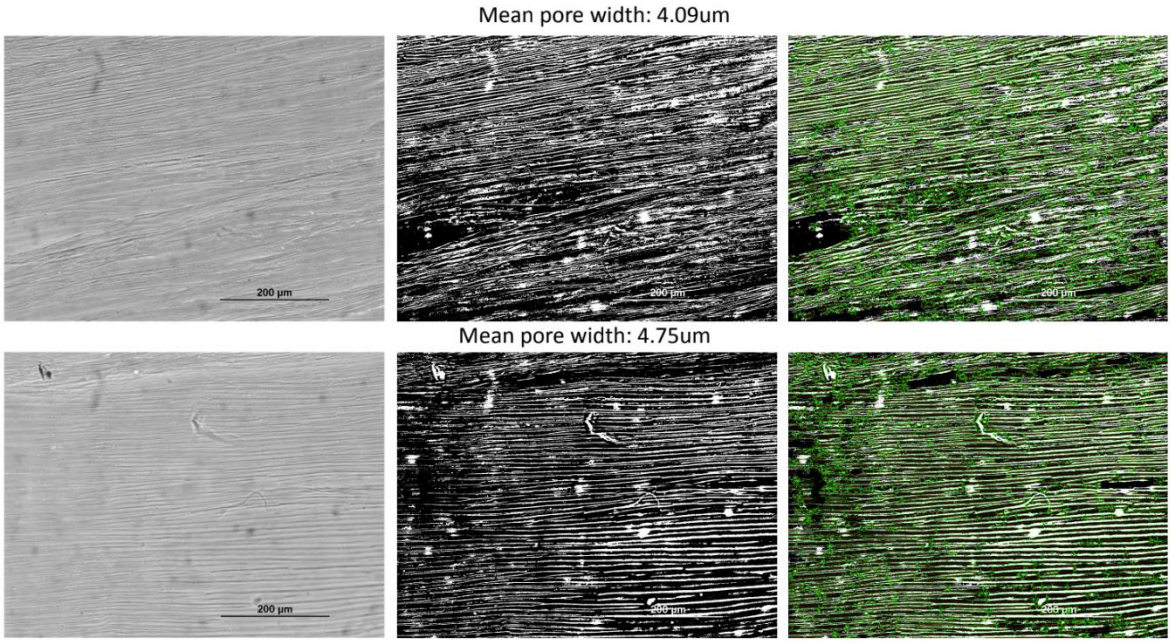
(Meat slurry, Meat and applesauce, Meat and vegetables)

When first printed, the meat plus additive was a little runny and the veggie product had a green tint. We can correct the runny aspect by decreasing the ratio of meat to fruits/veggies or increasing the ratio of alginate to additives. In general, the texture and results of printing a meat only slurry and a meat slurry that includes fruits or vegetables are indistinguishable.

While RS3Dprint was working on the 3D printer, a side project has yielded very interesting results that might help with meat texture and possibly the 3D printing of meat floss in the future.

Using alginate, we have been able to create a microstructure of fibres consistently of roughly 4.5 um. These fibres are thinner than muscle fibre which range from 10-80um.

Image analysis yielded consistent results



At this point we can't determine if this will bring us closer to meat floss but we believe that even printing the macro structure meat as we currently do and taking it through the process of creating the micro structure will bring us a texture even closer to butchered meat.

With the printer printing consistently, regardless of the contents of the slurry, we were able to start assessing the printing speed and volume of the 3D printer. For this phase of the project we have only used a one head printer from which we have extrapolated speed and volume.

We printed for 17 minutes with an extrusion rate of 1ml/min resulting in a section roughly 17 ml by volume. The velocity of printing was 7mm/min resulted in a segment 120 mm by 50 mm.

We believe that we can house at least six heads in our current printer box size and have the CAD drawings below to reflect that thought. Eventually we can increase the size of the printer box to fit more heads. Extrapolating these numbers to one year (365 days of printing at 12 hour days) we think a machine that is 3.5 feet by 7 feet with six heads can print and cook 1,576 kg of meat per year. At an input price for meat trim of $9* US a kg ($14,184.00) and sales price for meat snacks of $61* US a kg (96,136) the additional value of 3D printed meat snacks over conventional uses of emulsified meat would be $81,952 in additional value over putting the same product into current products.

*See Appendix Section 1

In the appendix below is our conceptual model of 3.5 feet by 7 foot printing table. These images are to give a general idea of the process and layout. The process would include the high volume extruder, the six printer heads, crosslinking station and cooking station as well. The results of a machine of this nature would be a fully printed and cooked meat chip.

3.2 Market Research Results **(Full marketing Report in Appendix)**

A large part of the objectives for this project was the market research of meat snacks. This milestone allowed RS3D to contract with Tiki Hut Brands, a food marketing research firm to determine and validate the marketplace opportunities for 3D printed snack foods.

RS3D was excited by this report as we saw a real push by major producers and retailers to try and create high value meat/protein snack foods.

- Cargill has a patent on a "new class of food that is crispy, tasty, and low in carbohydrates and has substantial levels of egg white protein and suitable shelf life for packaging in ready to eat form."
    - While we are not sure how they can produce these, RS3D believes our printing technology could.

- Whole foods sells Wilde chips which are made out of chicken
-
- Dietz and Watson have "meat nuts".
-

Below are highlights directly from the research.

3.2.1 Highlights:

Following an extensive 45-day period of research and conversation, there are clearly pathway and corridors of opportunity that highlight a marketplace opportunity for RS3Dprint in the meat market.

The direct factors that support a market, include:

- Global Food Factors shifting towards lower impact and higher value foods
- Supply Chain opportunities for more flexible manufacturing
- The 'Blur-ology' between tech + food, food + wellness, environment + edibility
- Consumer Trends towards 'better' solutions (better for me, better for planet) and 'convenient on-demand protein'
- A very significant number of Early Innovators and Industry Competition
- Retail/Shopper Trends towards convenient, on-demand protein and 'protein in every aisle'

3.2.2 Potential Corridors of Opportunity

Most exciting to us, because of the meat chips that we produced, was the section on Potential Corridors of Opportunity which we believe highlighted our competitive advantage.

- Convenience:

    "Consumers want satiating food that is easy and quick to fit their time-poor lifestyles. Consumers know protein to be satiating and protein snacks fit well into this category. Simply put, 3D printed food products can offer a lot of convenience."

- Environmental Sustainability:

    "…the benefit for meat that is produced via 3D printing is that it reduces waste per carcass"

- Product Differentiation:

> "Like a little more spice? A little more chew? A little less sodium? On a restricted diet? Only eat Halal meat? There's a solution for that. 3D meat printing offers the possibility to create nutrition tailored to any group's dietary needs"

- Meat Snacks

> "Whether it's beef jerky, meat sticks, bars, biltong or other, meat snacks are big business and have become an indispensable component of today's consumers' diet."

4 Discussion

4.1 Practical Discussion

3D printing of meat and meat + has many advantages and practical applications within the meat industry.

- Increased use of the carcass; meat trimmings can be used for purposed other than hotdogs, filler and dog food. This not only saves money on waste but gives a higher return on the cost of the carcass.
- Expansion of product offerings with meat and meat + snacks; Introducing new markets to high protein, high nutrition, low fat convenient meat snacks.
- Finally and most important of all is that 3D printing can turn low value meat into high value meat products.

For these advantages to come to fruition RS3Dprint must partner with a meat producer interested in producing meat snacks. While RS3Dprint can build the machines and engineer a printer at various levels, we are not familiar with the throughput needed for industrial level snack production. All our engineering is on a scientific level. We believe that with a meat producer interested in turning this technology into a scalable item, we can increase the printer head count, increase extrusion rate and other factors to print at an industrial level. However we need to partner with someone who can give us feedback and requirements to hit.

4.2 Hitting Project Objectives

- Validate the market opportunity for (Australian origin) Beef Floss
    - We found quickly in our research that the meat produced was not conducive to producing meat floss. The printed meat was too thin and did not have the micro fibers needed to shred into hair sized fibers. This issue as immediately reported to the MLA and we decided to continue our research in the direction of meat and meat + snacks.
    - The market opportunity for meat and meat + items was validated on many fronts. Acceptance of 3D printed meat is high, there is a desire for high protein/low fat meat snacks and there is movement for convenient ways of eating protein.

- Design and deliver CAD drawings for 3D meat floss printer that builds on the CryoLithography design from stage 1 (V.RMH.0001)

  - RS3Dprint delivered CAD drawings for a 3D printed meat snack printer that builds on the cryolithography design from stage 1. This design describes the process of extrusion of emulsified meat, through the printing, crosslinking and cooking process.

- Demonstrate meat floss printer working (minimum target 1-2 pounds at a time) – video footage, along with capability to be cooked and flossed.
  - A video was produced and sent to the MLA showing the extrusion of meat from a high volume syringe (meat in syringe and meat in tube is just less than a pound) onto a moving platform.
  - Images of cooked meat were also attached to this report showing various cooking techniques and their outcomes. (Section 3.1)

- Complete preliminary product specifications (including photos) and bills of material yields and costings plus cook-up assessments of proof of concept printed meat floss
  - Calculations for meat printing and costing are included in this report in section 3.1
    - Current extrusion rate of 1ml/min
    - Six head printer will produce 36 CL and hour
    - At $61 US a kilo this produces a $22 US product per hour
      - (Extrusion speed, volume and texture can be configured to match producer specifications)
  - Photos of full printer and its parts included in section 3.1

- Send a sample bag of printed meat floss to MLA's Washington and/or North Sydney Australia office
  - Had in-person meeting with MLA representative to present both raw and cooked printed meat. Discussed cooking technique, felt elasticity of product and results and feedback were both positive.

- Submit progress and final report to MLA.
  - Both delivered within agreed upon timeframe

5 Conclusions/recommendations

5.1 Heading

5.1.1 Sub heading

RS3D can print meat and meat + on a continuous basis with no volume limitations. The market research has shown a pathway and opportunities for 3D printed meat snacks.

At this point we believe that we can create a reproduceable low-cost high-volume 3D printer to be used for snack food products in a short amount of time. Through printing and volume optimization we can also increase volume output to an industrial scale.

RS3D is still a scientific research company and would need a partner and additional funding in order to increase volume printing to an industrial level. This however is a matter of understanding the needs of a producer interested in partnering with RS3Dprint.

