UNIVERSITY OF MARYLAND
OFFICE OF THE PRESIDENT

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April 2, 2021

James D. Fielder, Jr.
Secretary of Higher Education
Maryland Higher Education Commission
6 N. Liberty Street
Baltimore, MD 21201

Dear Secretary Fielder:

I am writing to request approval for a new Bachelor of Science program in Fermentation Science. The proposal for the new program is attached. I am also submitting this proposal to the University System of Maryland for approval.

The proposal was endorsed by the appropriate faculty and administrative committees and was recommended for approval by the University Senate at its meeting on March 3, 2021. I also endorse this proposal and am pleased to submit it for your approval.

Sincerely,

Darryll J. Pines
President
Glenn L. Martin Professor of Aerospace Engineering

DJP/mdc

cc: Antoinette Coleman, Associate Vice Chancellor for Academic Affairs
Ann Wylie, Senior Vice President and Provost
Craig Beyrouty, Dean, College of Agriculture and Natural Resources

Office Use Only: PP#

Cover Sheet for In-State Institutions
New Program or Substantial Modification to Existing Program

Institution Submitting Proposal	University of Maryland, College Park

Each action below requires a separate proposal and cover sheet.

- (●) New Academic Program
- ( ) New Area of Concentration
- ( ) New Degree Level Approval
- ( ) New Stand-Alone Certificate
- ( ) Off Campus Program
- ( ) Substantial Change to a Degree Program
- ( ) Substantial Change to an Area of Concentration
- ( ) Substantial Change to a Certificate Program
- ( ) Cooperative Degree Program
- ( ) Offer Program at Regional Higher Education Center

Payment Submitted: (●) Yes ( ) No Payment Type: (●) R*STARS # ( ) Check # Payment Amount: $850 Date Submitted: 4/13/21

Department Proposing Program	Nutrition and Food Science	
Degree Level and Degree Type	Bachelor's; Bachelor of Science	
Title of Proposed Program	Fermentation Science	
Total Number of Credits	120	
Suggested Codes	HEGIS: 011200	CIP: 01.1005
Program Modality	(●) On-campus ( ) Distance Education (*fully online*)	
Program Resources	(●) Using Existing Resources ( ) Requiring New Resources	
Projected Implementation Date	(●) Fall ( ) Spring ( ) Summer	Year: 2021
Provide Link to Most Recent Academic Catalog	URL: https://academiccatalog.umd.edu/	
Preferred Contact for this Proposal	Name: Michael Colson	
	Title: Senior Coordinator for Academic Programs	
	Phone: (301) 405-5626	
	Email: mcolson@umd.edu	
President/Chief Executive	Type Name: Darryll J. Pines	
	Signature: Darryll J. Pines	Date: 04/02/2021
	Date of Approval/Endorsement by Governing Board:	

Revised 1/2021

A. Centrality to the University's Mission and Planning Priorities

Description. The proposed Bachelor of Science in Fermentation Science is concerned with the application of the fundamental principles of the physical, biological, and behavioral sciences and processing to understand the complex materials recognized as the raw precursors or/and final food products and beverages of fermentation. The science-based curriculum includes foundational courses in chemistry, biology, and food and plant science, with tracks in viticulture, brewing, cheese and dairy products, and pharmaceuticals along with fundamentals of business. Through this program, the University of Maryland (UMD) seeks to support Maryland's agricultural workforce through providing graduates who have a solid foundation in the broadly defined fermentation industries that include beverages (beer, wine, distilled spirits and kombucha), vegetable foods (kimchi, tempeh, and miso), dairy foods (cheese and yogurt) and biotechnology industries (biofuels and pharmaceuticals). The program will be offered through a partnership between UMD's department of Nutrition and Food Science and the department of Plant Sciences and Landscape Architecture, both of which are within the College of Agriculture and Natural Resources. Students will learn not only the fermentation process, but also the agricultural production of grain, fruit, and flavor-enhancing crops that support fermentation-based industries. Graduates will be well prepared for career options in a variety of industries that use fermented products as their base. They will also be well-versed in the societal issues related to fermentation science such that they contribute to debates regarding the future of farming, the use of microbes & phages in fermentation, sustainability of our fermentation industry, the worker needs, and scaling fermentation enterprises up and down to meet our growing population's fermented product needs.

This program is being designed for offerings on the College Park campus and at the Universities at Shady Grove. Although the text describes offerings at both locations, this proposal is for the offering at College Park. If this proposal is approved, UMD will submit a substantial modification proposal to offer the program at Shady Grove.

Relation to Strategic Goals. The University's mission statement highlights the institution's role as the flagship campus and one of the country's first land-grant universities. As such, *UMD strives to use its research, educational, cultural, and technological strengths in partnership with state, federal, private, and non-profit sectors to promote economic development and improve quality of life in the State of Maryland.* In alignment with the University's land-grant responsibilities, the College of Agriculture and Natural Resources has developed five strategic goals[1], one of which is to *"advance innovative, profitable, and sustainable agricultural production systems."* The proposed program speaks directly to this goal through the education and training of students for future careers in the agricultural economy and promotion of economic development in an area of growth in Maryland.

Funding. Resources for the new program will be drawn from within the College of Agriculture and Natural Resources, which currently has the instructional capacity to grow its undergraduate student body. In addition to the on-campus delivery of the program, an offering of the upper years of the program is being proposed for delivery at the Universities at Shady Grove (USG), as a transfer pathway for community college students who seek to pursue a bachelor's degree, taking advantage of the strong partnership between Montgomery College and USG. The USG option will be supported by Governor Hogan's Workforce Development Initiative that was approved by the State Legislature

[1] https://agnr.umd.edu/about/strategic-initiatives

beginning in FY19. Funds were specifically directed to increasing the number of undergraduate degree offerings in STEM areas in Montgomery County. USG's mission is *"to support and expand pathways to affordable, high-quality public higher education that meet the distinctive needs of the region and are designed to support workforce and economic development in the state; to achieve these goals through partnerships and collaborations with academic, business, public sector and community organizations that promote student success, high academic achievement and professional advancement.*" This program contributes directly to the goals of access and affordability, to high quality programming, and to regional and state capacity building, as articulated in USG mission statement.

