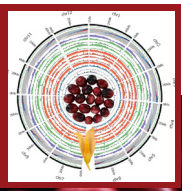
VacCAP

Improving Fruit Quality



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VacCAP Objective

The Vaccinium Coordinated Agricultural Project (VacCAP) is a nationwide project aimed at developing new genetic tools to enhance breeding for improved fruit quality of cranberries and blueberries.

VacCAP is a nationwide coordinated transdisciplinary project focused on addressing major bottlenecks limiting the growth of the U.S. *Vaccinium* industry by developing and implementing marker assisted selection (MAS) capacity in breeding programs.

This will enable breeders to select and pyramid fruit characteristics that positively contribute to fruit quality and market value.

Long term, the scientific resources developed will increase production of fruit with improved characteristics that meet ever-changing industry, market, and consumer preferences.

Buying Better Berries: What Does Fruit Quality Mean to Consumers?

By Josie Russo and Amaya Atucha, *University of Wisconsin-Madison*

VacCAP team members Dr. Elizabeth Canales (top) and Dr. Karina Gallardo (bottom).

While VacCAP team members are working to improve cranberries and blueberries, one question is prominent: will consumers actually buy them? That's what Dr. Karina Gallardo, Co-PD and Professor at Washington State University, and Dr. Elizabeth Canales, Co-PI and Assistant Professor at Mississippi State University, are trying to find out.

Canales and Gallardo's roles in VacCAP are to analyze the socio-economic aspects of improving fruit quality of blueberries and cranberries. They will contribute to the VacCAP project goals by examining consumers' perceptions of different fruit attributes, and their willingness to pay for those attributes.

"Our goal is to investigate consumer preferences as they relate to fruit quality, and the economic impact of their choices for the blueberry and cranberry industries" Canales said. "Once we know what the consumer wants, we can pass that information to the scientists to improve those fruit attributes."

It's important to understand consumers' preferences for the different fruits and options that they have in the market. Blueberries and cranberries are no exception.

For blueberries, they will investigate what are the

Dried cranberries (B)
(6-oz bag)

Nutrition Facts
Serving Size ¼ cup (40 g)
Servings Per Container About 9

Amount Per Serving	
Calories 130	Calories from Fat 0
	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Sodium 0mg	**0%**
Total Carbohydrate 33g	**11%**
Dietary Fiber 3g	**12%**
Sugars 29g	
Protein 0g	

Not a significant source of cholesterol, vitamin A, vitamin C, calcium or iron.

*Percent Daily Values are based on a 2,000 calorie diet.

Dried cranberries (A)
(6-oz bag)

Nutrition Facts
9 servings per container
Serving size ¼ cup (40 g)

Amount per serving	
Calories	**130**
	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Sodium 0mg	**0%**
Total Carbohydrate 33g	**11%**
Dietary Fiber 3g	**12%**
Total Sugars 29g	
Includes 23 g Added Sugars	**46%**
Protein 0g	

Not a significant source of cholesterol, vitamin A, vitamin C, calcium or iron.

*Percent Daily Values are based on a 2,000 calorie diet.

The Nutrition Facts Label (NFL) Canales and Gallardo used in their study. Figure B is an old version of the NFL for dried cranberries, and in Figure A there is the version where added sugars are reported. Photo contributed by Canales.

fruit quality attributes that will increase consumer demand and per capita consumption of blueberries.

"We know what the needs of growers are, we know what the needs of their packing houses are, but we don't know what are the quality attributes that will trigger increased consumption of blueberries," Gallardo said.

For cranberries, the team will investigate how the new FDA regulation that requires explicit language in the Nutrition Facts label declaring added sugars, which affects cranberry products, will affect consumer preferences, and thus the economic impact the change in label information will have for the cranberry industry. Industry groups are concerned the requirement to include added sugar to labels will strike against the "healthy halo" cranberry products have.

"I would like to estimate what is going to be the impact of this change in the language, so we are including questions about added sugars in our survey," Gallardo said. "This will help us see what the impact of this language is on the probability of consumers choosing cranberry products and the probability of purchase."

The team ultimately wants to look at what fruit quality traits could increase consumer demand while diminishing losses for growers and packing houses. But it isn't always as straightforward as asking the consumers if they want a firmer blueberry or less added sugar in cranberry products, as there are other aspects that influence consumers choices such as the type of technologies implemented to produce cranberries and blueberries with the desired fruit quality characteristics.