Because of the state of experiments and proof that have already been achieved, we believe we would need a relatively low capital infusion of $750,000 for two years of funding. This $750,000 would allow us to work with a production partner to understand the levels needed for production level output and build to those specifications. The machine manufacturing process would take less than a year and the printers could be installed in a partner's food manufacturing plant shortly after.

6 Key messages

6.1 3D printing brings a new market to the meat industry

There are four take aways from this report and the research that RS3Dprint has done.

1) There is a market for 3D printed meat and 3D printed meat +
2) This market has not been breached yet so there is a first mover advantage
3) 3D printing meat allows you to use more meat from a carcass
4) RS3Dprint can turn low value meat into high value meat products

7 Appendix

7.1.1 Numbers for calculations

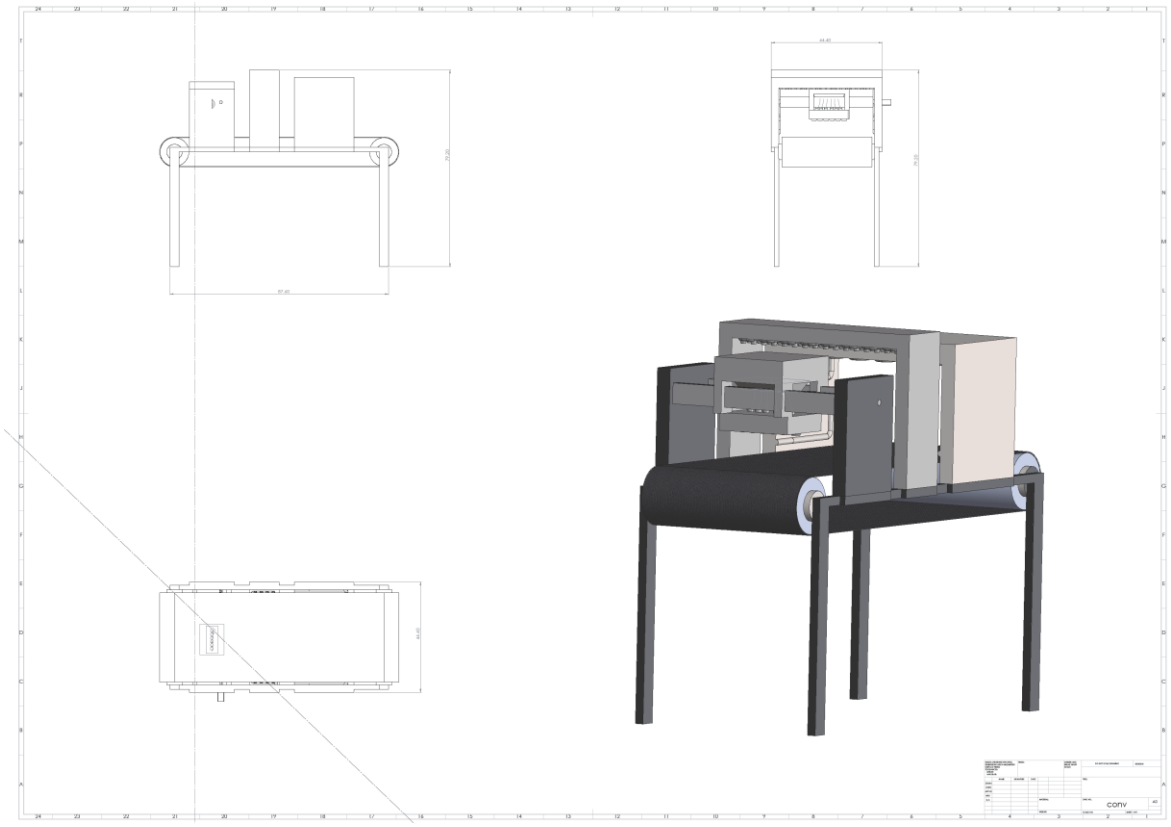
Price for ground beef: $3.74 in 2018 (rounded to $4 a pound) - $9 a kg

https://www.statista.com/statistics/236776/retail-price-of-ground-beef-in-the-united-states/

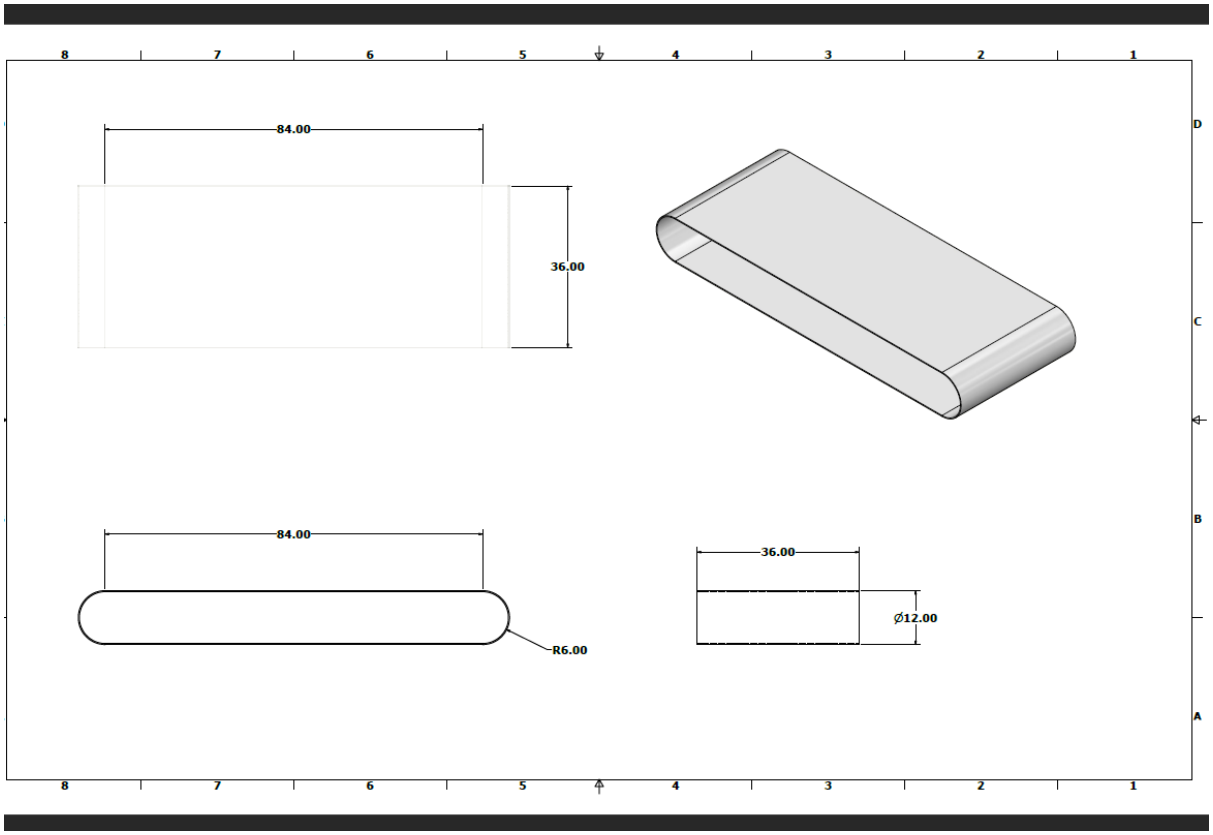
Price of snack food: Wilde Chicken Chips sell at $4 for 2.25 oz equalling $28 a pound - $61 a kg

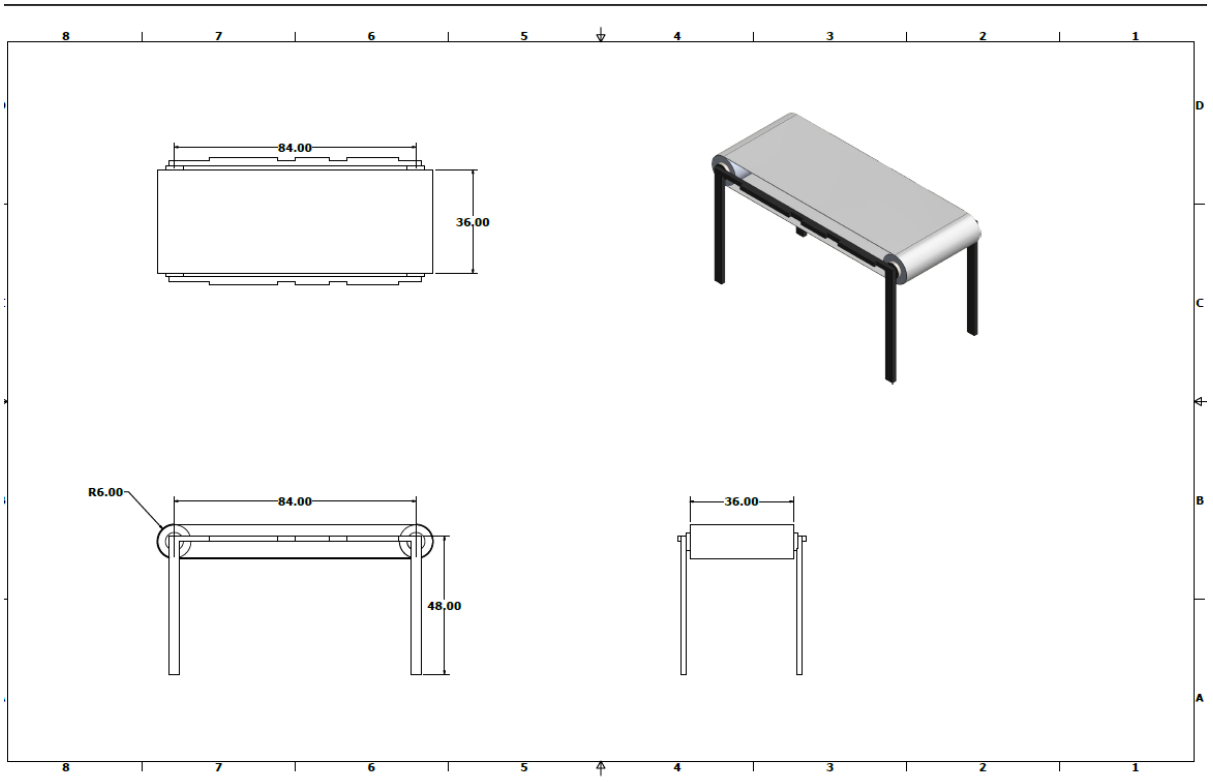
https://www.wildebrands.com/collections/chips

