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I = Interviewer

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I: Welcome to a bonus holiday episode of IFLScience The Big Questions. I'm your host, Eleanor Higgs. During the holiday season, I expect many of you are tucking into family meals, but have you ever thought about going meat-free at this time of year, or what the future of the meat industry could look like? For this episode, I am joined by Daniel, the Chief Technical Officer from Redefine Meat, who is going to talk to us all about creating delicious new meat products without the environmental impact.

So welcome Daniel to IFLScience, The Big Questions Podcast. Wonderful to have you on the podcast with us. To start off with, could you tell me about yourself and your role at Redefine Meat?

R: Yes, thank you. It's my pleasure being here and telling you about our technology and our products. My name is Daniel and I am the CTO of Redefine Meat. I've worked here for four years and my role is creating all the technological modules that are necessary for creating the perfect alternative of the meat that we love but without the animals.

I: Wow, amazing. So, as you said, Redefine Meat creates plant-based alternatives to meat products. How do you go about this?

R: Basically, as you know, animals consume plants and they build their body from these plants and they create the protein food that we then frequently use as meat. So, in Redefine Meat we just make a shortcut for this process, we take the plants and we turn them directly into meat using technology that we developed here. This technology allows creating all the full range of meat products addressing all the taste and preferences, not only of vegans and vegetarians but also of flexitarians, omnivores and even carnivores.

I: But why is that important to you to replicate that meat feel so closely?

R: This feel in general is very important for me, because I believe that we should provide an alternative to the industrial animal farming that, as we know today, is very polluting and creates a bunch of environmental problems starting from greenhouse gas emissions and continuing with land use and water use and a lot of pollution that it creates. When I switched my job, from my previous job that was in Stratasys, the biggest 3D printing company, I was looking for a place where my skills could create real impact and I met the founder of this company, Eschar Ben Shitrit who told me about Redefine Meat's approach to break the glass ceiling of the performance that these old, the legacy meat alternatives were facing. So, if you ask the customers what is missing in meat analogues to make them a clear choice, 80 percent of them would say number one is the taste. So, the actual performance of the meat analogues was not sufficient for more people to adopt it. Our approach is actually there to break this glass ceiling

and to generate products that are on a totally different level so that you can consume meat without any compromise. So, you do not compromise on taste and you do not compromise on environment.

I: Amazing. So, you mentioned that you have replicated...you've taken the plants to replicate these new meat products. Can you tell me more about that and what the Redefine Meat products are made of?

R: Sure. So, we basically take existing plant-based ingredients, so we do not invent any new molecule, at least not until now, and we were looking for a way that we can impact the industry in the short term. We don't want to use space technologies or like crazy scientific things, but we believe that there are simple solutions and these simple solutions are located, and I apologize if I speak too scientifically here because I am a scientist, but they are located at the multi-disciplinary junctions of different sciences. So, the food science alone could not produce a sufficiently good meat analogue because a steak has very sophisticated internal structure, as all of us know. It has fat marbling, there are fibers that are oriented in a certain way. There are meat juices that are distributed in a certain way. It has very sophisticated cooking behavior and you just cannot provide this set of performance by just using existing food manufacturing technologies, which are basically usually just a set of mixers that are mixing many components together. They cannot produce this level of structure and sophistication, so we actually had to look beyond this and look in other scientific fields, such as advanced manufacturing and material science in order to understand how you can reach this level of sophistication. That's how our technology that we call today plant-based tissue engineering, that's how it was formed. So this term, plant-based tissue engineering is a new term that we coined and I just submitted a paper to one of the leading scientific journals that will tell the full story of plant-based tissue engineering but basically, the concept is looking on the meat as a complex tissue the same way we do for living tissues, and although meat is not a living tissue, it still preserves many of the structural elements that the living muscle had. So, first of all we look on this as a tissue and then we break this tissue into the separate tissues – fat, muscle, connective tissue, and liquids – and we reconstruct each one of them separately and then we put them together during our manufacturing process. So, that's basically, in a nutshell, the way that our technology works.

I: So, you're using plant proteins and that sort of thing to recreate the structures that you would find within a steak, let's say?

R: Right. So, our main building block is a protein, primarily soy protein because it has very good nutritional qualities. So we basically use the same building blocks that are being used in other meat analogues, but we adjust them and we adapt them to the requirements of our components and we also use our proprietary technology that we developed for putting these elements together for delivering the set of texture, color, mechanical behavior, chewing behavior, fatty mouth feel, flavor and aroma, all the characteristics that you need in order to address your five senses. We have so many senses that are analyzing every piece of food that we are consuming, that in order to kind of trick the senses and make them understand that this is meat, you really need to reach a very high level of imitation or replication to livestock meat.