Gallardo points out they need to understand what technology consumers will accept or reject when it comes to producing a firmer blueberry or less acidic cranberries. This, of course, is linked to the consumer's perceptions of the science behind the implemented technologies and what trade offs they'd be willing to accept in order to get such products.

"In the cranberry case, if elevated sugar content is something that really concerns consumers, will they be willing to accept a new [breeding] technology if the new cranberry variety will not need added sugars?" Gallardo said. "And with blueberries, what if consumers want increased shelf life or a berry less prone to damage?"

The team notes there is already consumer rejection towards genetically modified produce, thus the need to investigate what new technologies consumers will accept or not. In addition, label regulations can vary and are confusing to the consumer, who might not necessarily have a good understanding on the differences in practices like marker assisted breeding or gene editing.

"[New technologies, such as marker assisted selection] are

and will be the standard for breeding programs within the years to come. We would like to see how consumers will respond to that," Gallardo said. "This new wave of consumers is more attuned to the environmental and socio-economic implications of their food choices. I think being transparent is the best thing and telling people what the science is about and why these new developments are so badly needed, in order for them to have the produce they most enjoy."

However, how to display this information in food labels is not well regulated or standardized, thus the critical need to assess how consumers will change, or not, their purchasing choices based on their understanding of the information presented in labels.

"We want to evaluate if the consumers understand the "added sugar" information in the cranberry product Nutrition Facts labels as included in the total sugars or they think it's something separate," Canales said. "We're also evaluating if the consumer changes their perspective towards added sugar if we provide additional information of why the sugar is added to the products, for example that it increases palatability of tart fruits."

With that in mind, the team will also assess if including information on the health benefits of consuming cranberries will counteract the negative perception consumers might have of the added sugars.

To be able to collect this information from consumers, Canales and Gallardo will implement a methodology called choice-based conjoint analysis or discrete choice modeling, which allows them to indirectly elicit how much consumers are willing to pay for specific attributes of a product.

"It has been proven that if you ask a person an open question like 'How much are you willing to pay for this product?', you're not going to get a realistic response, you will get a lower dollar amount that what they would be willing to pay," Gallardo said. "But if you force the consumer to make trade offs between an attribute and the money they want to pay for an improvement in the attribute , then we can arrive at the conclusion of what consumers are willing to pay in order to get an improvement in one attribute or another."

The team says this technique called conjoint analysis uses a series of discrete choice scenarios that are evaluated by consumers where the price and levels of a product's attributes (e.g., level of added sugars) are varied to arrive at dollar figures for different attributes of the product, based on economic theory and using statistical methods to obtain this consumers' willingness to pay estimate.

How the survey questions are worded is important too. Simply asking respondents if they do or do not like blueberries or cranberries isn't going to offer much insight to help the industry. But when you ask them "What sacrifice are you going to make to obtain these improved attributes?" that is when we get more realistic responses from the consumers.

This technique leads to respondents asking "'Am I willing to sacrifice my money in order to get something that does not have sugars, am I willing to sacrifice my money in order to get a blueberry that is firmer or crunchier, or is going to last more than two days in my kitchen?' That is the key to our methodology." Gallardo said.

When choosing to survey consumers, a representative sample of the population in terms of gender, age, income, and education throughout the country is critical. Using audience panels, through services such as Qualtrics, allows them to survey communities of respondents based on their consumers behavior and familiarity with blueberries and/or cranberries.

"In the case of respondent groups that are identified as not consuming these products, we ask them why they don't consume, to get information on what will potentially make them consume the product," Canales said. "This type of information is key to the industry to make the necessary changes to increase consumption."

The team has already received all the responses from one of the surveys they designed for the cranberry study and have started the preliminary statistical analysis with help from Xueying Ma, a third year PhD student at WSU.

Canales and Gallardo have important tasks at hand for VacCAP. While other team members are working diligently in labs and fields across the country to develop better cranberries and blueberries, they will be making sure consumers are ready and willing to put the new and improved berries in their shopping carts.

Fruit Quality: An Industry Perspective

By Josie Russo, *University of Wisconsin-Madison*, Amaya Atucha, *University of Wisconsin-Madison*, and Lisa Wasko DeVetter, *Washington State University*

When you hear the term "fruit quality", what comes to mind? Quality is often a subjective term. Fruit quality may mean something different to everyone—especially a breeder, a grower, industry member, or a consumer. We spoke to Rod Serres, Senior Manager of Agricultural Sciences at Ocean Spray, and Brian Bocock, Vice President of Product Management at Naturipe Farms, about the industry perspective on cranberry and blueberry fruit quality, respectively.