7.1.2 Full Process Machine

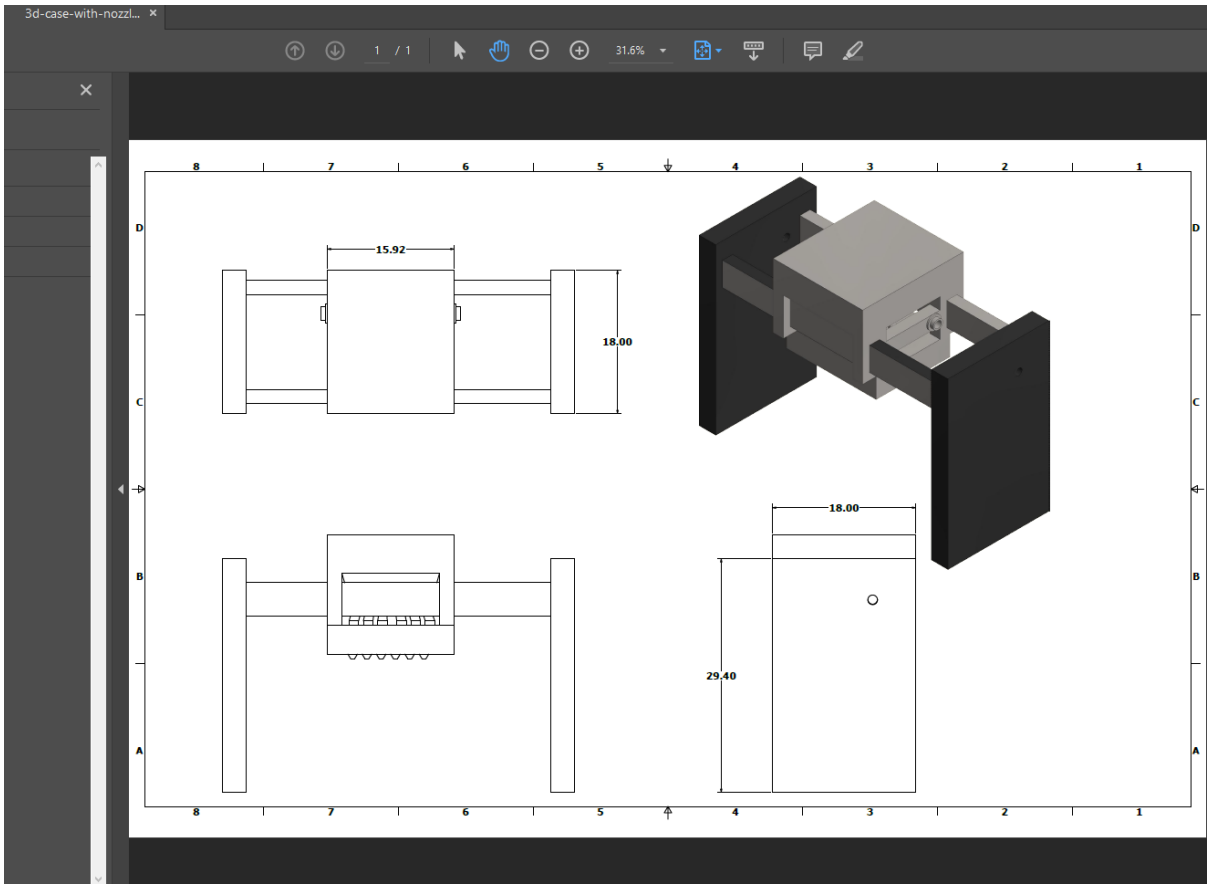


7.1.3 Conveyor Belt



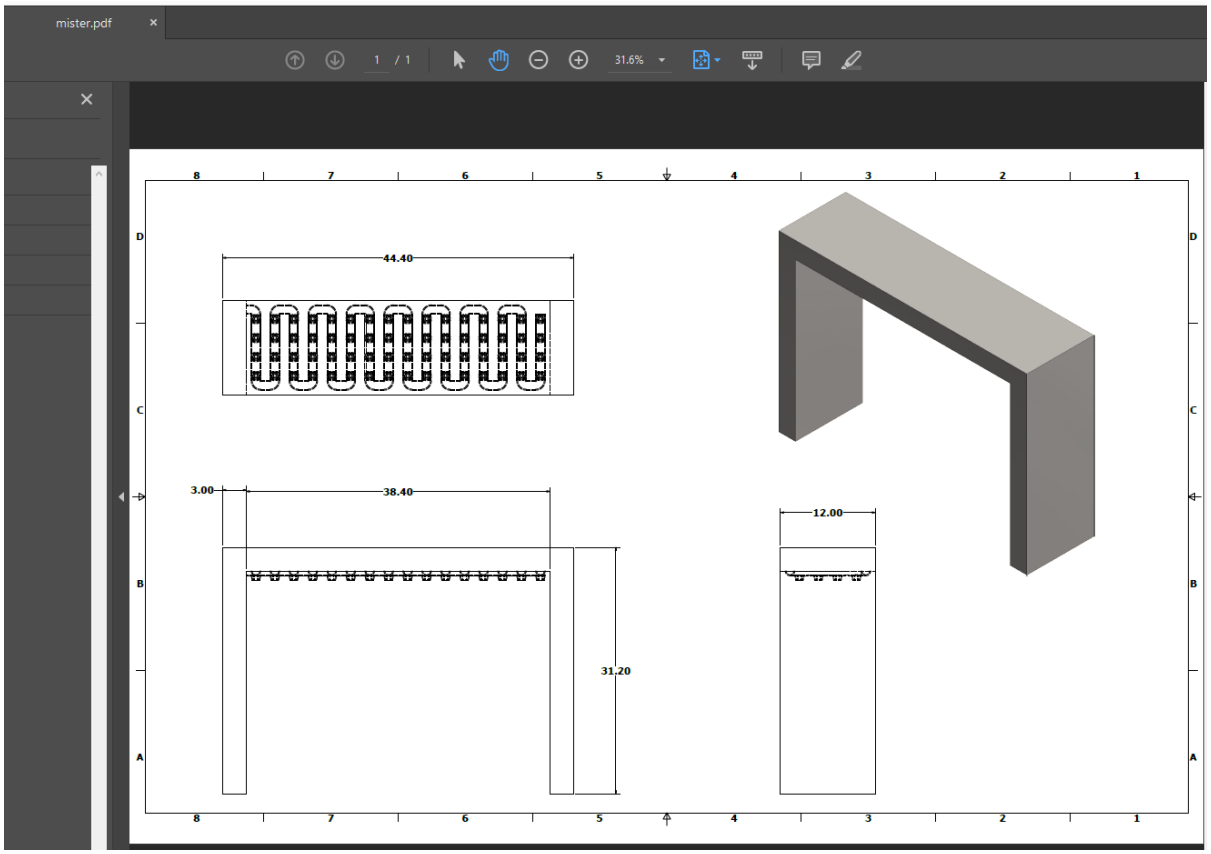


7.1.4 3D Printer



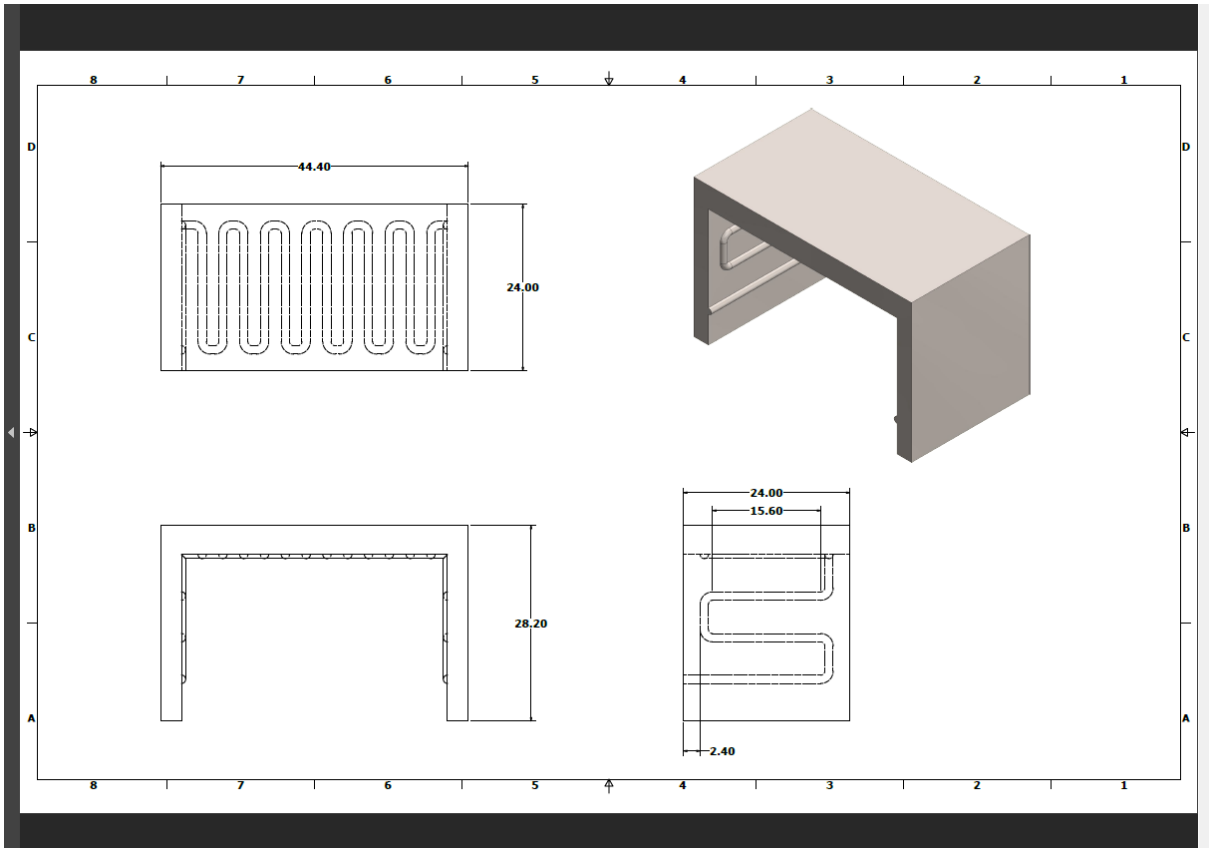
Please note the height of the nozzle is not to scale

7.1.5 Crosslinking Station



In our current diagram we are working with a liquid crosslinker. Based on alginate, there is also an ability to crosslink using UV light. This would give an added advantage of sterilization.