I: Yeah, absolutely. I think it must be very difficult to recreate meat without even using any animal products whatsoever. Can you tell me more about the three pillars of your technology, the new meat science and the meat matrix manufacturing?

R: Yes, sure. I would love to. I will start from meat science because again, when we face all this complexity of the different meat products that we are familiar with from the supermarket, so we have different cuts of the animal, we have different animals of different ages, sometimes the butchers do some aging to the meat product and there are just also variations from animal to animal. To recreate this huge set of characteristics you really need, first of all, to understand what meat is. That's why we invest so much effort in studying livestock meat. We have in-house meat scientists and we analyze all cuts of meat in existing testing methods, but we also developed our own testing methods. For example, there is almost zero information in the meat science literature about the characteristics of the meat at the serving temperature, because usually when you go to a restaurant and you get your steak, it will be between 50 to 60 to 70 degrees Celsius (122 to 140 to 158 degrees Fahrenheit) and all tests that are being done, they are being done at room temperature. So, just to create the set of tools and methods to test the meat characteristics at the serving temperature, even this is a challenge. All the data that we collect, we put in a database that actually lists all the characteristics and serves as a reference for all the plant-based work that we do. Sometimes, these characteristics are just a modified testing tool, but sometimes we go really far, for example, we did research at the Canadian Light Source, which is a synchrotron facility, where we scanned a piece of tenderloin with a tiny x-ray beam to recreate all the structures of the fibers, of the connective tissue and to see how the cooking affects this structure. So, that's about the meat science. Now, when we have all the data that we've collected about livestock meat, we can collect the same data for plant-based meat and very easily to compare between them and to identify what are the gaps, so we can close these gaps. I will give you just one example that one of the gaps is that, as you know, meat has fibers and you break it apart, you see that the fibers break in a way that creates a kind of staggered interface between the two pieces of meat that you are holding or that you cut with a knife. If the fibers stick too much together, then you will get like a plastic [unclear 0:11:51], it will be just homogenous material and it will not be like meat. Or, if the fibers do not stack together, they will just break apart and it will behave like a long-cooked meat and not like a steak. So, you need a very certain level of adherence between the muscle fibers for recreating this texture. This is an example of work that we do and we adjust all of the characteristics of the meat that we are producing in the various manners that we have so that it will generate the desired behavior.

I: Yeah absolutely. So, really looking at it from a molecular sort of, on a scale of really close through all the x-rays through everything, so you can recreate it as exactly as possible using your proteins.

R: Right. So, sometimes, indeed we need to look on the molecular level, especially if we speak about aroma, for example, because aromas are volatile molecules that we feel. So, in this case, we need to go to the molecular level, but in terms of fiber texture, the fibers that you see with the naked eye in the steak, anatomically it's called fascicles. Muscle is a hierarchical structure of fibers. It starts from very tiny fibers that are on nanometer scale and then they are grouped to much bigger fibers of about 20-micron scale and these 20-micron fibers are grouped together

into fascicles, which are about 2 millimeters thick and that's what you see with the naked eye when you play with a piece of meat. In this case, you don't really need to overdo sophistication because then you will pay a lot of pricing for getting this level of resolution. So sometimes you want to decrease the resolution and work on this scale of millimeter-scale in order to make your meat fast and meet the commercial demands, which is not only quality, but also the cost of your technology.

I: Yeah, absolutely. You mentioned before about 3D printing, how does that fit into the creation of all these meat products that you are making?

R: I'm glad that you are asking and I love 3D printing. As I mentioned, I am coming from Stratasys. I worked more than 10 years in the areas of 3D printing and additive manufacturing. Actually, my last role in Stratasys was a project manager of a product that's called Digital Anatomy Printer. It's a 3D printer that prints body parts. These body parts are identical to human body parts but they are not biological, you cannot implant them, but you can use them for training of hospitals and medical companies instead of cadavers and animals. So, they replace cadavers and animals in this training and they deliver amazingly high levels of biomechanical accuracy. So, if you take a bone, for example, it has all this porous structure inside the bone and bone marrow and the cortical bone, for example, and they also use eight different materials at the same time to recreate this complexity. So, this is an example of inspiration that the food industry can get for reaching these levels of sophistication that are required with meat. So, in the beginning of our company we were very much inspired by this approach first in order to create these fascicles, these fibers that I mentioned, second to create the different arrangements of marbling, the fat marbling that you have in a steak, it has certain shapes that are very difficult to create otherwise and third, is that 3D printing is also an excellent tool for making prototypes and many redesign cycles. So, today if Apple is developing a new cell phone they will probably print a few thousand variants of the cell phone in order to get the best ergonomic functionality and in order to optimize it. And the same of course, if you want to make a product that is totally new to the market, not a cell phone, but a steak that never existed, so you need to do so many redesign cycles, and this 3D printing and the additive manufacturing allowed us to solve both the structural targets and address the overall performance targets of our plant-based meat. Today, the additive manufacturing has only a relatively smaller role in our technology. Many of our products, mince products, for example, and the pulled beef, they do not use any 3D printing whatsoever because there is zero sense in using 3D printing for homogenous products like burger, but in steaks you still need a very large set of advanced manufacture and technologies and 3D printing is only one of them that you need to use to create all the structures that you need for addressing livestock meat sophistication.