Cranberry

For Serres, fruit quality is rooted in consumer satisfaction. And that starts with a consistent, quality ingredient—the cranberry.

"When consumers buy fresh cranberries, they are looking for sound, uniform red fruit," Serres said. "So that's the big thing that hasn't changed for years; fresh cranberries during the holidays are a tradition for many families."

15 YEARS AGO
the cranberry industry changed with the arrival of SDCs

But even consistency and tradition are variable based on where in the country you live.

"Wisconsin berries are generally larger than those from other regions. While Massachusetts has 'Early Blacks' and 'Howes'—which are much smaller berries, almost half size berries," Serres said. "And one time, we had some fresh cranberries from Wisconsin stocked at grocery stores in Massachusetts. We had a few calls asking what type of cranberries these were, and if they could get their regular size cranberries. The consumer usually sticks with what they're used to when it comes to the cranberry fresh fruit business."

However, what quality means when it comes to the processed cranberry business has changed significantly in the last two decades with the introduction and consumer demand for sweetened dried cranberries (SDCs, commonly referred to as Craisins™). The cranberry industry was dominated by the juice market up until 15 years ago, but that all changed with the arrival of the SDC.

"Now, virtually every berry needs to become an SDC," Serres said. "When we started needing fruit for SDCs, each individual berry needed to have full color and the size of the berries became an important trait, since larger berries are better for slicing to make the SDCs."

The development of this new product changed the definition of fruit quality from the qualities of a 'lot' of fruit to the qualities of an individual berry. And now those important characteristics included not only color, but size and firmness. It also strengthened the connection between efficiency and quality, posing the question: what is a good quality characteristic that would increase efficiency and increase consumer-based quality of those products?

"Efficiency is the other big thing as far as fruit quality goes," Serres said. "How can we produce the products more efficiently? And in the case of Ocean Spray that has a variety of cranberry products, how can we get several different product streams out of the same fruit?"

Quality also takes on a different meaning from the processing side of things. With the need to get more product out of the same berry, size has become a critical trait. Getting more slices per berry increases efficiency and reduces waste, and it has producers looking at aspects of a berry they never thought of before.

"We had little interest in size as far as juice goes. But now it's important, so we would like larger berries," Serres said. "We need to be careful in breeding programs though. Dr. Juan Zalapa has identified variability in vacuole size [those air pockets in the middle of a berry], which we almost never paid attention to before. It matters now because SDCs need the flesh not the vacuole. So, a large berry with a lot of flesh is going to be much more valuable than a large berry with huge vacuoles."

Firmness of berries also has more emphasis now. A firmer berry makes it easier to slice for SDCs after they have been frozen. If a berry is too soft or overripe when frozen, it will not keep its integrity once it's thawed, and the skin will separate from the pulp. This prevents them from getting back into shape after being sliced, something important for producing SDCs.

Uniformity—especially of color—has always been an important trait for fresh fruit, but fresh fruit accounts for only 5% of all cranberry production. Color has definitely become more vital over the years with the increase in demand for SDCs which require full red color of each individual berry.

"Anything from a breeding program, or anything from a cultural program that promotes uniformity among all the fruit in a bed for key quality characteristics will be valuable," Serres said.

All of these characteristics—and understanding what controls them genetically—is even more important as the industry looks to market innovative cranberry products to consumers. Serres says the industry is always looking to give consumers something new and exciting in cranberries.

That could be everything from non-red or low acid cranberries to a whole diversity of new products like cranberry powder or seeds—enhanced with omega three oils—that could be used in breads and muffins.

But even with the highest of quality cranberries, it isn't as simple as putting it on the shelf and hoping it sells. Serres says that consumers, faced with lots of choices, are going to have to be directly marketed to, so they see cranberries as the best option for a healthy refreshment, snacking, meal accompaniment, baking and whatever else is down the innovation road.

"I think the mindset here is we're going to have to go all out and say this is the next best thing since sliced bread," Serres said. "When it comes to cranberries, it's an education marketing effort that you have to go through. Otherwise, it takes decades for it to catch-on on its own."