Institutional Commitment. The program will be delivered by a collaboration between two academic units within the College of Agriculture and Natural Resources. UMD's Provost and President fully support this development.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

Need. To assess the need for trained graduates in fermentation science, the College of Agriculture and Natural Resources contracted with Towson University's Regional Economic Studies Institute (RESI) to carry out a workforce study, which is attached as Appendix D. RESI determined that the state of Maryland has had a large increase in fermentation-related businesses, with breweries and distilleries growing by 218% and 375%, respectively, between 2014 and 2018. As of 2018, fermentation-related industries employed 21,918 Maryland residents, and they are still projected to grow by 7% by 2026. As noted below, there are no fermentation programs within the state of Maryland at present; thus, the program proposed here would contribute to meeting a current workforce need.

State Plan. The proposed program aligns with the *Maryland State Plan for Postsecondary Education* in several ways. First, the program aligns with the state's emphasis on career training and applied research. Strategy 7 of the *Maryland State Plan* is "Enhance career advising and planning services and integrate them explicitly into academic advising and planning."[2] Career advising will not only be integrated with student advising but will also be incorporated in the program coursework. All core courses for the program will help students achieve this outcome.

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State

As noted above, the University of Maryland contracted with Towson University's Regional Economic Studies Institute (RESI) to identify regional workforce demand, as well as an assessment of related programs nearby. RESI used the North American Industrial Classification System (NAICS), which identified a large increase in fermentation-related establishments in Maryland. Consumer demand for all fermentation products, not just alcoholic beverages but also foods such as kimchi, tempeh, and miso as well as use in pharmaceuticals, has grown significantly. Section 6.2 of RESI's report goes beyond the agricultural sector to identify market needs in all areas in which fermentation is a core element.[3] These include positions in the life sciences, biotechnology, and biochemistry. Recommendation for

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[2] Maryland Higher Education Commission. (2017). *Maryland State Plan for Postsecondary Education.* (p. 60). Retrieved October 29, 2018 from: http://www.mhec.state.md.us/About/Documents/2017.2021%20Maryland%20State%20Plan%20for%20Higher%20Education.pdf.

[3] RESI's report (p. 15) includes reference to data at O*NET online (https://www.onetonline.org/search/t2/?s=fermentation&g=Go) and Maryland occupational projections (https://www.dllr.state.md.us/lmi/iandoproj/maryland.shtml) as data sources.

development of the program also came from the Brewers Association of America, the Maryland Wineries Associate, and the Maryland Department of Commerce.

Regarding supply, no colleges in the state of Maryland offer fermentation science program. Within the 500-mile region of College Park, only four institutions offer bachelor's fermentation science programs to a total of 213 students. These four regional institutions are the Appalachian State University (B. S. in Fermentation Sciences), Edinboro University (B.S. in Fermentation Science), SUNY Cobleskill (B.T. in Applied Fermentation) and Virginia Polytechnic Institute and State University (B.S. in Food and Beverage Fermentation).

RESI's report also highlights the results of a 2016 survey showing that *"56.2% of students attending a public four-year college remained within 50 miles of home, with an additional 12.7% within 100 miles of home. Maryland students are far less likely to attend comparable fermentation science programs that are not within the state. The proximity effect continues after students graduate from college, with 40% of graduates from state universities remaining within 50 miles of campus."*

D. Reasonableness of Program Duplication

The lack of programs within the state of Maryland negates any issues of program duplication.

E. Relevance to Historically Black Institutions (HBIs)

Many members of the UMD faculty within the College of Agriculture and Natural Resources also serve as educators within the University of Maryland Extension (UME). Similarly, many of the Agriculture faculty at the University of Maryland Eastern Shore have this dual role, and the two institutions collaborate on the execution of UME's statewide outreach and education programs. These efforts promote agricultural production and profitability, improvements in human, animal and environmental health, and the sustainability of natural resources through innovative approaches, as well as undergraduate instruction and graduate research programs. These collaborative efforts will provide natural opportunities for UMES students and faculty to participate in projects related to this new program.

F. Relevance to the identity of Historically Black Institutions (HBIs)

Given the lack of a program anywhere in Maryland we do not anticipate any impact on the identities of the State's HBIs.

G. Adequacy of Curriculum Design, Program Modality, and Related Learning Outcomes

Curricular Development. The curriculum was developed jointly by faculty in the department of Nutrition and Food Science and the department of Plant Sciences and Landscape Architecture with support of the dean's office. NFSC faculty consists of five professors, six associate professors, one assistant professor and three instructors. The unit anticipates hiring additional faculty as the program develops. The Plant Science and Landscape Architecture (PSLA) Department will collaborate with the NFSC Department to deliver two new courses and to redesign three existing courses as requirements for the major.

As noted above, during the planning stage the College in collaboration with the Maryland Department of Commerce sought assistance from the Regional Economic Studies Institute (RESI) at Towson University to conduct a workforce study that resulted in a very positive report about the potential of such a program on the UMD campus. Meanwhile, the Universities at Shady Grove and the PSLA Department have agreed to use the funded workforce development grant by the Maryland legislature to support a parallel effort on the Shady Grove campus. After the program is established, efforts will be made to establish additional collaborative relationships with the Maryland Department of Agriculture, Department of Commerce, the US Department of Agriculture (USDA), the Food and Drug Administration, the fermentation and cheese industries, the Maryland Wineries Association, and the Brewers Association of Maryland. Industry partners have the potential to provide hands-on learning opportunities for students in the program.

Faculty Oversight. Initially, the dean of the college (Dr. Craig Beyrouty), the associate dean for academic programs (Dr. Joseph Sullivan), the acting assistant dean (Dr. Frank Coale) and the chairs of NFSC, PSLA and Animal and Avian Sciences (ANSC) departments will coordinate to provide academic direction and oversight for the program. Once the program is established, an oversight committee consisted of the core faculty, student representatives and industrial advisory members will be formed to play the role in providing guidance and suggestions on program development, oversight, and management.

Appendix A contains a list of the relevant faculty who will be actively engaged in teaching the core elements of the curriculum.