I: I suppose it helps as well that 3D printers print in layers, so I guess that would help to build the flavor and you could build different things into each layer maybe as well.

R: Exactly. So, we can precisely control the special arrangement of all our components. It can be fat or it can be muscle and it also allows you to introduce elements that would not be possible to introduce otherwise, for example, connective tissue. So, one of the things that we discovered when I just joined the company, that connective tissue is playing a crucial role in the behavior of

meat. If you take a piece of meat and you try to pull it apart you will see tiny white layers and films that bind together the fascicles or the muscle fibers. There is a kind of scaffold that is entrapping and holding together all the muscles and also in the fat, in the meat fat, there is also a matrix that is holding all the fat cells together and preventing them from completely falling apart during cooking. So, in order to create this connective tissue, we developed a set of fails that we can introduce during the printing process and recreate also this part of the composite structure of muscle and drive the right mechanical behavior that you would expect from a piece of meat.

I: I wanted to ask you as well, given that you're creating these new meat plant-based products so close to what meat product is on that level, are the nutritional levels different? Does it vary? Or are they equally very similar from what a Redefine steak would look like to what a cow-based steak would look like?

R: Nutritional value, of course, is a key consideration for everything that we do. It's not nice material to play with, at the end of the day you consume it and first of all, even before taking care of nutritional value we take care of food safety and say, in food safety, it can be something trivial in existing food manufacturing technologies but in our case, since we developed our own manufacturing technologies, so just providing them with the right set of food safety standards and we match the high standards in the industry. Only these took us so much effort and time and work, so for example, all our systems operate at 4 degrees Celsius (39.2 degrees Fahrenheit), so basically a chilled temperature, so there is zero development of any kind of microbial growths that you can imagine. So, everything is working in a completely food-safe environment. So, once you take care of the safety, of course, you need to take care of the nutrition and livestock meat is a great source of protein, of oils that are necessary for our body, and also of some vitamins and micronutrients and our product is delivering all these. It is very rich in protein, it has fat, actually much better composition of fat than in livestock meat, it has lower fat in general and much lower saturated fat and also it doesn't have any cholesterol, obviously, because cholesterol we can find only in animal products. In addition to this, some of our products are fortified with micronutrients. So, basically, it's a part of a balanced diet that you would expect from a meat product.

I: I was going to ask you as well, you mentioned before that there is a need to do it with this because of water consumption associated with livestock rearing, deforestation, pollution, all the problems with industrial animal products. Do you have any stats on how yours is different, like the carbon footprint of Redefine Meat products compared to a steak or beef mince or any livestock products?

R: As I mentioned in my last role in Stratasy, I started to look in...even though I did amazing things that changed the way that the technology helped humans in many fields, such as medical, but I was looking for things where the amplitude of the change that I can bring with my development will be much higher and I identified this area of meat alternatives in general and I was looking into it, but only after I joined the company I realized how severe is the damage that is being caused by industrial animal farming. That's specifically true for beef. So, beef is about three times more than poultry and much higher than any other animal meat and there are many levels on which it damages our planet. It starts with greenhouse gas emissions

that for the livestock meat can be compared even to the transportation sector and it continues with a huge use of land, so it's not only the land that is being used for the animal themselves, but also the land that is being used to grow the feed for the animals. So, sometimes people that are advocating for livestock meat, they are saying that the land that is required to grow the soy for plant-based meat is compared to the area that is required for the cows, but that's funny because the cows, in addition to everything that you grow, you need to grow even more soy just to feed the animal. Then you have water pollution, then you have antibiotics that are being used for animals that are leaking into the water and they lead to the creation of microorganisms that are immune to antibiotics. Then you can talk about all the diseases and viruses that came from livestock, from industrial meat production, including the COVID virus that came also from a market where they were selling animals, right? So, there are so many problems associated with this and after realizing it, I actually reduced very substantially my own consumption of meat in general and specifically beef meat, only rarely I will consume beef meat if it's not for tests or science that we do, where it's really important for us. Also, to [unclear 0:24:56] with livestock meat so make sure that we are [unclear 0:24:59] to the right reference.

I: Yeah, absolutely. So, your products are far better, you would say, for the environment and far less pollution and far less negative consequences?