Over the last several years, what has defined fruit quality in cranberries has evolved from a simple red fruit needed for juice to needing large, uniformly red, firm berries capable of being transformed into a myriad of products. And with new, innovative products constantly on the horizon, that definition of cranberry fruit quality could see another transformation in the coming years.

Blueberry

Texture, firmness, and flavor—that's what makes a quality blueberry according to Bocock.

"At the end of the day, it really comes down to that," he said. "Of course, you can't have mold. Of course, you can't have wet leaky berries. That goes without saying, right? But what separates one berry from the other?"

When a consumer bites into a blueberry, they don't want something that is squishy and soft. It doesn't make for a pleasant eating experience. That makes texture a priority in blueberry quality. And imported blueberries bring that even more to light.

In the last decade, there has been an increased adoption of southern high bush cultivars that have higher quality texture attributes (e.g. crisp) in southern US states and South America (Peru, Mexico, Chile). The uptick in these cultivars—which were developed in the US—likely fueled the US market and contributed to a new fruit quality experience for US consumers.

"Eight years ago, no one knew about blueberries from Peru," Bocock said. "And within the last five or six years, all of a sudden here comes this consistently large piece of fruit with good texture, that almost crunches in your mouth."

But the imported blueberries from Latin America lack flavor, compared to the US blueberries, which is also a very important fruit quality characteristic.

"Imported blueberries from [Latin America] are not the perfect blueberries. But they are better than a lot of the late season blueberries from North America," Bocock said. "When the flavor is at least as good and the quality is similar, the texture just makes all the difference in the world."

Flavor is still a prominent and interesting characteristic for blueberries, given their profile. According to Bocock, roughly 75% of the American palate prefers a sweeter flavor with just a touch of tart, versus tart with a touch of sweet.

"Blueberries tend to be pretty acidic. It comes across as a very tart berry," Bocock said. "And so, the problem we have with blueberries and with the consumer, is you got 25% of the population that likes this kind of tart with a touch of sugar. Then, you got 75% of the population that likes a really sugary berry with a touch of tart on the back end of the palate."

Bocock believes texture trumps flavor in the eating experience but are both key in terms of quality.

"If texture didn't trump flavor, blueberries from Peru would

have not become as successful in the US market as they have," Bocock said. "Blueberries from Peru looked great. It popped in your mouth. But the flavor was not necessarily there. However, they are still very successful. I think texture is one [characteristic] and flavor is one, and that they're really closely attached to each other."

Latin America entering the US market was also a gamechanger in what consumers began to expect of blueberry quality over the last five years. This has led to a diversion from decades of the status quo and blueberry breeding programs popping up all over the world. The advances made in texture highlights how important this trait will be for US growers and is why the VacCAP team is including texture in their work.

Bocock notes that the consumers' definition of quality is always a matter of what you're comparing yourself against, such as imported berries from Latin America.

"It's all been driven by the consumers expectations by the retailer's desires," Bocock said. "And so, the retail is the gatekeeper to your refrigerator, right? But they are a reflection of their consumer."

Demand for bigger berries is one result of that, with consumers expectations shifting to larger fruit. This may lead to them carrying a premium in the marketplace in the future and trigger more selection pressure for size on the grower's end. Unless they have powerful flavor, smaller berries could fall to the wayside.

"If you see a smaller berry, it'll sit on a shelf a little bit more, unless you can really call out flavor," Bocock said. "If that smaller berry can really deliver a powerful punch on flavor, your marketer should call that out on the package and the consumer should experience that flavor differentiation. If successful, that will be something that would trump the size. But other than that, if flavor, texture, and firmness are consistent, then the large one will become the consumers' expectation."

At the end of the day, fruit quality and how the industry defines it often relies on the consumer. Without a customer, you don't have an industry.

"When's the last time you ever went into a produce department and saw any item it had mold? Or the bananas had a whole bunch of dark pits on it. And the apples had pitting on it. And you said, am I buying that and paying full price'?" Bocock asked. "The answer is never... That's why quality is important. Because if you do not deliver something that's going to meet the consumers expectation of quality—and that's key, that consumers' expectation on quality—you're not going to have an industry. Period. End of story. You can yield 100 million pounds to the acre. But if consumers walked in and said, 'That is nasty,' it isn't going to survive."