Educational Objectives and Learning Outcomes. The educational objectives of the program are as shown below:

1. Careers and opportunities - Graduates will be well prepared for at least four career options [in beverage (beer, wine, distilled spirits and kombucha), vegetable foods (kimchi, tempeh and miso), dairy foods (cheese and yogurt) and biotechnology industries (biofuels, pharmaceuticals and nutraceuticals] based upon their UMD fermentation science training, experience and interests.
2. Fermentation science - Graduates will be able to apply fermentation science knowledge and research to enhance fermentation process, propagation and modification of fermentation microbes, fermenter design and downstream processing including effluent treatment. Students will demonstrate mastery of the manufacturing steps involved in various fermented products and gain hands-on experience in making these products at pilot scale and evaluate their quality and safety.
3. Fermented food, feed and pharmaceuticals - Graduates will be able to correctly apply their knowledge in the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. Students will be able to describe fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.
4. Fermentation science literacy - Graduates will be able to select, understand, and critically evaluate scientific studies in fermentation science disciplines such that they employ research that is applicable, timely, accurate, and useful for their fermentation production and management needs.
5. Knowledge of major issues - Graduates will be well-versed in the issues related to fermentation science such that they contribute to societal debates around the future of farming, the use of microbes & phages in fermentation, sustainability of our fermentation industry, the worker needs, and scaling fermentation enterprises up and down to meet our growing population's fermented product needs.

Individual course-level learning outcomes are established in alignment with the program level objectives.

Institutional assessment and documentation of learning outcomes. Undergraduate programs complete annual assessments, with each learning outcome evaluated at least once in a four-year cycle. Programs report findings each fall in summary form following a template structure and are informed by a "best practices" guide and a rubric. Assessment summary reports for each college are collected by the College Coordinator, who works to promote high standards through support and guidance to programs and with continuous improvement practices.

Student Learning Outcomes are evaluated through course-specific performance indicators. The department will establish rubrics for each performance indicator and develop a course-related assessment as part of this evaluation. Faculty members will then be asked to evaluate the students through these course assessments. Assessment of learning outcomes will take place each year. Draft rubrics for the assessment of target courses is attached as Appendix C.

Course requirements. The Fermentation Science program is based on a strong background in biology and chemistry, along courses specific to the development of fermented products. The program includes 87-90 credits of required courses (including Fundamental Studies general education), along with an additional 30-33 credits of general education and electives related to the discipline. Elective courses will be drawn from the departments of Agricultural and Resource Economics, Business, Communication, the Institute for Applied Agriculture, Nutrition and Food Science, Animal Science and Agricultural Science and Technology.

Course List		
Course	**Title**	**Credits**
BSCI170	Principles of Molecular & Cellular Biology	3
BSCI171	Principles of Molecular & Cellular Biology Laboratory	1
BSCI223	General Microbiology	4
CHEM131	Chemistry I - Fundamentals of General Chemistry	3
CHEM132	General Chemistry I Laboratory	1
CHEM231	Organic Chemistry I	3
CHEM232	Organic Chemistry Laboratory I	1
CHEM241	Organic Chemistry II	3
CHEM242	Organic Chemistry Laboratory II	1
CHEM271	General Chemistry and Energetics	2
CHEM272	General Bioanalytical Chemistry Laboratory	2
ENGL101	Academic Writing	3

Course List		
Course	**Title**	**Credits**
ENGL393	Technical Writing [1]	3
MATH120	Elementary Calculus I	3
NFSC112	Food: Science and Technology	3
BCHM463	Biochemistry of Physiology	3
NFSC398	Seminar	1
NFSC421	Food Chemistry	3
NFSC423	Food Chemistry Laboratory	3
NFSC430	Food Microbiology	3
NFSC431	Food Quality Control	4
PLSC110	Introduction to Horticulture	3
or PLSC112	Introductory Crop Science	
PLSC130	Did Yeast Create Civilization?	3
AGST3XX	Viticulture and Enology	4
AGST3XX	Brewing and Distilling	4
NFSC412	Food Processing Technology	4
NFSC2XX	Fermented Food, Feed, and Pharmaceuticals	3
NFSC4XX	Fermentation Science Laboratory	4
NFSC4XX	Cheese and Fermented Dairy Products	3
NFSC386	Experiential Learning	3-6
NFSC4XX	Sensory Analysis Lab	3
Total Credits		**87-90**

Course numbers boxed and with “XX” are new to the program, all other courses already exist. Below is a representative course of study for a new freshman at UMD; specific articulation agreements will be established with each of the local community colleges for the offering at Shady Grove as well as for students transferring to College Park.

Year 1

Course	Title	Cr
	FALL	
MATH 120	Elementary Calculus I	3
PLSC 130	Did Yeast Create Civilization?	3
CHEM 131/132	General Chemistry (plus lab)	4
ENGL 101	Academic Writing	3
INAG 110	Oral Communication	3
	SPRING	
PLSC 110 OR 112	Introduction to Horticulture OR Introduction to Crop Science	3
	General Education requirement	3
CHEM 231/232	Organic Chemistry (plus lab)	4
BSCI 170/171	Principles of Molecular and Cell Biology (plus lab)	4
	Total Year 1 Credits	**30**

Year 2

Course	Title	Cr
	FALL	
NFSC 112	Food Science & Technology	3
CHEM 241/242	Organic Chemistry (plus lab)	4
BSCI 223	General Microbiology	4
	General Education requirement	3
	SPRING	
CHEM 271/272	General Chemistry & Energetics (plus Bioanalytical lab)	4
	General Education requirement	3
	General Education requirement	3
	elective	3
NFSC 2XX	Fermented Food, Feed, and Pharmaceuticals	3
	Total Year 2 Credits	**30**

Year 3

Course	Title	Cr
	FALL	
BCHM 463	Biochemistry of Physiology	3
ENGL 393	Professional Writing	3
AGST 3XX	Viticulture and Enology	4
NFSC 430	Food Microbiology	3
	Elective	3
	SPRING	

NFSC 431	Food Quality Control	4
AGST 3XX	Brewing and Distilling	4
NFSC 4XX	Cheese and Fermented Dairy Products	3
	Two electives	3-5
	Total Year 3 Credits	**32**

Year 4

Course	**Title**	**Cr**
	FALL	
NFSC 4XX	Fermentation Science Lab	4
NFSC 4XX	Sensory Analysis Lab	3
NFSC 421	Food Chemistry	3
NFSC 423	Food Chemistry Lab	3
	SPRING	
NFSC 412	Food Processing Technology	4
NFSC 386	Experiential Learning	3-6
NFSC 398	Seminar on selected topics	1
	Two electives	6
	Total Year 4 Credits	**28**

TOTAL DEGREE CREDITS	**120**

See Appendix B for course descriptions for those courses offered by the two departments that will deliver the major. All other course descriptions are available in the University's Undergraduate Catalog (https://courseleaf.umd.edu/undergraduate/).