R: Definitely. So, plant-based products in general and our products specifically, and we are not taking this for granted, but we do our own LCA analysis. LCA means life cycle analysis and it covers all the emissions and all the environment impacts that your product has, starting from the ingredients to all the processing and the energy that is being consumed during the processing, the packaging, the cardboard, the plastic, everything that you use, until the product reaches the final shelf in the supermarket, everything is being calculated and I can say that we know that our product is at least 10 times better than beef, has more than 10 times less environmental impact, yes. So, the difference is really huge.

I: Yeah absolutely, enormous. What would you say are the main challenges with creation and marketing of these products? What are the consumers worried about?

R: Of course, there are many challenges and if there were no challenges I wouldn't expect livestock meat to still be presented in such a big amount on our shelves because there is all possible motivations to do the change, so if the change doesn't happen it means we have more work to do. Of course, when we expanded our target audience from vegans or vegetarians to flexitarians and meat lovers, we actually had to face much higher standards, because many vegetarians and vegans, the last time they had livestock meat, if at all, was a long time ago and sometimes they don't even want the meat to be too meaty. Sometimes they say it's disgusting if it's too meaty. But when you go to a person that eats livestock meat [unclear 0:27:17] and you give him an alternative, you really need to aim very high and this is what we do. The biggest challenges, challenge number one in the whole industry is taste. Everybody that you ask, they will say the taste should be better. It means more meaty taste, less odd flavors, and better performance on this subject. Second, versatility. So, Redefine Meat really provided a totally new level of versatility. So, if until now you could have a burger or maybe chicken nuggets as a plant-based version, today we offer a huge variety of products that you can create a lot of culinary creativity, we unleash the culinary creativity for people that work with our products. I

cook lasagne, people do pizza, of course burgers, steaks in different variants, beef Wellington, different types of sausages, koftas, almost everything you can think about. But there is still more to improve and we constantly work on higher levels of products, providing the fat marbling, providing all the fatty mouth feel that people love so much about cuts like ribeye for example, or picanha. So, as scientists we'll look ahead at the products that are already on the shelves and we think about the next generation of products and what are the technological modules that are required for enabling these kinds of products and we provide it.

I: Amazing, incredible. How do you see the future of these plant-based new meat products evolving? Are there exciting developments that you're working on or what would the customer begin to expect in the next five or 10 years?

R: Sure, we work on two factors at the same time. One factor is improving, constantly improving all the products that we already have on the market. So, constantly making our mincemeat tastier, juicier, more healthy, constantly making our steaks being able to imitate all the different cuts that you have from the animal, constantly providing versatile meat that is compatible with all cooking conditions, with all the different kitchens and cuisines. So, we are constantly expanding our spectrum so that all meat lovers can get everything they want as they used to have with livestock meat. I believe the future of the sector will be a major growth of the plant-based alternative. Of course, I don't think it should replace 100 percent of livestock meat. There are many environmental studies that show that actually, taking the industrial farming to zero is also wrong, so there should be some good balance between the two and we are not fighting against anyone. We respect people and their choices, but we believe that if we put a product, the tests, all the performance without the negative impact on the world, people will prefer this product. We also believe that the governments will prefer this kind of product and that there will be policymakers that will come with policies that give preference to things that are more healthy for us and more healthy for the world, the same that you do with electric cars, the same that you do with smart homes. So, as a modern society, we should drive the preference towards a better Earth.

I: What a perfect place to end. Is there anything else that you would like to add about your products or your technology, or anything else you want people to know?

R: Yes, one thing that I wanted to mention that we are super excited about the launch of our products in the retail market in the UK and the Netherlands and today we sell our products in Ocado and we sell our products in Crisp and Albert Heijn in the Netherlands and it's the first time that our products are getting not only to food service and restaurants, but also to customers. We make sure that we take all the qualities that the food service loves so much and we keep them also for the home users. All our development was made with leading chefs from the culinary field, people like Marco Pierre White, like Ron Blaauw, so we really aimed high when we developed our products and now we are very excited to see what the use that people at home will make with our meat. We are looking to hear the feedback and we are looking to deliver more and more meat that will address the taste of everybody.

I: Brilliant. I think because this is our special holiday episode it's really good to hear that your products are available in these countries and if people listening fancy a plant-based

alternative for their holiday meal, they can go out and try some Redefine Meat products instead of traditional livestock meat.

R: Yes, we also have publicly available recipes especially for Christmas dinners. If you are interested please enter our website and you will find it there.

I: Brilliant, thank you so much for joining me Daniel, and talking all things plant-based meat alternatives.

R: Thank you so much Eleanor.

I: That's all from us for this season, but we'll be back in 2024 with more Big Questions, as well as some new IFLScience podcasts to keep an eye or an ear out for. See you there.

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