Podcast Feature: 'The Business of Blueberries' Coordinated Effort to Improve Blueberry Genetics

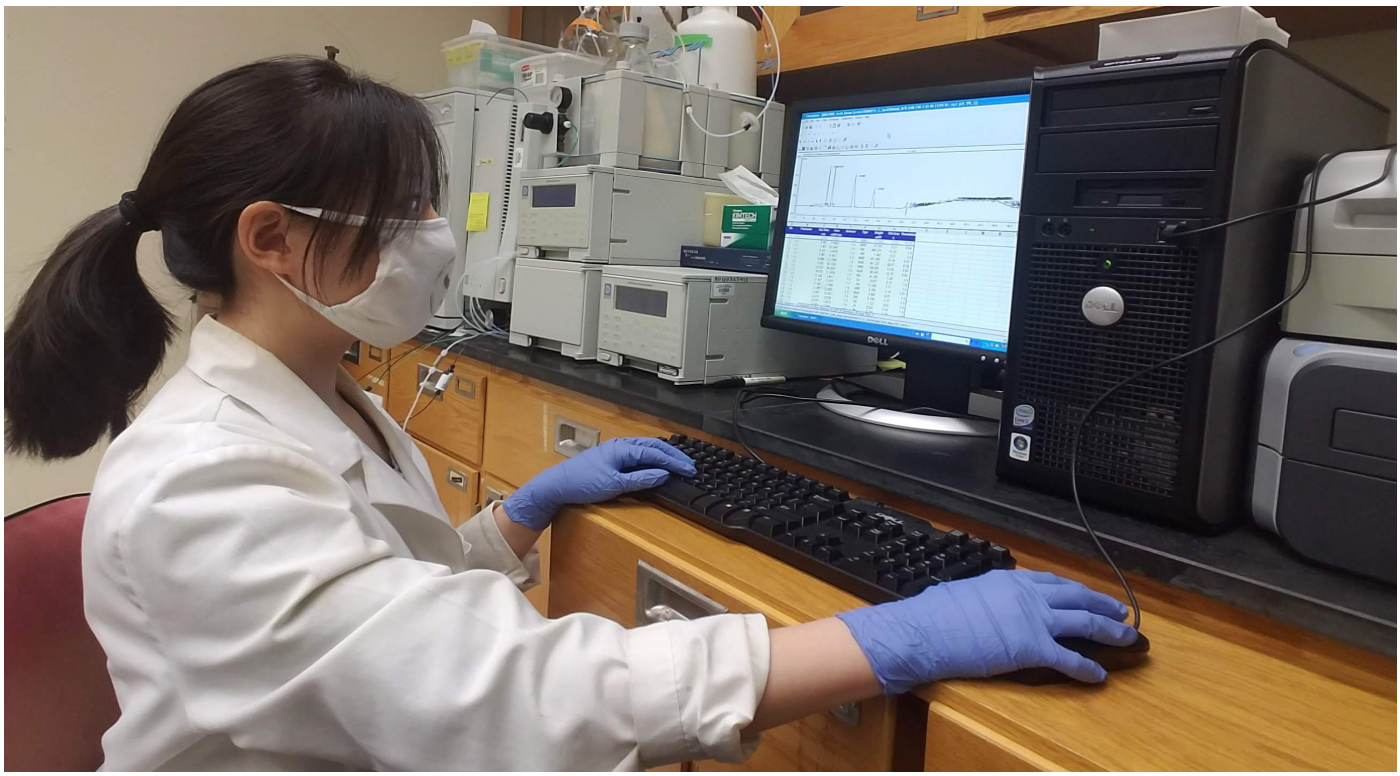
Be sure to tune into the January 21, 2021 episode of "The Business of Blueberries" podcast to hear VacCAP team members discuss the project and research. You can listen on the U.S. Highbush Blueberry Council website or on major platforms Apple Podcasts, Spotify, and Stitcher.

Guests:

- Massimo Iorizzo, Ph.D., associate professor in the North Carolina State University Department of Horticultural Science
- Jim Hancock, Ph.D., professor emeritus at Michigan State University and recent recipient of the NABC Duke Galletta Award
- Patricio Munoz, Ph.D., assistant professor in the Horticultural Sciences Department in the University of Florida.

Topics covered include:

- Overview of the VacCAP Specialty Crop Research Initiative.
- What VacCAP hopes to accomplish for blueberry breeding.
- Current status of the initiative.
- How researchers are creating the genome of the ideal blueberry.



Graduate student Yurah Kim evaluating organic acid HPLC profiles in a progeny (family) segregating for the low malic acid gene. Photo contributed by Nicholi Vorsa.