General Education. Students will complete their science and mathematics general education requirements by way of fulfilling major requirements, with space in the curriculum for all other General Education requirements. Students who transfer to UMD with an associate degree from a Maryland community college are deemed to have completed their General Education requirements except for Professional Writing, which is typically taken in their third year of study.

Accreditation or Certification Requirements.

N/A

Other Institutions or Organizations. The department does not currently intend to contract with another institution or non-collegiate organization for this program.

Student Support. Faculty in the two departments will be responsible for student counseling, internship management, research functions and extension services to the industry. Initially, a 0.5 FTE staff support will be assigned to assist the management of the fermentation science program. Two teaching assistants will be allocated for the program each semester to assist with classroom instruction/discussion and laboratory operations. Shady Grove students will receive academic advising and support from a full-time academic advisor at Shady Grove who will report up to the NSFC unit. This advising includes the usual scheduling of classes, evaluation of progress towards the degrees, and identification of resources.

Marketing and Admissions Information. The NFSC department has developed a plan for recruiting students at area high schools, through AGNR's Ag Discovery summer program offered jointly with the USDA, and via other outlets in which the College is already engaged with community stakeholders across the state. The College has close working relationships with the Maryland Department of Agriculture, the Maryland Agricultural Education Foundation, and Farm Bureau offices across the state and regularly hosts or participates in county activities as well as the Maryland State Fair. Local industry stakeholders will be encouraged to promote the program and provide scholarships and internship opportunities.

Undergraduate admission to the University of Maryland is managed centrally through a holistic review process. The Office of Undergraduate Admissions works closely with academic units across the university to recruit and admit students into programs at both the College Park and Shady Grove locations. On the College Park campus, many students enter the University without a declared major, so the College has continued opportunities to recruit students to the major once the students are already on campus. Students at Shady Grove, all of whom come as transfer students, are admitted directly to the major.

H. Adequacy of Articulation

Montgomery College is typically the largest feeder of transfer students to the university at both the College Park and Shady Grove locations. Prior to program launch at Shady Grove, the AGNR faculty will work with counterparts at Montgomery College to outline specific curriculum requirements for the transfer pathway into years 3 and 4 of the program. As the program develops, outreach will continue with other local community colleges in, for example, Frederick and Prince Georges County.

I. Adequacy of Faculty Resources

Program faculty. Appendix A contains a full list of Nutrition and Food Science faculty as well as those faculty within Plant Sciences and Landscape Architecture who are expected to teach courses required for the program.

Faculty training. Faculty teaching in this program will have access to instructional development opportunities available across the College Park campus, including those offered as part of the Teaching and Learning Transformation Center. For online elements of the coursework, instructors will work with the learning design specialists on campus to incorporate best practices when teaching in the online environment.

J. Adequacy of Library Resources

The University of Maryland Libraries has assessed library resources required for this program. The assessment concluded that the University Libraries can meet, with its current resources, the curricular and research needs of the program.

K. Adequacy of Physical Facilities, Infrastructure, and Instructional Resources

Dedicated and shared laboratory and classroom facilities, as well as office space, have been identified for the program. The NFSC Department is renovating a pilot plant facility in the Animal Sciences Building that can be used to house pilot-scale fermenters and equipment for teaching demonstration, student laboratory practices and research functions. The departmental laboratories and walk-in cold rooms in Marie Mount Hall and Skinner Building, after remodeling, can also be used for teaching and laboratory practice of fermentation science courses. The Shady Grove offering will be in the new Biomedical Sciences and Engineering (BSE) Education building, which will have dedicated laboratory space for the program, along with shared classrooms.

L. Adequacy of Financial Resources

Resources for the program will come primarily from the College of Agriculture and Natural Resources. For the Shady Grove option, resources will come from tuition revenue and from the Governor's Workforce Development Initiative funds that were specifically directed towards implementation of STEM degree programs at the Universities at Shady Grove. See Tables 1 and 2 for anticipated resources and expenditures. A brief description of expenses and revenue is included here as well.

Resources:

1. Reallocated Funds: The University anticipates that some additional startup costs will be incurred until a full cohort of students is enrolled in the program. Reallocated resources will come from a redirection of effort from within the College and academic units.
2. Tuition revenue: For the on-campus delivery of the program, the University does not anticipate an overall increase in enrollment, and thus no new additional tuition revenue is projected for those students. Students enrolling in the Shady Grove offering are expected to be new to the University, and student counts and tuition revenue only for those students is included.
3. Grants, Contracts and External Sources: The Shady Grove offering will be supported by the Governor's Workforce Development initiative, most specifically for increasing opportunities in STEM disciplines on the Shady Grove campus.

Expenditures:

1. Most courses are already available and being taught by NFSC and PSLA faculty. Four additional of faculty time will be required to teach the seven new courses, spread over both campuses.
2. Approximately 0.5 FTE of administrative support will be assigned to assist with program management.
3. Approximately 1.0 FTE of additional support will be assigned for student advising, class coordination, and communication.
4. Two teaching assistants will be allocated for the program each semester to assist with classroom instruction/discussion and laboratory operations.

5. Equipment funding will go towards laboratory facilities. The NFSC Department is renovating a pilot plant facility in the Animal Sciences Building that can be used to house pilot-scale fermenters and equipment for teaching demonstration, student laboratory practices and research functions. The departmental laboratories and walk-in cold rooms in Marie Mount Hall and Skinner Building, after remodeling, can also be used for teaching and laboratory practice of fermentation science courses.
6. No new library resources are required for the program.
7. Renovations to or reallocation of space will be managed by the College.
8. Operational expenses include classroom rental at USG, travel to/from Shady Grove for instruction and field work, and materials and supplies for the laboratories.

M. Adequacy of Program Evaluation

Formal program review is carried out according to the University of Maryland's policy for Periodic Review of Academic Units, which includes a review of the academic programs offered by, and the research and administration of, the academic unit (http://www.president.umd.edu/policies/2014-i-600a.html). Program Review is also monitored following the guidelines of the campus-wide cycle of Learning Outcomes Assessment (https://www.irpa.umd.edu/Assessment/LOA.html). Faculty within the department are reviewed according to the University's Policy on Periodic Evaluation of Faculty Performance (http://www.president.umd.edu/policies/2014-ii-120a.html). Since 2005, the University has used an online course evaluation instrument that standardizes course evaluations across campus. The course evaluation has standard, university-wide questions and also allows for supplemental, specialized questions from the academic unit offering the course.