7.1.6 Oven



7.2 Marketing Report

3D Meat

Market Opportunity

Deep Dive

Prepared for **RS3Dprint**

by Tiki Hut Brands, LLC

March 2019

TABLE OF CONTENTS

ABOUT THIS REPORT

The research included in this report is derived from Tiki Hut Brands, LLC analysis of primary and secondary industry research. It includes information from conversations with a variety of leaders within the meat, retail, and innovation industries. Additional analysis came from extensive review of secondary resources, directories, company websites, annual reports, and investor presentations.

The report makes use of databases, such as Hoovers, Bloomberg, Crunchbase, Businessweek, Statista and Factiva to collect useful information for an extensive, market-oriented, and commercial study of the potential corridors of opportunity. This was done to obtain crucial information about the industry's value chain, key players, prevalent technologies, different verticals, and food types.

The information contained herein is based on expectations, estimates and projections as of the date such information is available. Any recommendation contained in this report may not be suitable for all investors or businesses. Market conclusions are, necessarily, based upon multiple estimates and assumptions that, while considered reasonable by Tiki Hut Brands as of the date of such statements, are inherently subject to market fluctuations and business, economic and competitive uncertainties and contingencies. While care is taken when making such statements, no guarantees are made to the complete accuracy of such recommendations, estimates and assumptions.

EXECUTIVE SUMMARY

RS3DPrint has developed multiple patents to improve 3D printing for the food sector. The resulting printing process brings new innovation and improvements to how meat can be printed. This opens up greater commercial applications and appeal as the meat industry is estimated to be valued at $67BN in the United States alone.

The immediate and high-value opportunity is to create more value for the meat market taking low value meat and transforming it into higher value at scale.

Tiki Hut Brands, LLC was engaged to research potential marketplace corridors of opportunity for 3D Printed Meat in commercial volume in the United States (as well as understanding and unearthing other, related opportunities).

Following an extensive 45-day period of research and conversation, there are clearly pathway and corridors of opportunity that highlight a marketplace opportunity for RS3Dprint in the meat market.

The direct factors that support a market, include:

- Global Food Factors shifting towards lower impact and higher value foods
- Supply Chain opportunities for more flexible manufacturing
- The 'Blur-ology' between tech + food, food + wellness, environment + edibility
- Consumer Trends towards 'better' solutions (better for me, better for planet) and 'convenient on-demand protein'
- A very significant number of Early Innovators and Industry Competition
- High Value Market opportunities (retail, healthcare, government)
- Retail/Shopper Trends towards convenient, on-demand protein and 'protein in every aisle'

Four different Value Drivers have been determined based on the nexus of what is known about RS3Dprint's technology combined with close-in and longer-term market opportunities:

Meat: Opportunities based on the advantages delivered by 3D printing

Meat +: Opportunities to enhance meat given 3D printing

My Meat: Opportunities based on the precision and customization power of 3D printing

Not Meat: Opportunities from the technology not including traditional meat

These factors and other will be addressed in detail over the remainder of this report.

BACKGROUND

The meat industry is big business.

United States meat production totaled close to 52 billion pounds in 2017, with the industry processing 32.2 million cattle, 2.2 million sheep and 121 million hogs. The industry constantly seeks growth opportunities, including new markets, improving value (through incremental revenue, pricing, value-adds, etc) and increasing forms of offerings.

3D printing is a relatively new technology still in the relatively early stages. The technology allows for production of everything from plastics, metal, ceramics and now, food. The food industry has experimented with the 3D printing of food, including everything from pasta to potato chips. It is an area that has shown some promise for protein as well.

Today, companies are developing “meat” grown from stem cells printed into steaks. Others are using 3D printing to create veggie-based meat alternatives. Still others are using 3D printing for real meat on a smaller scale which has included “small batch” offerings or single restaurant-only opportunities. To date, these have been more “curiosity” versus “mass consumption”.

All of the above has value and may create potential corridors of opportunity. However, there exists an even bigger commercial-sized opportunity for the industry that has yet been fully explored.

Currently, one-third of each animal slaughtered ends up as relatively “low value” trimmings. Often used for burgers or animal feed, rather than “higher value” meat or steaks which command multiples of five, ten, or even fifteen times the value.

The opportunity to create more value for the meat market – taking low value meat and transforming it into higher value at scale – is a large one.

It is this opportunity that RS3Dprint is exploring.

Tiki Hut Brands, LLC was engaged to research potential marketplace corridors of opportunity for 3D printed meat in commercial volume in the United States (as well as understanding and unearthing other, related opportunities).

This document provides discovery based on extensive industry research including primary interviews with industry leaders, secondary research of existing (online and offline) resources.

Introduction

New technology is often able to take advantage of significant opportunities.

Over the last decade, the food industry has witnessed a massive transformation, owing to the increasing global demand for sustainable food manufacturing and delivery systems. Rising global population and high-income growth have resulted in increased concerns regarding food security across the globe. Various food processors and technology innovators are developing numerous sustainable food production systems.

As compared to the conventional food manufacturing system, 3D printing technology, though at a nascent stage, has the ability to supply food to an ever-increasing global population. With the rapid technological advancements, 3D food printing is expected to present an extensive amount of opportunities to revolutionize the global food industry.

That being said there is still not concrete market evidence of the exact size, neither globally nor only in the US. However, the opportunity can be extrapolated based on the available data of 3D food printing industry and the market trends and growth.

At the surface level, 3D printing of food offers a large number of advantages over traditional food manufacturing systems. Technological advancements in the field of 3D food printing have resulted in an increased level of food customization, longer shelf-life, and benefits to transportation as well, thus reducing overall production cost and increasing efficiency.

Every aspect of eating – from how food looks, to the nutrition it delivers, to the impact it makes on our environment – is being transformed by the 3-D printing industry. Since there are no creative limits to 3-D printing, it's our imaginations and appetites that will dictate how far this technology can take our taste buds.

The key question at this stage of technology development is whether 3D printed meat products are feasible, at scale. Can it work? Who will benefit? What markets will be interested? What are the impacts to industry? What is the long-term impact?

MARKET INSIGHTS

It's critical to identify relevant present and future market insights to help identify and prioritize any business opportunity. This is especially true as marketplaces are dynamic, constantly shifting and highly interrelated. Combining existing business knowledge with the economic, human and financial forces shaping the world bring proper context to understand business opportunities. Understanding market insights requires more than simple analysis. It requires a forecast of market shifts based on global consumer trends in addition to an understanding of any category and competition. Trends often manifest themselves first as seemingly small shifts in the world or a business which, when aggregated globally, are leading indicators of marketplace change.

When looking for market insights, the macro and micro are deliberately combined to anticipate the future to help prepare for it. This is done through the **4 Lens Analysis** to guide an in-depth

understanding of any System in the content of the market. This is a sequential process that drives better exploration of the dynamics encountered, better explain what can be learned as it relates to a business, and expand on that learning to exploit opportunities.

HUMAN AND CULTURAL INSIGHTS

Human and Cultural Insights provide deeper context on people's lives that enable a business to capitalize on present-day opportunities and anticipate future ones. It is important to move from simply describing current reality to identify forces and drivers that have the potential to shape the environment over the next five to ten years.

While secondary data sources and information are used to perform this analysis, immersion via spending time in the market observing, experiencing and learning has always been and always will be the best insights gathering tool. Human and Cultural Insights require looking at the market through multiple lenses. Doing this to source inputs and develop insights will help determine the most powerful corridors of opportunity for a business.

Macro Forces

Macro Forces are large contextual shifts that impact large numbers of people for extended periods of time. Macro Forces are valuable in long-term strategy development and represent considerable risk to organizations who ignore them.

Global macro forces of specific interest to RS3Dprint include:

- Health and Wellness
- Growing Insecurity
- Shifting Demography
- Time Poverty
- Technological Acceleration