A Low Malic Acid Trait in Cranberry Fruit: Genetics, Molecular Mapping, and Interaction With a Citric Acid Locus

By Josie Russo, *University of Wisconsin-Madison*

Commercial cranberry cultivars have high concentrations of acids, about five times that of fruit eaten fresh, that contribute to high titratable acidity (TA)—or tartness within the fruit. To offset the tartness for consumers, higher amounts of sugar need to be added in the cranberry products, such as sweetened-dried-cranberries and juices. The added sugar has deterred consumers from increasing cranberry product consumption despite cranberry health benefits.

Authors

- Stephanie Kay Fong, Joseph Kawash, Yifei Wang, Jennifer Johnson-Cicalese, James Polashock, and Nicholi Vorsa

- Tree Genetics & Genomes 17, 4 (2021).
- https://doi.org/10.1007/s11295-020-01482-8

Highlights

- Commercial cranberry cultivars have high concentrations of acids, about five times that of fruit eaten fresh, that contribute to high titratable acidity (TA)—or tartness within the fruit.
- To offset the tartness for consumers, higher amounts of sugar need to be added in the cranberry products, such as sweetened-dried-cranberries and juices. The added sugar has deterred consumers from increasing cranberry product consumption despite cranberry health benefits.
- Within the cranberry germplasm collection at Rutgers University, a unique cranberry plant was identified with fruit having a lower percent TA than is normally found in commercial cultivars and may offer cranberry products with less added sugar.
- Crosses using this plant identified a naturally occurring genetic trait that produced fruit with a lower malic acid, which impacts TA.
- Utilizing these populations—segregating for the low malic acid traits—it was possible to generate effective genetic markers for use in breeding of cranberry cultivars with TA.

Key Words

- Locus: fixed position on a chromosome where a genetic marker is located
- Allele: one of two or more versions of a gene
- Heterozygous: two different versions of a gene present in an individual.
- Homozygous: two copies of the same version of a gene in an individual

Introduction

- Cranberries are known for their health benefits, but due to the fruit's relative tartness, most cranberry products typically contain up to 40% added sugars (Ocean Spray

Cranberries Inc. 2019).

- Cranberry fruit has three organic acids that contribute to tartness or TA: malic (MA), citric (CA), and quinic acid (QA)—though to a lesser extent
- Modeling MA in peach showed that both MA and CA are significant contributors to TA (Lobit et al. 2002).
- A germplasm accession was collected from a native cranberry population in Suffolk County, NY which exhibited lower MA in a subsequent germplasm screen.
- If TA is affected by the concentration of MA, then reducing the latter will reduce overall acidity/tartness in cranberry fruit, thus reducing the amount of added sugar needed in cranberry products.

Objectives of this Study

- As the first characterization of the genetics of a qualitative low MA trait in cranberry fruit, the objectives of this study were to:
  - describe the inheritance of the *mala* allele (a low MA allele), its effect on TA and MA, and its relationship with CA and QA.
  - identify, develop, and validate molecular markers that could be used to select for the low MA trait.
  - determine the effect of the *mala* among other cranberry genotypes that have the *cita* allele (a low CA allele)

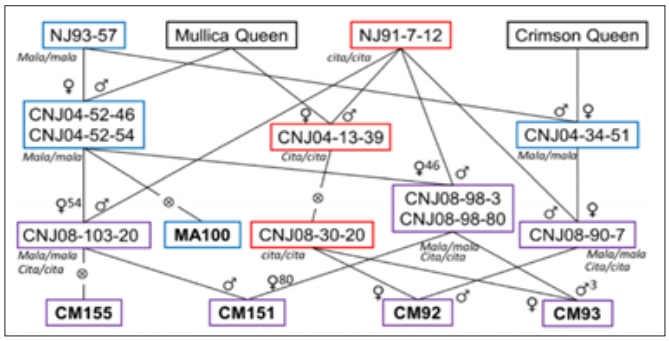
Experiments

1993

- A germplasm accession, NJ93-57, was collected and exhibited lower MA in a subsequent germplasm screen.

2004-2012

- An initial cross, of the germplasm accession with cv. Mullica Queen (MQ), was made in 2004 to generate the CNJ04-52 population (Fig. 1). Between 2004 and 2012, various crosses were made to produce varying populations.



- Crosses were made manually during April and May in the greenhouse during 2004–2012.
- Seedlings were maintained in the greenhouse and in the field for at least three years.