N. Consistency with Minority Student Achievement goals

An important aspect of this program is to draw upon students in the community colleges, which have traditionally larger numbers of African and Latin Americans than does UMD, and thereby improving the numbers of underrepresented minorities in STEM education. This will be a factor in student recruitment.

O. Relationship to Low Productivity Programs Identified by the Commission

N/A

P. Adequacy of Distance Education Programs

N/A

Tables 1 and 2: Resources and Expenditures

TABLE 1: RESOURCES

Resources Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1.Reallocated Funds	$100,000	$100,000	$100,000	$50,000	$50,000
2. Tuition/Fee Revenue (c+g below)	$35,280	$90,854	$159,110	$212,094	$273,071
a. #FT Students	3	8	15	20	25
b. Annual Tuition/Fee Rate	$8,824	$9,089	$9,361	$9,642	$9,931
c. Annual FT Revenue (a x b)	$26,472	$72,710	$140,421	$192,844	$248,287
d. # PT Students	2	4	4	4	5
e. Credit Hour Rate	$367	$378	$389	$401	$413
f. Annual Credit Hours	12	12	12	12	12
g. Total Part Time Revenue (d x e x f)	$8,808	$18,144	$18,689	$19,249	$24,784
3. Other External Sources	$500,000	$500,000	$500,000	$500,000	$500,000
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 - 4)	**$635,280**	**$690,854**	**$759,110**	**$762,094**	**$823,071**

Tuition revenue is based on AY2020-21 rates for the University. It does not include mandatory fees or laboratory fees. The University is not anticipating overall enrollment growth on the College Park campus because of this new major, so no new tuition revenue is included for the on-campus delivery. Students at the Universities at Shady Grove are likely to be new to the University and only those students are included in computing the tuition revenue. Reallocated funds assume support from the State's Workforce Development Initiative targeted towards programs to be delivered at the Universities at Shady Grove. For the purposes of budgeting, all students are assumed to be residents of Maryland.

Projected student enrollment					
#FT UMCP students	5	10	20	25	30
#PT UMCP student	2	4	8	8	8
#FT USG students	3	8	15	20	25
#PT USG students	2	4	4	4	5
TOTAL student enrollment	12	23	46	52	58

TABLE 2: EXPENDITURES

Expenditure Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1. Faculty (b+c below)	$478,800	$493,164	$507,959	$523,198	$538,894
a. #FTE	4.0	4.0	4.0	4.0	4.0
b. Total Salary	$360,000	$370,800	$381,924	$393,382	$405,183
c. Total Benefits	$118,800	$122,364	$126,035	$129,816	$133,710
2. Admin. Staff (b+c below)	$39,900	$41,097	$42,330	$50,866	$52,392
a. #FTE	0.5	0.5	0.5	0.5	0.5
b. Total Salary	$30,000	$30,900	$31,827	$38,245	$39,393
c. Total Benefits	$9,900	$10,197	$10,503	$12,621	$13,000
3. Total Support Staff (b+c below)	$79,800	$82,194	$84,660	$87,200	$89,816
a. #FTE	1.0	1.0	1.0	1.0	1.0
b. Total Salary	$60,000	$61,800	$63,654	$65,564	$67,531
c. Total Benefits	$19,800	$20,394	$21,006	$21,636	$22,285
4. Graduate Assistants (b+c)	$0	$88,949	$91,617	$94,366	$97,197
a. #FTE	0.0	2.0	2.0	2.0	2.0
b. Stipend	$0	$49,440	$50,923	$52,451	$54,024
c. Tuition Remission	$0	$39,509	$40,694	$41,915	$43,172
5. Equipment	$40,000	$20,000	$20,000	$15,000	$15,000
6. Library	$0	$0	$0	$0	$0
7. New or Renovated Space	$0	$0	$0	$0	$0
8. Operational Expenses	$12,321	$12,198	$13,990	$12,574	$13,693
TOTAL (Add 1 - 8)	**$650,821**	**$737,602**	**$760,556**	**$783,203**	**$806,991**

Notes: Graduate assistants are included in the budget to support instruction. Other expenses include lab equipment and software maintenance, materials and supplies, program outreach, and travel related to the program.

Appendix A: Faculty who will support the Fermentation Science Program

All faculty hold doctoral degrees in a field relevant to the discipline. Faculty biographies and research interests can be found on the department web sites (https://nfsc.umd.edu/people/faculty, https://psla.umd.edu/people/faculty). All faculty listed below are full-time. Specific course assignments have not yet been made but will be made in time to schedule the courses for the target start term of the program. Additional hires are anticipated to support the program as it develops.

Faculty Name	**Highest Degree Earned - Field and Insitution**	**Rank**
Cheng-I Wei	Ph.D., Microbiology, University of California at Davis	Professor and Interim Chair, NFSC
Jianghong Meng	Ph.D., D.V.M., Preventive Medicine and Food Safety, University of California at Davis	Professor, NFSC, Director of the Center for Food Safety & Security Systems (CFS3), and Director of the Joint Institute for Food Safety & Applied Nutrition (JIFSAN)
Rohan V. Tikekar	Ph.D., Food Science, Pennsylvania State University	Associate Professor, NFSC & CFS3
Abani K. Pradham	Ph.D., Biological Engineering, University of Arkansas	Associate Professor, NFSC
John Erwin	Ph.D., Horticulture, Michigan State University	Professor and Chair, PSLA
Angus Murphy	Ph.D., Biology, University of California at Santa Cruz	Professor, PSLA
William Phillips	Ph.D., Weed/Crop Ecophysiology, University of Maryland	Clinical Assistant Professor, PSLA
Diana Cochran	Ph.D., Agricultural Science, Mississippi State University	Clinical Assistant Professor, PSLA

Appendix B: Course Descriptions for NFSC and PLSC courses in the Fermentation Science major

All approved course descriptions can also be found in the University's Undergraduate Catalog

(https://courseleaf.umd.edu/undergraduate/approved-courses/). Courses with an XX numbering are new to the program and will undergo the normal campus approval process in parallel with program development.