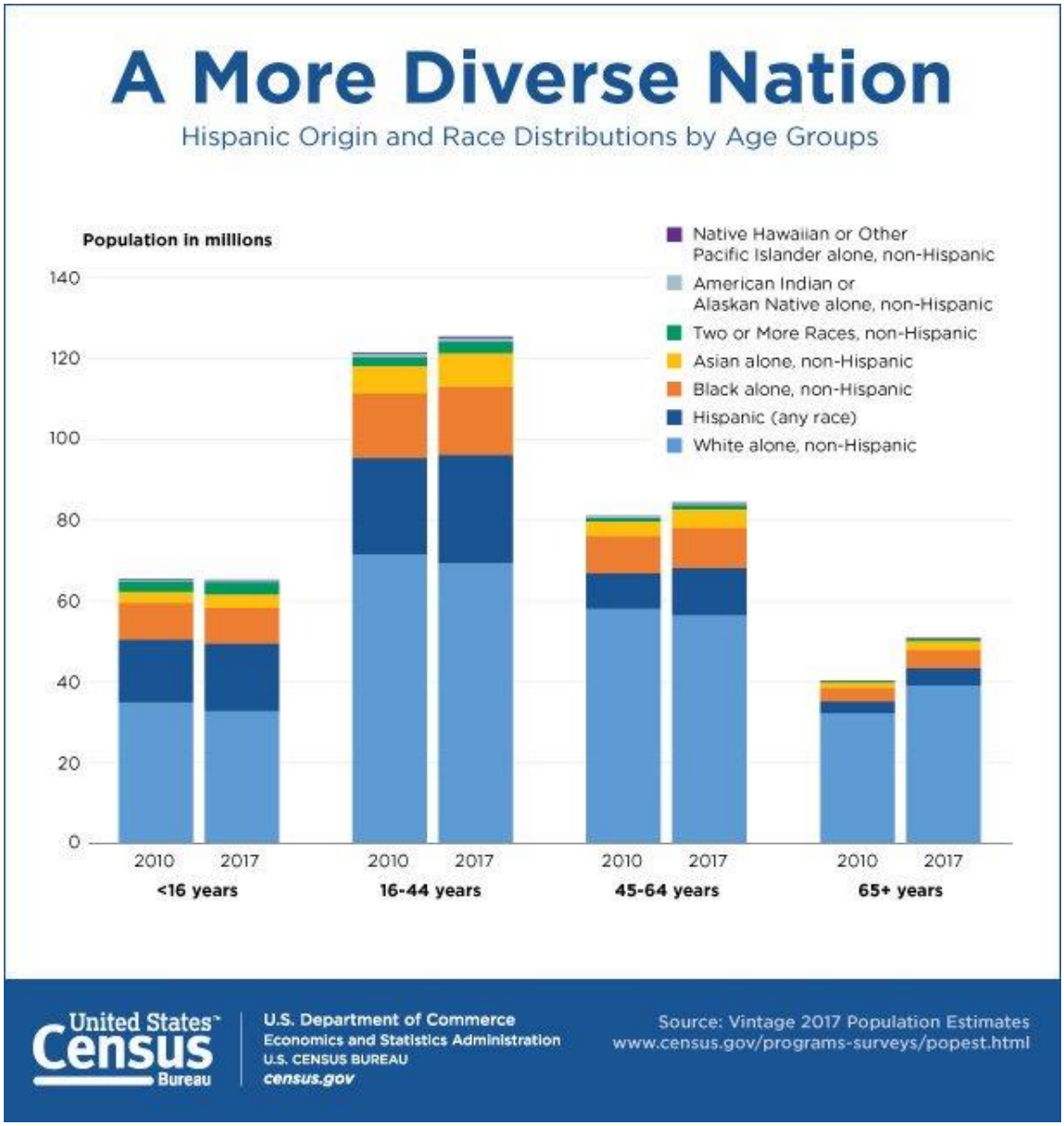
Each of the above will be briefly addressed in the context of the market:

Health and Wellness – For at least the past two decades, the market has witnessed consumers becoming much more health conscious. The increased incidence of health disorders such as diabetes, osteoporosis, cardiovascular diseases, and – of course – obesity, have had a significant impact on how people live. "Natural", "clean", "eco-friendly", "probiotic", and "sustainable" are the new buzz words in today's food and beverage industry. Products and ingredients bearing these tags – as well as others that play to this macrotrend – have seen increased demand from consumers and have (in themselves) become significant purchase influencers. Products seen as artificial and overly processed may be penalized as a result. For RS3Dprint, this trend is both opportunity and watch out.

Growing Insecurity – The global financial crisis that began with the 2008 housing market crash is clearly over, but a long-term impact lingers. The lack of financial confidence felt by many, most

specifically by the Middle Class, has led to the rise of more “conscious consumerism”. Many are very concerned about their economic position and fear that unexpected economic events could take away their financial security. For the past several years, the food industry has experienced a period of slow growth. From a retail perspective this trend has fueled a rise in discount stores and has placed a strain on more traditional food retailers. As RS3Dprint contemplates how to enter the market, know that retailers are more cautious than in the past. But, this also means existing food companies are hungry for new opportunities.

Shifting Demography – The world’s population is shifting significantly. According to the Census Bureau, Americans are growing more racially and ethnically diverse; the US is projected to be even more diverse in the coming decades. Millennials, born after 1980, have surpassed Baby Boomers as the largest US generational cohort. They are the most racially diverse generation in American history, are on track to be the most educated generation to date, and appear to care more about the products and services they buy. While younger consumers are likely open to new opportunities like those RS3Dprint will foster, the aging population with disposable income also offers an opportunity.



Time Poverty – Almost a century ago, the economist John Keynes predicted the emergence of a "leisure society" with ample free time. The reality turned out to be very different. Today, time is a scarce resource. "Time poverty" leads consumers and organizations to not only be harried but to trade money for convenience and speed. People's perception of time is crucial for how they act when researching, choosing, buying and using products in the market place. For food and beverage brands, this megatrend has led to the emergence of a variety of new products that cater to personal convenience: double drive-thru's, on-the-go packaging, smoothies and meal replacement products.

Technological Acceleration – It's been less than 15 years since the introduction of the iPhone. In (almost) one fell swoop, society was trained to live their lives looking at a screen in their hands with (almost) unlimited information available at their fingertips. Importantly, society is now constantly on the lookout for the next advancement. Every year (or more often) the latest and greatest version of existing technology is released to much fanfare, resulting in planned

obsolescence and a new outlay of people's hard-earned money. It is with this backdrop that people will likely be curious and more accepting of 3D printed food than ever before.

Trends

Trends can be defined as "currents of change that bring about new adaptive behaviors". Lasting approximately three to five years in length, trends are mainly valuable in inspiring communication and innovation possibilities. There is much "on trend" for RS3Dprint in terms of the marketplace opportunity. However, there are also headwinds that may impact the growth potential.

Current Trend		Implications
Transparency and environmental values go mainstream		Consumers and shoppers are **looking for the story of meat**, with **branded, authentic options seeing growing shopper uptake and sales**
The Sandwich Generation is really feeling the 'pinch' now		**Millennials now the largest spending cohort** at the same time, society must deal with health care for ageing Baby Boomers
Variety of experience is valued over possessions		Same old, same old is boring. **Variety is important**. Thoughtful product curation tailored to shopper needs and **innovation drive sales**.
"Protein-in-Every Aisle" Society is Pervasive		Increased desire for **healthy food options**, with an increased emphasis on protein at the center of American diets to support our lifestyles.
Extended work hours lead to busier and more hectic lives		Need for **convenient foods** that provide an option of eating quickly **while maintaining a relatively healthier and wholesome diet**.

4 LENS ANALYSIS

The **4 Lens Analysis** approach seeks to look at the market more purposefully and to identify powerful links for a business. By looking at the market in the context of the System in which a business operates, a broad market overview can be understood. This allows for a helpful examination of market insights in the context of Macro Forces.

Keep in mind each of the **4 Lenses** is equally important. Throughout the analysis, it is important to recognize and harness the interrelationship between all of the lenses…one size does not fit all. The dynamics of a particular market will determine the depth of analysis in each lens.

System

Most of the thinking around 3D printing of meat has focused on the possibility of portable 3D printers which can print affordable and tasty meals without an extensive need of cooking knowledge versus more mass production. Although in its nascent phase, 3D printing is poised to change the future of the food industry, and its impact is already being felt on a global scale.

RS3Dprint has developed a new-to-the-world technology taking “liquified meat” and producing meat “assembly line-like” at mass scale, which can be further shaped and cooked afterwards. This can be produced 100% meat, or it can be combined with vegetables or fruits to create value-added opportunities. Importantly, it looks, smells, cooks and makes it feel like one is eating “actual meat”; the process of “printing” actually improves the taste and texture.

The consistency of RS3D’s printed meat replicates the initial mouth feel of real meat. It is thin and when fried it soaks up oil and becomes juicy. It has been described as “weirdly satisfying” and likened to the difference between Pringles (dissolves as it is not solid) and Ruffles (sliced potatoes).

RS3Dprint has developed technology that employs a freeze-inducing liquid that can control the size of ice crystals within the material, a critical process for biological material (whether it is animal or plant based). This is important as most of today’s 3D printing technology can only print items that solidify at room temperature or in molds.

RS3Dprint’s process uses mechanically-separated meat blended with an alginate that flows through a feeder tube (versus cartridge) to the printer head which allows for continuous printing on a conveyer belt (where it is treated with a “finishing mist”) prior to cooking (in the over, fryer or pan). However, it does not need to be cooked immediately. Although processed, the core ingredients can qualify as “all natural”.

While the printer can theoretically print “meat cuts” using several layers of printing, the low hanging fruit is finding uses for the mass-produced meat as “on demand meals” does not appear to be readibly scalable. RS3Dprint holds patents that provide protection in the 3D meat printing field, for the following:

- Printing into a free-inducing liquid
- Intentional contact printing (ie must touch the layer that was printed to deliver meat graining)
- Nozzle design
- Production (alginate, binding, etc)

The best commercialization scenario for RS3Dprint is to develop, design, test and prove out the technology and then license it to others (with potential for building machines) to drive a commercial model measured in tons, not pounds.

The technology allows for multiple forms of products and offerings which will be explored throughout the remainder of this report.

Category

While the world produces more food than ever before, some say the world's current model is unsustainable. With almost 8BN mouths to feed. The United Nations Food and Agriculture Organisation (FAO) estimates that by 2050 the world's food requirement will double.

The question has been posed, "how can current food production keep up?".

3D printing of food has been recognized as a potential answer to this question.

While 3D printing is hot, it is not new; it has existed for 20+ years. It has already been used as a novel production technology in many markets, including the auto industry, aerospace and health care. But, 3D printing of food is a (relatively) new technology that some industry insiders believe may not only allow the food industry to keep up with rapid population growth, but may also help advance food as we know it today.

In fact, 3D food printing has already been used by creative chefs, catering companies and corporations in the food industry. It opens up a great deal of freedom for manufacturers, not only in the shape of the food, but in its composition (nutrients, color, flavor and texture). This may take the form of improving the nutritional value of meals, or solve hunger in regions of the world that lack access to fresh, affordable ingredients.

The 3D food printing market is projected to reach $525.6 million by 2023 according to Research and Markets. However, this projection only considers current technology, thinking and applications (versus technology like that of RS3Dprint). Regardless, this is still a healthy market segment given the relatively recent introduction of 3D printing with food materials. Like any new technology that exhibits promise, it's far from a silver bullet; there are rather difficult challenges that must be overcome. Chief amongst the issues are food safety, structure and geometry limitations, taste, and handling of multiple ingredients, not to mention process productivity (which should improve over time).

Given the technical complexity and scientific know-how it is not surprising that many research intuitions are working on 3D food printing technology today. These include groups at Cornell University, MIT, University of Utah, Colorado State University, University of California at Berkley, Polytechnic University of Catalonia, Netherlands Organisation for Applied Scientific Research, Masstricht University Netherlands, and The Culinary Institute of America.