2017 and 2018

- During the spring and summer, flowering plants were taken outside for bee open pollination.
- Fruits were collected from each individual in each population once a year during late August and September in 2014–2018 for analysis of TA and organic acids with HPLC .
- Leaf tissue was collected in the spring of 2017 for DNA extractions.

Results

- This study characterized a low MA trait in cranberry fruit derived from a native germplasm accession (NJ93-57) and determined its interaction with genotypes at the *CITA* locus.
- NJ93-57 was determined to be heterozygous (*Mala/mala*). In an F2 population, derived from an F1 Mullica Queen × NJ93-57, progeny with a MA concentration as low as ~ 2 mg/g were recovered (compared to the typical 6–8 mg/g range).
- This progeny has the lowest level MA phenotype reported in cranberry and is a result of a *mala/mala* homozygous genotype.
- The high correlation of MA levels across years indicates a strong qualitative genetic effect of the *mala/mala* genotype.
- However, significant differences in MA and TA between populations with the low MA trait, indicate general genetic background also influences acidity to some extent.
- To characterize and map the low MA trait, *mala*, three populations (119 unique individuals) were phenotyped and genotyped. The three populations segregated for the low MA trait (~ 2 mg/g FW) consistent with a single, co-dominant gene in a Mendelian pattern and we named the locus *MALA*.
- The *mala* allele had a significant effect on QA and CA as well as TA.

The homozygous mala plants have a dwarf-like growth habit which is likely not commercially viable. Photo contributed by Nicholi Vorsa.

- Although the *mala/mala* genotype yields TA < 1%, there is a caveat, as the homozygous mala plants have a dwarf-like growth habit which is likely not commercially viable.

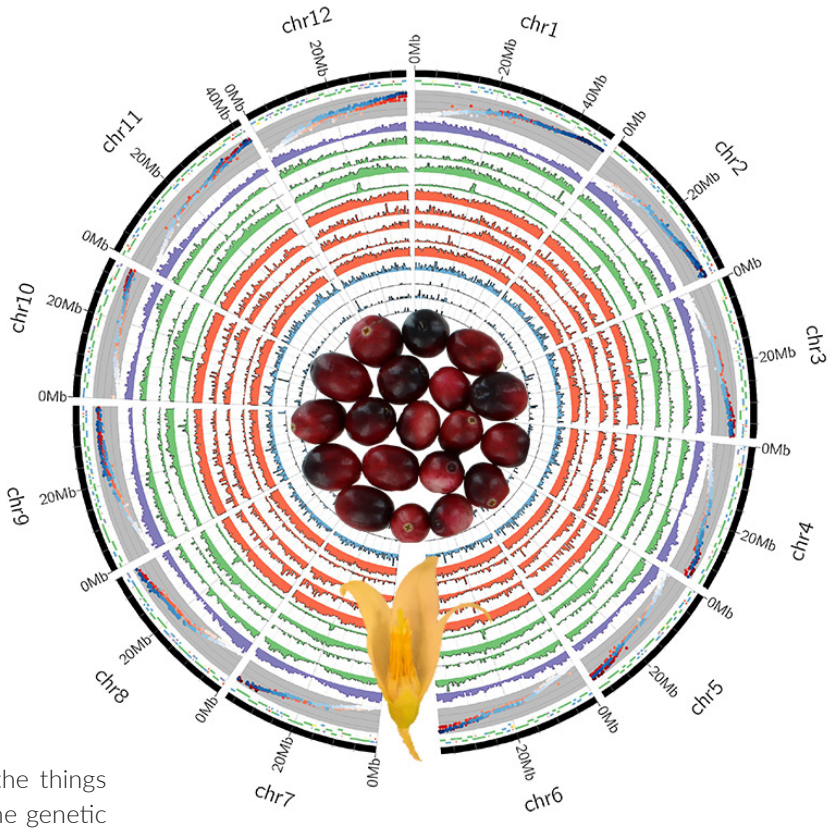
Conclusion

- A low MA trait was characterized, and a genetic locus was identified that presents a decreased TA to below 1%—within the range of fruit that is consumed fresh (Kallio et al. 2000).
- Other than variation in acidity, there were no other apparent fruit quality traits affected.
- Markers have been identified and are being developed for genetic screening, including screening the germplasm collection for low MA.
- Identifying the genes controlling CA and MA accumulation would allow greater ability for marker-assisted selection and gene editing applications in the future. This will allow seedlings of no value to be culled—saving space, time, and money.
- Continued work will contribute to breeding efforts to develop commercially viable cranberry cultivars that require less added sugar.