NFSC 112 - Food: Science and Technology

Introduction to the realm of food science, food technology and food processing. An overview of the largest industry in the U.S. with emphasis on the science of food and the technology of food preservation from harvest through processing and packaging to distribution and consumer utilization.

NFSC 398 – Seminar

Presentation and discussion of current literature and research in food science.

NFSC421 - Food Chemistry

Basic chemical and physical concepts are applied to the composition and properties of foods. Emphasis on the relationship of processing technology to the keeping quality, nutritional value, and acceptability of foods.

NFSC423 - Food Chemistry Laboratory

Analysis of the major and minor constituents of food using chemical, physical and instrumental methods in concordance with current food industry and regulatory practices. Laboratory exercises coincide with lecture subjects in NFSC421.

NFSC430 - Food Microbiology

A study of microorganisms of major importance to the food industry with emphasis on food-borne outbreaks, public health significance, bioprocessing of foods, disease control, and the microbial spoilage of foods.

NFSC431 - Food Quality Control

Definition and organization of the quality control function in the food industry; preparation of specifications; statistical methods for acceptance sampling; in-plant and processed product inspection. Instrumental and sensory methods for evaluating sensory quality, identity and wholesomeness and their integration into grades and standards of quality. Statistical Process Control (SPC).

PLSC110 - Introduction to Horticulture

An overview to the art and science of horticulture. Relationships between plant science and plant production, the use of horticultural plants and plant stress as influenced by cultural practices.

PLSC112 - Introductory Crop Science

Major crop plants including anatomy, physiology, morphology, history, use, adaptation, culture, improvement and economic importance**.**

PLSC130/AGST130 - Did Yeast Create Civilization?

Fermented foods have played a major role in the transition from nomadic to settled agrarian societies, the establishment of social and religious customs, the expansion of empires, and modern economies. To what extent are our past and current attitudes towards fermented foods rooted in historical and cultural imprints? Explore the central role of fermentation in human history and culture, the basic microbiological processes underlying fermentation processes, and the processes used to produce and distribute fermented foods. Find out how the fruits, grains, and dairy products used to produce fermented foods are grown and selected. Students will learn about the development and modern use of fermented dairy products, pickles, bread, tea, chocolate, wine, beer, distilled liquors, and pharmaceutical/manufactured products.

NFSC412 - Food Processing Technology

Provides in-depth study of the major industrial modes of food preservation. It integrates aspects of the biology, microbiology, biochemistry, and engineering disciplines as they relate to food processing technology and food science.

NFSC386 - Experiential Learning

Opportunities for internships and fieldwork, with permission of the department. Requires junior standing or higher.

AGST3XX - Viticulture and Enology

A scientific introduction to viticulture (grape-growing) and enology (winemaking). Topics include grape biology, species and cultivars, vineyard establishment and maintenance, fermentation and aging, wine classification, production, evaluation, storage and service, regulations, wine as food.

AGST3XX - Brewing and Distilling

A scientific introduction to beer production and distillation of spirits, societal influence, the science of fermentation, brewery and distillery operations, and economics of scale. Students will be able to analyze and demonstrate the steps in the brewing process like grain handling, wort production, starch conversions, boiling, filtration, pumping, fermentation, and distillation.

NFSC2XX - Fermented Food, Feed, and Pharmaceuticals

This course provides an introduction to the microbiology and biotechnology involved in the production of fermented food, feed, and pharmaceuticals. Students will gain important knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students will learn about the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.

NFSC4XX - Fermentation Science Laboratory

This course provides an introduction to the microbiology and biotechnology involved in the production of fermented food, feed, and pharmaceuticals. Students will gain important knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students will learn about the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.

NFSC4XX - Cheese and Fermented Dairy Products

A scientific introduction to production of cheese and other fermented dairy products. Students will be able to analyze and demonstrate the steps in their manufacturing process, determine quality control parameters, identify food safety risks and how to mitigate them.

NFSC4XX - Sensory Analysis Lab

This course provides an in-depth introduction to building students' sensory evaluation skills and developing a greater understanding of the science behind food sensory perception. Students will be introduced to the various aspects of sensory evaluation, from human taste and flavor perception to sample preparation, the various sensory testing methods, and analyzing data obtained from sensory analyses using a combination of hands-on demonstration and experiential learning.

APPENDIX C: RUBRICS for DETERMINING PROFICIENCY in FERMENTATION SCIENCE LEARNING OUTCOMES

1. **Careers and opportunities in Fermentation Science** - Graduates of the fermentation science program will be able to describe many career paths available to them with the knowledge, skills, and experience they receive as undergraduates in the program. Graduates will be able to devise useful, feasible plans for courses, experiential learning, networking, and skill development leading to careers or advanced education programs that match their abilities, experience, and interests.

Target assessment:

NFSC112 Food: Science and Technology

Career nights run by the NFSC department.
200-level Critical Thinking and Speaking (COMM200)
NFSC386 Experiential Learning (Internship Experience in fermentation science) Advanced FS electives with relevant content

- **No evidence**: Student demonstrates minimal to no competency in this area.
- **Beginning**: Student struggles to define the fermentation science discipline and the types of careers it includes. Student may be able to name one or a few jobs outside of food industry related to fermentation science.
- **Developing**: Student can name several careers or areas of further study and connect those opportunities to the knowledge, skills, and experience they receive as an undergraduate.
- **Approaching proficiency**: Student is able to describe several career options available to them and makes deep connections between the knowledge, skills, and experience they receive as an undergraduate and specific job or educational opportunities.
- **Proficient**: Student can describe many career paths available to them with the knowledge, skills, and experience they receive as an undergraduate in the fermentation science program. Student is able to devise plans for courses, experiential learning, networking, and skill development leading to careers or advanced education programs aligned with their unique abilities, experience, and interests.
- **Advanced**: Student is successful in obtaining a job in an fermentation science-related discipline that requires a minimum of a bachelor's of science degree, or in earning admission to a program of advanced study.

Scoring: Optimal score aimed to be attained within 4 years after the establishment of the fermentation science program (Optimal score attained by food science major in NFSC112 Food: Science and Technology & NFSC386 Experiential Learning (Internship Experience in fermentation science).

2. Fermentation Science

Graduates of the undergraduate program will be able to apply fermentation science knowledge and research to enhance fermentation process, propagation and modification of fermentation microbes, fermenter design and downstream processing including effluent treatment. Students will learn the manufacturing steps involved in various fermented products and gain hands-on experience in making these products at pilot scale and evaluate their quality and safety.