The market for 3D printers today is driven by customization as 3D printing saves both time and effort. Nutrients can themselves be customized, so people can benefit from food that is tailor made for their dietary or nutrient requirement. Currently, the category is dominated by confections such as candies, chocolates, cakes, and pastries. Chocolate, sugar, and marzipan are the most commonly used material for 3D printing, owing to their ability to be easily printed and extruded into different

shapes. Interestingly, 3D printing has been touted as a manufacturing method for cell-based (or cultured) meat as well as plant-based offerings.

3D food printing requires a great deal of technical development. As such it requires a significant amount of initial funding and on-going capital expenditure for getting into the 3D food printing market. This provides category barriers to entry, however (as we'll see) there are a high number of competitors and investors in the market.

As mentioned, there is a great deal of complication with production not just from the technology but this is exacerbated when dealing with food. The effect of regulations and active involvement of government authorities and associations is currently limited. Oversight will certainly increase in the coming years as more category offerings are readied to enter the marketplace.

In summary, 3D printing in the food industry is still in its early stages…especially at the commercially viable volumes RS3Dprint envisions. But, as technology evolves and costs drops, 3D printing is poised to have a big impact on the food industry.

As further evidence, the 5-year growth rate for published patent applications in the Patent Classification B33Y Additive Manufacturing grew at a compound annual rate of 35% from 2013 to 2017. The only technology with a higher 5 year growth rate was e-Cigarettes at 45%. In fact, as a sign of how rapidly the category has developed, there is even a 3D Food Printing Conference that was launched in June 2017. Can success be far behind?

Competition

The competitive landscape discovery work for this analysis was unique in that RS3Dprint brings new, uncommercialized technology to the market. As such, identifying direct competition – and specifically direct competition with any type of true market entry – is difficult. This is made even more complicated as considerable funding and capital is a significant category barrier to entry for research and development, let alone commercial production.

However, there are multiple category entrants that are playing in similar areas and can be considered competition. Organizations developing technology, processes and testing similar products can be reviewed and analyzed. Accordingly, the 3D food printing competitive market can be divided into (1) competitors with "products" in-market today that may cross over into 3D printed meat, and (2) competitors reported to be in development with similar technologies.

In-Market Offerings - The 3D food printing market, as it stands, is currently dominated (if one can even say that) by companies in the confection and candies vertical (including candies, chocolates, bakery, and pastries).

WASP (Italy) Has developed and manufactured 3D printers since at least 2015. Food is only one multiple verticals in which they operate (homes, art and culture, energy, digital fabrication, health and food). In food, WASP is developing technology to produce gluten-free versions of popular foods. This area (food customization) is a slow process with high manufacturing cost. They appear focused on developing printing technology to sell printers for home and restaurant usage.

Choc Edge (UK) Based on technology developed from at the University of Exeter, this company designs, manufactures and retails 3D chocolate printers. Their current 3D chocolate printer is called the Choc Creator V2.0 Plus, which is available for sale on their website. While they seem very focused on the confectionary vertical and selling small scale printers, their experience commercializing and selling 3D printers to industry should not be overlooked.

byFlow (Netherlands) A family business with a mission "to change the way food is prepared and experienced to contribute to a more sustainable world". As of 2017 they changed their business model to focus solely on 3D printers for food, and more so for personalized and customized applications. They believe "3D food printing will be adopted by multi-national food companies with industrial-type 3D food printing". Their printers can print 50+ ingredients, including chocolate, vegetables, fruit, dairy and meat.

BeeHex (US) Founded in January 2016, Columbus, Ohio-based BeeHex was spun out of a $125,000 project at NASA to make pizza "pies in the sky". The company recently raised $1MM for further development of its Chef 3D printer thanks to Donatos Pizza. BeeHex's extruder uses a pneumatic system to deposit layers of edible materials, using cartridges filled with the different ingredients, such as dough and sauce. Their website claims to have offerings for commercial application with high-volume 3D food printing technology.

Natural Machines (US) Founded in November 2012, Natural Machines is developing the Foodini, the only 3D food printer that we've found that claims it can make anything you want using fresh ingredients. The company says the Foodini employs AI and computer vision to monitor and optimize each dish before it's printed. The printer also connects to the internet, with a built-in touchscreen interface for 3D printing food.

TNO (Amsterdam) Dutch scientific research firm to develop a 3D printer capable of printing a variety of differently shaped pasta, enabling customers to 3D print their own CAD files with different pasta designs quickly and easily (Barilla)

"Closer" Competition

The 3D meat printing industry in the US is at early stages without a dominant player or players. Several established companies as well as start-ups are developing 3D printing technologies to expand their market penetration and have focused on the meat opportunity. Several of these have chosen the path to develop 3D printers to help "solve the problem" of meat production sustainability while others are using the technology to replicate the meat people are more accustomed to.

Nova Meat (Spain) A startup that invented and patented technology which uses a 3D printer to produce plant-based meat with the "muscley" texture of animal meat. Using techniques for cultured meat, and techniques borrowed from bioprinting and adapted for use with materials for plant-based meat, 100 grams of meat takes 30 minutes to produce, costing approximately €2. After printing, the "meat" must be cooked. The patent is meant to work for large-scale industrial processes and the technology "allows for scalability, so that you don't need lots of printers working simultaneously. With a continuous supply of material and several extruders working at the same time, it will be possible to create much more product in a lot less time."

Modern Meadow (US) A pioneer of what they call "biofabrication", making materials inspired by nature and grown of life's essential elements: cells, DNA and protein. They are working on a machine capable of 'printing' raw meat from stem cells or other specialized cells from an animal. 'Bio-ink', made up of hundreds of thousands of live cells, is squirted through the printer nozzle into a mold where the particles naturally fuse to form tissue similar to natural raw meat. They claim the process consumes 96% less water and 45% less energy than the meat production methods we know today.

JUST Inc (US) San Francisco-based company has developed a plant-based egg sunstitute and is in development for chicken and cultured Wagyu beef using cells from highly-regarded Toriyama cows. By printing meat muscle strands, they claim to mimic the texture of cuts of meat beyond burgers, meatballs, and sausages. Awano Food Group (a premier international supplier of meat and seafood) will market and sell the meat; exactly how they do today with conventionally produced Toriyama Wagyu meat at retail.

Jet Eat (Israel) Startup disrupting the vegan food market by developing 3D printing technology to produce meat substitutes using plant-based formulations. The company which was established in early 2018 aims for its products to hit the markets by 2020. Jet Eat currently has already risen funding from angel investors. and the company recently won the European Food Accelerator Network Competition.

Biozoon (Germany) Biozoon conducts research, development and distribution of innovative products for gastronomy and private users. The company sells licenses, concepts and products in international markets. They have created a 3D printer that can transform fresh food ingredients into a healthy puree called Smoothfood. It is claimed that this is especially useful for people with medical conditions who find consuming whole food difficult.

Memphis Meats (USA) produces meat from self-reproducing cells, thereby producing meat that is an "animal-based" product but avoiding the need to breed, raise, and slaughter huge numbers of animals. The company debuted its first synthetic meatball in 2016 and followed up with the world's first cell-cultured chicken and duck in 2017. Memphis Meats aims to decrease the cost of lab-grown meat in order to compete with commercial meat. Memphis Meats has considerable fire power behind them; Bill Gates and Richard Branson invested in a Series A Round in 2017, followed by Tyson Foods investing in 2018.

It's clear there is significant innovation happening in the market. With so much competition – and likely lots more out there – this is, in and of itself, evidence that a market opportunity exists (or is about to). The question becomes: who will emerge as the leaders for this new opportunity and where will the market go long term?

Consumer

Food is a part of our lives that is highly charged with affect, identity, social relations, concepts of tradition and cultural meaning. Initiatives that seek to introduce new types of foods or new methods of processing familiar foods must consider all of the above. Further, we know that "natural" is an important, positive attribute for food likely harkening back to our early agrarian roots. This attribute

connotates healthiness, superior sensory properties, purity and safety. Natural is often associated with the absence of ingredients (or added ingredients) and a lack of human intervention.

It is into this consumer view 3D meat will find itself.

There does not seem to be any question regarding the "if" of 3D printed meat, but the key questions may be "when" or "why". Perhaps one of the greatest hurdles will be consumer acceptance of 3D printed meat. What could make the endeavor less compelling for researchers as well as food producers is the issue of consumers' potential aversion to a food that is unarguably processed at a time when, more and more, people are interested in organic products.

An article from Deloitte in Forbes in May 2018 sums up the consumer conundrum for printed meat: 3D Printed Food -- Just Because We Can, Doesn't Always Mean We Should. The article addresses both ethical and societal implications of bringing new offerings to market. Chief concerns noted include the unknown consequences of deconstructing whole food into processed food, "We may never be able to engineer a truly perfect food profile and, even then, doing so brings a risk of specific deficiencies both of known and unknown substances." The psychological impact of automating our lives for convenience is another complication that may occur.

As with any new to the world introduction, when asked their reaction to early food produced by 3D printers, consumers were somewhat confused. People described the attractive appearance of the food and deem it healthy because it is made from 'real purees'; at the same time, they considered the same food 'artificial' because it was formed by a 3D printer.

If the food itself is healthy – maybe even healthier – does the process of making it create 'unhealthy' food?

This apparent contradiction suggests that those who wish to promote 3D food printing technologies need to consider a wide variety of attributes to encourage people to accept the technologies not just their products.

This contradiction is further evidenced in consumer surveys about 3D printed meat. In one recent study by American Food Specialist Report 60% of those surveyed claimed that they would eat 3D printed meat, with another 17% affirming that they might eat. Yet, in another survey highlighted in Global Meat News, only 34% of those asked replied in the affirmative with 41% saying "no" and 26% weren't sure. (Of course, we must consider the source of these two surveys and the fact that there is no agreed upon definition of what 3D printed meat really is, or how it's processed.)

From work done in Australia, beyond the process itself, key attributes influencing participants' responses to food were discovered: (1) content, and (2) sensory qualities. The content of the food (or to what extent its ingredients are considered tasty, healthy, familiar or natural) is an important driver of acceptance. The sensory qualities of the food (or to what extent it looks normal, natural, appealing or more 'food-like') is the other important driver. These findings, and an understanding of these attributes, can help RS3D develop offerings that will be more widely accepted.