Piecing Together the Cranberry Genome Puzzle

By Josie Russo and Amaya Atucha, *University of Wisconsin-Madison*

Over the last decade, Dr. Juan Zalapa has been working on a puzzle—a 500-million-piece one. Zalapa and others in his team—such as Luis Diaz-Garcia—is working to assemble the 'Stevens' cranberry genome in order to identify which genes control what traits in cranberry cultivars.



"Cranberries have 12 chromosomes. So, one of the things that we need to do for sequencing is to decipher the genetic code (bases) of those 12 chromosomes," Zalapa said "When you do any kind of genetic sequencing, you can't get a single piece sequence for a whole chromosome. There are 500 million bases of chromosome sequence—divided into 12 chromosomes roughly, it could be 50 million bases per chromosome. And assembling this is like putting together a puzzle."

Newer technology over the last ten years has made that puzzle assembly a bit easier and faster, allowing Zalapa and his team to obtain more and longer sequences at once and move closer to their sequence assembly goal. Zalapa and his team had to learn how to assemble or build the chromosomes back together, making improvements over the years before arriving at this current 'Stevens' genome iteration. And there is still some work to do for the sequencing project to refine and improve the chromosomes.

"There's still some gaps in different places of the chromosomes. And then we have some loose pieces here and there. So, this is still a chance for improvement," Zalapa said. "That is why the VacCAP is going to continue to improve the assembly. And, in a couple years, we should have 10 more genomes of cultivars representing a wide diversity in cranberry. So, the Stevens cultivar genome is the first of many to come in."

Having the 'Stevens' cranberry genome allows for more accurate marker selection in breeding the cranberries. While marker selection can be done with current linkage maps—roadmaps of general locations where certain genes are within the chromosomes—it isn't as accurate.

"A molecular map is like a freeway or a highway, and you have signs that say there's a McDonald's coming up. But the sign is not the McDonald's, it is only announcing the exit to it is coming up," Zalapa said. "So, the linkage map only tells you when something is around a general location. The cranberry genome actually gives me the exact location of something."

Sequencing the genome is the key to finding the differences across cranberry cultivars that lead to different traits. According to Zalapa, there could be more than 99 percent similarity between cranberry cultivars, but that one percent or less that is different, is really what controls all of the differing traits for the cultivars—like high yield versus low yield, and high quality versus low quality.

"When we're talking about high fruit firmness, high yield, improved quality, or even the ability to survive under the adverse conditions or in a wider set of environments, all these traits are related to a very tiny amount of genetic information in the chromosomes, so we're talking about a sea of information that is the same, and only a few drops of water that matter," Zalapa said. "And what [the 'Stevens' cranberry genome] allows us to do is match all of the things that are in common, and the things that are different among different cultivars. And then, we're going to start looking at what those differences are and what they actually do in terms of traits. This is why we need multiple diverse genomes sequenced, and this is the first of many genomes we have to do to understand the 'good' and 'bad' trait variation"

A better understanding of the cranberry genome and what genes control certain traits is important for an industry seeking to improve fruit quality. In time, this research will be invaluable for breeders and researchers to produce cultivars faster and more efficiently based on what traits the industry and the public demand.

"Through VacCAP, we're going to have multiple genomes; we will know more efficiently the chromosomes locations where the most important variation is that produce better cultivars and better traits" Zalapa said. "Once we know where the important chromosome locations are, we can start looking at the variation in traits in those areas. And this is going to

accelerate the efficiency in selecting crosses and cultivars with the traits we want."

The research was recently accepted for publication in Frontiers Plants Science journal as "Chromosome-level genome assembly of the American cranberry (Vaccinium macrocarpon Ait.) and its wild relative Vaccinium microcarpum."

The current data for the genome is also available on the Genome Database for Vaccinium (GDV; www.vaccinium.org) site for immediate use. This genome represents an extremely important resource for any ongoing and future cranberry genetic-genomic based projects or other projects seeking to effectively translate massive DNA and phenotypic datasets into useful information for the Vaccinium research and breeding community.

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If you are interested in contributing or have announcements for events, publications, or another other initiative that you want to share, contact Josie Russo at jrusso2@wisc.edu with the subject line "VacCAP Newsletter Contribution"

VacCAP
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