Targeted assessment:

NFSC112 Food: Science and Technology (3)
NFSC421 Food Chemistry (3)
NFSC423 Food Chemistry Lab (3) NFSC412
Food Processing Technology (4) NFSC430 Food
Microbiology (3) NFSC434 Food Microbiology
Lab (3)

NFSCxxx Fermentation Science Laboratory **(4)**

- **No evidence**: Student demonstrates minimal to no knowledge, skills or abilities in this area
- **Beginning**: Student can list the principle of fermentation process, propagation and modification of fermentation microbes, fermenter design and downstream processing including effluent treatment.
- **Developing**: Student can describe, in more detail, the general fermentation process, propagation and modification of fermentation microbes, fermenter design and downstream processing including effluent treatment.
- **Approaching proficiency**: Student combines knowledge of manufacturing steps involved in various fermented products and attains limited hands-on experience in making these products at pilot scale and evaluating their quality and safety.
- **Proficient**: Student can provide a detailed description of manufacturing steps involved in various fermented products and attains entry-level hands-on ability in making these products at pilot scale and evaluating their quality and safety.
- **Advanced**: In addition to proficiently describing the very detailed steps in manufacturing involved in various fermented products, the student demonstrates advanced proficiency in hands- on ability in making these products at pilot scale and evaluating their quality and safety.

Scoring: All target courses listed above, except NFSCxxx Fermentation Science Laboratory (4), have attained optimal scoring for the Food Science program in NFSC. Optimal score for NFSCxxx Fermentation Science Laboratory (4) in the program is aimed to be attained within 4 years after the establishment of the fermentation science program.

3. **Fermented Food, Feed and Pharmaceuticals** - Graduates of the fermentation science undergraduate program will be able to correctly apply their knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students will learn about the science of fermentation, fermenter design and scale- up, fermentation byproducts and downstream processing, and different types of fermentations.

Targeted assessment:

NFSC421 Food Chemistry (3) NFSC423
Food Chemistry Lab (3) NFSC430 Food
Microbiology (3) NFSC434 Food
Microbiology Lab (3) 200-level
management courses
300 advanced electives and internships (NFSC386)

NFSCxxx Fermented Food, Feed & Pharmaceuticals (3)

- **No evidence**: Student demonstrates minimal to no knowledge, skills or abilities in this area.
- **Beginning**: Students can list knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students will learn about the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.
- **Developing**: Students can briefly describe knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students will start to develop knowledge about the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations
- **Approaching proficiency**: Students can describe knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students' knowledge is approaching proficient in the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.
- **Proficient**: Students can describe accurately knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students can describe in depth the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.
- **Advanced**: Student can expertly describe knowledge on the use of prokaryotic and eukaryotic microorganisms in the fermentation of dairy, vegetables and fruits, meat, and grains (food), feed, and pharmaceuticals. The students can expertly describe their knowledge in the science of fermentation, fermenter design and scale-up, fermentation byproducts and downstream processing, and different types of fermentations.

Scoring: All target courses listed above, except NFSCxxx Fermented Food, Feed & Pharmaceuticals (3), have attained optimal scoring for the Food Science program in NFSC. Optimal score for NFSCxxx Fermented Food, Feed & Pharmaceuticals (3), is aimed to be attained within 4 years after the establishment of the Fermentation Science program.

4. **Fermentation Science literacy**- Knowledge of major issues in fermentation science. Graduates of this program will be well-versed in the issues related to fermentation science such that they contribute to societal debates around the future of farming, the use of microbes & phages in fermentation, sustainability of our fermentation science industry, worker needs of the industry, and scaling fermentation science enterprises up and down to meet our growing population's needs for fermented products. Graduates of this undergraduate program will also be able to select, understand, and critically evaluate scientific studies in fermentation science disciplines such that they employ research that is applicable, timely, accurate, and useful for their fermentation science and management needs.

   Targeted assessment:
   NFSC112 Food: Science & Technology (3)
   NFSC412 Food Processing Technology (4)
   NFSC421 Food Chemistry (3)
   NFSC423 Food Chemistry Lab (3)
   NFSC431 Food Quality Control (4)
   NFSC430 Food Microbiology (3) NFSC434
   Food Microbiology Lab (3)
   NFSCxxx Fermented Food, Feed & Pharmaceuticals (3)
   AGST3xx Viticulture and Enology (4)
   AGST3xx Brewing and Distilling (4)
   NFSCxxx Cheese and Fermented Dairy Products (3)
   NFSCxxx Fermentation Science Laboratory (4) NFSCxxx
   Sensory Analysis Laboratory (3)

   - **No evidence**: Student demonstrates minimal to no knowledge, skills or abilities in this area.
   - **Beginning**: Student can correctly name and order the steps of the scientific method and explain the value of critical source evaluation.
   - **Developing**: Student can describe the principle strengths and weaknesses of several types of scientific study designs. Student can describe the role of different types of bias in our interpretation of research findings. Student can explain the scientific method and the process of scientific discovery.
   - **Approaching proficiency**: Student can evaluate the 2-3 principal strengths and weaknesses of a study design and identify sources of bias in the study's methodology and data analysis. Student can document a laboratory experiment or exercise using standard scientific formatting, basic data presentation methods, and scientific language and relate this process to the reporting of research in scientific journals.
   - **Proficient**: Student is able to select, understand, and critically evaluate scientific studies in fermentation sciences disciplines such that they employ research that provides the highest quality of evidence available for their information needs. Student is able to write about scientific research in using evidenced based research.
   - **Advanced**: Student can create scientific grant proposals, professional presentations, review papers, or other professional analyses of scientific evidenced based research

   Scoring: All target courses listed above, except those with NFSCxxx and AGST3xx labeled courses, have attained optimal scoring for the Food Science program in NFSC. Optimal scores for those with NFSCxxx and AGST3xx

labelled courses are aimed to be attained within 4 years after the establishment of the Fermentation Science program.

5. **Knowledge of major issues in Fermentation Science** - Graduates of the fermentation science program will be well-versed in the issues related to fermentation science such that they contribute to societal debates around them. Student will be able to describes, analyze, and critically evaluate the scientific, ethical, legal, and social dimensions of these issues.