MARKET IMPACT

As mentioned, the global 3D food printing market is expected to reach $525.6 million by 2023. This growth is attributed to the rising awareness among the food innovators about the need to elevate food manufacturing systems. Whereas up to this point in time, the global 3D food printing market was more motivated by desire for customized food products with nutrient content tailored for individual dietary needs. Clearly, any nascent market estimates can be widely off the mark, but one thing is clear: massive investments by food-tech companies – and those outside the industry – are driving the 3D printed food market upwards rapidly.

Four different Value Drivers have been determined, based on the nexus of what is known today about RS3Dprint's technology combined with close-in and longer-term market opportunities:

Meat: Opportunities based on the advantages delivered by 3D printing

Meat +: Opportunities to enhance meat given 3D printing

My Meat: Opportunities based on the precision and customization power of 3D printing

Not Meat: Opportunities from the technology that don't necessarily include traditional meat

Meat: The potential of 3D printing in the food industry has been recognized. It can help drive greater consumer convenience, customization and cost savings. Considering the strategic benefits of the technology (at present capability) for meat products and producers, several market opportunities stand out based on consumer benefits:

Value Driver	Description	Perceived Market Benefit
More value per carcass	• Turn low value trimmings into high value (value added) products	High
Less waste per carcass	• Based on processing and production techniques there is potential to use more of the animal in the production process • 3D food printers can reduce waste by using only the required amount of raw materials to make food	Low
Reduced cost of processing, capital and running cost	• At this stage, not enough is known to understand full economics of commercial production, but clearly this must be explored	TBD
Precision production	• Programmability of 3D printers is exact offering new and different opportunities versus traditional meat cuts • Machines can be instructed to stop printing when total calories reach a certain amount • Regulate preservatives, additives and other chemicals typically added to your food	Medium

Additional volume of meat	• New markets opportunities or product offerings can be created to drive additional demand and sales (Chicken Chips and Meat Nuts are examples)	Medium

Meat +: 3D food printers also have the potential to revolutionize how we consume meat, not just what. Thinking beyond the traditional meat of today, the possibilities are endless in terms of how our food can be enhanced. This corridor of opportunity goes beyond simply regulating preservatives, additives and other chemicals typically added to food (which is still important as an opportunity). Overall nutrition can be enhanced by ideas such as: adding new vitamins, carbohydrates, and amino acids to the meat before production. This can also include blending meat with fruits and vegetables to produce a completely balanced meal in a convenient, easy to use form. This could effectively target our time starved lifestyles and help us eat on the go.

My Meat: Personalized food is a big opportunity and not only for one off applications envisioned by many in the industry. Certainly, there is a future where people can have their meat created on a customized basis (similar to how a smoothie can be blended on the spot based on dietary needs or personal preference). This concept, however, can also be taken to larger scale commercial applications to meet the dietary desires and needs of larger groups (diabetics, gluten free, low sodium, low fat, no sugar, high protein, etc). With increased attention on health and wellness, approaches that can better meet dietary choices will be appealing to consumers.

Not Meat: Much of our research conducted for RS3Dprint found efforts using 3D printing for plant-based or lab-grown (cultured) substitutes. Many believe the promise in the technology is that it has the ability to use plant-based, synthetic animal, or even insect proteins to create meat without the associated environmental or (in some cases) ethical concerns. Techniques such as those which Modern Meadow is attempting would reportedly consume 96% less water and 45% less energy than current meat production methods.

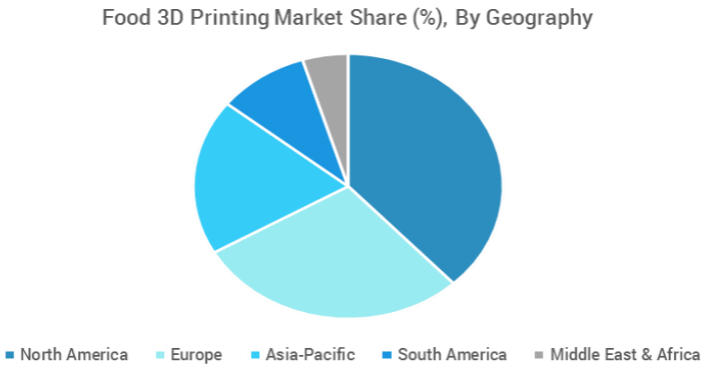
However, the regulatory future of lab-grown “meat” is unknown. While the USDA regulates meat production and advocates for agriculture, and the FDA ensures the safety and security of human drugs and biological products there is (understandably) potential issues with oversight of alternatively grown meat. To overcome this, the USDA’s Food Safety and Inspection Service and the FDA announced a formal agreement March 7, 2019 to jointly oversee the production of human food products derived from the cells of livestock and poultry.

According to reports market research firm Euromonitor, US meat substitute sales in the packaged food industry have risen an average of 4.7% each year between 2012 and 2017, outpacing the 1.6% average annual growth of processed meat over the same period. The alternative meat market still has a long way to catch up to the conventional processed meat market. The US meat industry is estimated at $67BN compared against $700 million in meat substitutes sales.

This is a growing corridor of opportunity and should not be ignored, but it is only one opportunity for RS3Dprint…and likely not the biggest.

REVENUE MAPPING

According to Mordor Intelligence, North America is currently the largest market for food 3D printing. This is due to the availability of the technology and its usage (especially within food service channels). “Mass customization of commoditized products and the ability to create complex food products quickly and inexpensively” is what boosts the North American market for 3D food printing.



During our market analysis, three high-value revenue opportunities were identified based on review of technology, acceptance of technology, benefit, and value projections. These include: Retail, Government (Military, space), and Health Care (Hospitals, Assisted Living).

Retail

Retail is one of the largest contributors to the US economy, so it’s no surprise that this ranks high on the opportunity list. Annually in the US, retail represents a $2.6 Trillion financial impact, or 7.7% of US GDP. This segment includes retail stores (convenience retail, grocery, drug, mass merchandise, etc) as well as restaurants (from single location to large chains and from fast food to fine dining).

This segment should perform well on a volume basis for 3D printed meat, likely deriving most of the value from meat snacks, burger substitutes and value-added products at retail stores. Whereas, we believe the “volume play” for restaurants is more niche, even that restaurants are the largest “commercial” end-user of 3D food printing devices today.

Specifically, at retail, 3D food printing offers significant market opportunities for fast-moving consumer goods (FMCG) food manufacturers to produce and market differentiated and/or healthier food options. As proof point, IRI data shows the total dollar sales of dried meat snacks (measured from grocery, drug, mass-market, convenience, c-stores, as well as select club and dollar retailers) was $3.13BN for the 52 weeks ending November 4, 2018, up 4.4% year-on-year.

Government: Military and Space

Military spending in the US accounts for approximately 54% of the total government budget. This amounts to $598.5 billion in annual spending. While this budget covers everything from hams to hand grenades (the latter is costlier), military spending is a true economic engine in the US. Protecting the country involves an awfully broad array of goods and services, everything from food to gas to medicine to schools to nuclear weapons. As the largest discretionary spender in the US economy, this is clearly a market opportunity for 3D printed food.

3D food printing technology has established itself to be an innovative solution for significant applications in the government vertical for the military and space research. In fact, in 2012, the

government spent $1.5MM to develop a special new roll-up beef jerky. That's something that 3D printing can do at scale easily. MREs (Meals, Read-to-Eat) are a long-lasting form of protein for battlefield troops. MREs offer the flexibility and variety to tailor the meals to meet nutritional requirements for individual soldiers and are free from any assembly, food skills and further cost.

3D printing's ability to create nutritional and sustainable foods is also valued by NASA. The space agency is now testing ways to include this food production innovation on deep space missions. They granted $125,000 to the Systems and Materials Research Corp. to make a prototype 3D food printer and will test its ability to feed astronauts on lengthy flights.

Health Care: Assisted Living/Institutional

The year 2030 marks an important demographic turning point in history according to the US Census Bureau's 2017 National Population Projections. By 2030, all baby boomers will be older than age 65. This will expand the size of the older population so that 1 in every 5 residents will be retirement age. "The aging of baby boomers means that within just a couple decades, older people are projected to outnumber children for the first time in U.S. history," said Jonathan Vespa, a demographer with the US Census Bureau. Spending of more than $10BN a year in federal and state funds for assisted living services (or, an average of more than $30,000 a person) has been documented by the Government Accountability Office.

What does this mean for 3D printed meat? A lot of potential eaters (as one of the benefits of RS3Dprint's process is greater chewability with a typical meat mouthfeel).

According to one study, "15%–25% of elderly people over the age of 50 and up to 60% of nursing home residents suffer from chewing and swallowing difficulties". People suffering from this disease are often provided with unappealing 'porridge-like food', which cause the loss of appetite and even nutritional deficiencies." Many times, in aged care facilities food is overcooked due to food safety requirements and therefore tough to eat. 3DP food presents a unique opportunity to overcome the barriers of this segment and offer a real consumer benefit. 3D food printing technology has paved its way in the hospital food sector as well, owing to its nutrient customization and easy chewability features.

POTENTIAL CORRIDORS OF OPPORTUNITY

Beyond the potential markets for revenue, it's worthwhile to spend some time postulating on potential Corridors of Opportunity based on what's know about markets and RS3Dprint's technology. While this is, of course, nothing more than a speculative exercise, it does speak to possible directions and potential applications.

The main benefits of 3D printed meat products are that they offer consumers convenience, environmentally sustainable practices, health and nutrition (although we've addressed the consumer conflict between ingredients and processing), and product differentiation. There are also multiple categories where 3D printing technology will be of appeal.

Following are a variety of opportunities identified throughout research for this report.

Convenience

Consumers want satiating food that is easy and quick to fit their time-poor lifestyles (or in the case of younger consumers can compensate for a lack of cooking expertise). Consumers know protein to be satiating and protein snacks fit well into this category. Simply put, 3D printed food products can offer a lot of convenience. This can come in the form of product, package or both. Snacking has become big business for fast moving consumer packaged goods manufacturers (taking a variety of 'better for you forms' including meat-based snack bars, Meat Nuts and Chicken Chips).

These are all options and varieties that can be replicated with 3D meat printing (and potentially would be better produced that way today). Although out of scope for the focus of this report if the technology makes its way into homes, scenarios such as the one outlined below could be commonplace: After the end of a long work day, an office worker selects their menu item of choice before leaving the office. A signal is sent to the printer to start creating dinner which is ready when they get home. Very convenient.

Environmentally Sustainable Practices

With a growing population there is a growing demand for food and sources of protein, including meat. As outlined, the benefit for meat that is produced via 3D printing is that it reduces waste per carcass and, we believe, will also reduce the cost of processing. For those that prefer plant-based proteins because of the perception that this option is environmentally more sustainable 3D printing fits the bill, too. In fact, Bill Gates and others recently invested $108MM million into a food start-up company creating meat substitutes. However, the belief that plant-based proteins are environmentally sustainable and animal-based proteins are not is not fully accurate. Whereas grazing animal produce methane, cropland uses fertilizer that contains nitrous oxide, another powerful greenhouse gas.

Product Differentiation

Like a little more spice? A little more chew? A little less sodium? On a restricted diet? Only eat Halal meat? There's a solution for that. 3D meat printing offers the possibility to create nutrition tailored to any group's dietary needs, allergies or taste preferences (and, obviously this can be done on an individual level as well). Food printing can help control portion sizes without waste, reduce chemical additives and calibrate nutritional. At first thought this may seem a more personalized need, but in the US today there are many sizable groups with the same nutritional needs or desires. Consider the fact that by 2020, the gluten free market is projected to be valued at $7.59BN and the Halal market will be over $22BN. There are clearly riches in niches.

Meat Snacks

This is likely the closest in, and most obvious Corridor of Opportunity. Meat snacks are an important source of protein with low-calorie content. Whether it's beef jerky, meat sticks, bars, biltong or other, meat snacks are big business and have become an indispensable component of today's consumers' diet. Ready-to-eat snacks such as meat snacks are becoming increasingly popular among consumers as they save time and effort. 3D printing can create enhanced offerings to expand this category, including beneficial additions like vitamins, fruit or vegetables).

The price of red meat is important to industry operators, as meat represents one of the costliest items for most jerky makers and about 90.0% of jerky is made from red meat. Input prices cannot always be fully passed on to downstream wholesalers, retailers and consumers and sometimes cut into producers' profit margins. Using lower value 'trimmings' versus higher cost meat can create a market opportunity for RS3Dprint and partners.

ADOPTION BARRIERS AND CHALLENGES

Before we complete this analysis, it is important to address barriers to adoption and challenges to the industry to provide a complete assessment. Interestingly, these barriers and challenges are less about technology and more about market adoption.

Societal Barriers

Let's start with the overarching issue that consumers don't necessarily know what to make of 3D printed food, let alone 3D meat. It is likely that the health benefits will outweigh the perception of highly-processed production and aversion to the raw materials used. While there is no apparent "solution" to this anxiety, if anything the past has shown us that what was once disparaged can become accepted. As example, in 1877, The New York Times wrote a ferocious attack against Alexander Graham Bell's telephone for its invasion of privacy and 'uselessness'. One writer wrote, "We will soon be nothing but transparent heaps of jelly to each other." The wealthy Mark Twain was the first in his town to put a phone in his house, yet passed on an opportunity to be an early investor, thinking it had no market.

Consumer Acceptance

Even if/when societal barriers are overcome, sensory and appetite issue may be an obstacle. The texture of 3D printed meats may be a double-edged sword. It may appeal – or even be required – by certain markets, but be unpalatable to others. This may be true for the taste, appearance and odor as well. While it's true that no one likes every single food, the market for RS3Dprint will be limited unless taste and texture appeal can be overcome, or even enjoyed by significant segments of the US.

Food Safety Regulations

Unlike other 3D printed materials, the handling of food requires much more strict controls. Federal regulations regarding food handling (raw, during production, and after processing) may impact the 3D printed meat industry. Safety and labeling regulations may play a role here, too. As the USDA and FDA begin to delve deeper into production of plant and cell-based meats, new regulations and requirements may come about. This is a rapidly developing technology which typically means regulations have yet to catch up, so development should take government regulation into account.

New Technology Hurdles

Still in its development stage, 3D meat printing has yet to reach commercial production let alone high-volume commercial production. Moving from academia and other small-scale applications will likely bring unanticipated hurdles. Obviously as a new technology, there will be higher costs for startup and ramp up that must be factored into the equation. Lastly, oftentimes new technology also experiences a lack of technical expertise whether it be in the development or roll out phase.

The hurdles are not insurmountable but require diligence and planning to overcome.

CONCLUSION/RECOMMENDATIONS

Following our extensive 45-day period of research and conversation, we have identified significant evidence of a market indicating that RS3Dprint should seek funding and support for continued development of their technology.

There are clear Corridors of Opportunity that highlight significant value for commercial-volume 3D printed meat in the US.

The direct factors that support a market, include:

- Global Food Factors shifting towards lower impact and higher value foods
- Supply Chain Issues offer opportunities for more flexible manufacturing
- The 'Blur-ology' between tech + food, food + wellness, environment + edibility
- Consumer Trends towards 'better' solutions (better for me, better for planet) and 'convenient on-demand protein'
- A very significant number of Early Innovators and Industry Competition
- High Value Market opportunities (retail, healthcare, government)
- Retail/Shopper Trends towards convenient, on-demand protein and 'protein in every aisle'

The Value Drivers (based on the nexus of what is known today about RS3Dprint's technology combined with close-in plus longer-term market opportunities) should be explored and developed further as all offer distinct future revenue pools:

Meat: Opportunities based on the advantages delivered by 3D printing

Meat +: Opportunities to enhance meat given 3D printing

My Meat: Opportunities based on the precision and customization power of 3D printing

Not Meat: Opportunities from the technology not including traditional meat

While the market is not necessarily 100% ready today – and it will take further work to develop technology, products and partnerships to take advantage of – we recommend this work proceed with confidence.

DISCOVERY POINTS

Discovery Point are examples and evidence of opportunity seen in the market. They may be new to the world products or other type of tangible opportunity that helps confirm the hypothesis that there is a market for 3D printed meat.

Wilde Brands: Chicken Chips

WHAT IS IT?

- Positioned more as a "better way to chip" with a halo of "complete-food, high-energy snack" for clean eating vs empty-calorie snack foods
- Wilde Chicken Chips are low in carbs, high in protein, and positioned as great tasting
- Started shipping/selling in July 2018
- Available at Whole Foods (regionally) + online (currently seeking additional Wholesalers

Dietz & Watson: Meat Nuts

the world's first meat nuts

As far as we know, no one else has ever made meat nuts before. And we thought it was high time someone did something about that. You're gonna love Dietz Nuts.

WHAT IS IT?

- Dietz Nuts are protein-packed, savory sausage bites.
- The recipe is based on their traditional European landjaeger, dried and cured to snackable perfection.
- The snacks are available vis Amazon, GoPuff and direct from Dietz & Watson

Schweid & Sons: Prime Burger

WHAT IS IT?

- Focused on burger market exclusively
- Developed a mechanical system and molding process for forming ground beef patties to appear hand formed
- Process allows air to flow through the meat for better handling and improved mouth feel
- Provides a more even cooking surface due to uniform forming process, resulting in a firm, almost steak-like bite

Pizza That's Out of This World

WHAT IS IT?

- Founded in January 2016, Columbus, Ohio-based BeeHex was spun out of a $125,000 project at NASA to make "pies in the sky"
- BeeHex's extruder uses a pneumatic system to deposit layers of edible materials, using cartridges filled with the different ingredients, such as dough and sauce
- A computer controls the output, allowing the pie to take different shapes, all in about in about 5 minutes
- Raised $1MM in 2017 for further development of its Chef 3D printer from Donatos Pizza.

High Protein Egg Chip

WHAT IS IT?

- The World Intellectual Property Organisation (WIPO) has published Cargill's request to protect IP covering a "high protein egg chip" in response to changing consumer eating.
- The demand for healthier snacks continues to grow with an emphasis on products bearing claims for protein, absence of gluten, and being made from a simple list of ingredients.
- US Patent Application Publication No. 2005/0089623 describes a "proteinaceous" food product formed by extrusion that is a stated to be a crisp or frangible product that is high in protein. The protein source for this product is preferably selected from seed products and legumes.
- US Patent Application Publication No. 2013/0022731 relates to high protein, low carb meal replacements and food. The Summary of the Invention relates to a new class of food that is crispy, tasty, and low in carbohydrates and has substantial levels of egg white protein and suitable shelf life for packaging in ready-to-eat form.
- According to a Cargill spokesperson, the earliest the patent is likely to be granted would be around July 2020…"so we don't have more information to share at this time"

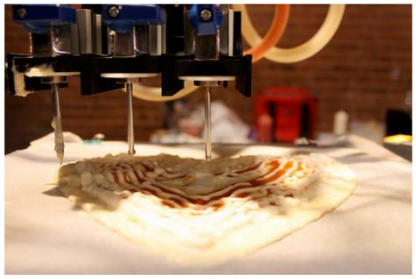
Biozoom Elderly Care

- In Germany, nursing homes are offering their residents soft 3-D-printed vegetables that are easier to swallow, freeing them from the bland, unappetizing purees, which were their only option before.

WHAT IS IT?

- Biozoon developed a "smoothfood" concept in 2010 – food that is visually appealing, tastes good and does not require complete changes to production thanks to 3D printing.
- The printing process has no impact on taste, and Biozoon only uses plat-based texturizers such as algae-derives carrageenan. The food can withstand microwave or oven heating.

NASA and Space Development



WHAT IS IT?

- NASA has awarded multiple grants to study feasibility of 3D printing for making food in space
- Systems and Materials Research Consultancy conducted a study for the development of a 3D printed food system for long duration space missions. Phase I SBIR proposals are very early stage concepts that may or may not mature into actual systems
- Funded by a grant from NASA, BeeHex created a 3D printer as a way for astronauts to select and produce delicious food for themselves on missions

Government: Military MREs

WHAT IS IT?

As a result of The Army Food Lab's efforts…

- In 2012, the government spent $1.5MM to develop a special new roll-up beef jerky, but it was never able to quite happen

  Scientists from the Natick Army Lab have managed to engineer a special kind of meat stick that contains an equivalent of a cup of coffee's worth of caffeine — more than enough to keep a hungry fighter both awake and with a full tummy while in the trenches

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