Targeted assessment:

NFSC112 Food: Science & Technology (3) NFSC412 Food Processing Technology (4)
NFSC421 Food Chemistry (3)
NFSC423 Food Chemistry Lab (3) NFSC431 Food Quality Control (4)
NFSC430 Food Microbiology (3) NFSC434 Food Microbiology Lab (3)
NFSCxxx Fermented Food, Feed & Pharmaceuticals (3) AGST3xx Viticulture and Enology (4)
AGST3xx Brewing and Distilling (4)
NFSCxxx Cheese and Fermented Dairy Products (3) NFSCxxx Fermentation Science Laboratory (4) NFSCxxx Sensory Analysis Laboratory (3)

- **No evidence**: Student demonstrates minimal to no knowledge, skills or abilities in this area.
- **Beginning**: Student can name a few major controversies related to fermentation science.
- **Developing**: The student can describe several key controversies related to fermentation science, including the history of the issue, the major stakeholders' positions, and the arguments they have in support of their point of view.
- **Approaching proficiency**: The student can describe several core controversies related to fermentation science and identify key stakeholders and their positions in those debates. Students start to apply scientific, ethical, legal, and social analysis to their evaluation ofthe issues in class lectures and assignments.
- **Proficient**: The student can describes, analyzes, and critically evaluates the scientific, ethical, legal, and social dimensions of the controversial issues surrounding fermentation science in class lectures and assignments.
- **Advanced**: Student can lead others in respectful, accurate, and relevant debates regarding controversial issues in animal science in class lectures. The student can propose feasible, useful avenues for addressing these issues.

Scoring: All target courses listed above, except those with NFSCxxx and AGST3xx labeled courses, have attained optimal scoring for the Food Science program in NFSC. Optimal scores for those with NFSCxxx and AGST3xx labelled courses, are aimed to be attained within 4 years after the establishment of the Fermentation Science program.

Appendix D

Potential for a Fermentation Science BS at University of Maryland College Park

Prepared for

University of Maryland College Park's College of Agriculture and Natural Resources and MD Department of Commerce

Regional Economic Studies Institute

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1.0 Executive Summary

The growth in fermentation science occupations in the Mid-Atlantic region has prompted

University of Maryland College Park's (UMCP) College of Agriculture and Natural Resources to consider developing a fermentation science program at UMCP. The Bachelor of Science (BS) in Fermentation Science would provide students with a solid foundation in this growing occupational field.

Prior to establishing this degree, UMCP, in conjunction with the Maryland Department of Commerce (Commerce; collectively these two entities are the Client), seeks a workforce study that examines the potential need for fermentation science at UMCP. Towson University's Regional Economic Studies Institute (RESI) has completed this analysis on behalf of the Client.

To determine the potential for a bachelor's program in fermentation science at UMCP, RESI considered the demand for and the supply of workers with a background in fermentation science in the state's economy. These analyses are contextualized with industry and employment data at the state and regional level. In addition, the supply analysis examines existing programs to identify key traits or characteristics of successful educational programs.

RESI's analysis yielded these key findings:

- Consumer demand for fermented products—such as alcoholic beverages, kombucha, kimchi, tempeh, and miso—has grown significantly in recent years.
- As of 2018, industries related to fermentation science employ 21,918 Marylanders.
- Maryland has seen a particularly large increase in establishments related to fermentation science, with breweries and distilleries growing by 218 percent and 375 percent, respectively, from 2014-2018.
- Despite historically not having a competitive advantage, Maryland is increasing its specialization in the fermentation science industry, adding 194 more jobs than expected in 2018.
- Fermentation science occupations in Maryland are projected to experience a robust growth rate of almost 7 percent (14,736 jobs) by 2026.
- Despite multiple programs being within a day's drive of Maryland, there are currently no fermentation programs at colleges within the state.
- In total, only four comparable programs within 500 miles of College Park offer a bachelor's degree in fermentation science.
- UMCP should consider that the BS in Fermentation Science could fill a gap in the state's

educational system, which could benefit businesses in the state's economy and incentivize students to study—and likely remain—within the state's borders.

2.0 Report Overview

The growth in fermentation science occupations in the Mid-Atlantic region has prompted

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The report continues as follows:

- Section 3.0 presents an overview of the proposed degree program at UMCP,
- Section 4.0 presents the methods used for the analyses,
- Section 5.0 presents the demand analysis,
- Section 6.0 presents the supply analysis, and
- Section 7.0 presents the conclusion and recommendations.

The report also contains additional analysis and more detailed results in the appendices.

3.0 Proposed Program Overview

UMCP's proposed BS program in fermentation science would be housed within the College of Agriculture and Natural Resources and, more specifically, in the Department of Nutrition and Food Science. This four-year degree would allow UMCP to expand its educational offerings for Maryland residents and increase its community outreach activities and extension programming, further fulfilling its mission as the land-grant institution in the state.

The program can draw upon existing faculty at UMCP, supplementing with additional hires as needed. In addition, the program would allow for industry collaboration to both ensure that the needs of future employers are met and that students are well prepared for the workforce after they graduate.

UMCP intends to have a dedicated research facility for the fermentation science program and has identified space on campus that could be converted for this purpose. Additional specialized teaching laboratory space will strengthen educational opportunities for students. These

planned dedicated facilities provide the opportunity for the university to apply for and/or obtain additional research and program-support funding.

4.0 Existing Fermentation Science Program Components

This section will provide an overview of existing fermentation science bachelor's-level programs that are recognized by the Master Brewers Association of America.[1] While not an exhaustive list of all programs available nationally, the seven highlighted below are models of successful programs to help inform program development at UMCP.

4.1 Virginia Tech: BS in Food Science and Technology, Food and Beverage Fermentation Option

The BS in Food Science and Technology, Food and Beverage Fermentation Option degree at Virginia Tech combines core courses in basic sciences (biology, chemistry, organic chemistry, biochemistry, and microbiology), food sciences (food chemistry, quality assurance, product development, and packaging), and fermentation science in the context of food preservation and the human microbiome.[2] Additional educational opportunities for students include study abroad experiences within the major and the university-wide Cooperative Education and Internship Program.[3,4]

4.2 Appalachian State University (North Carolina): BS in Fermentation Science

At Appalachian State University, the BS in Fermentation Science is an interdisciplinary program within the Department of Chemistry in the College of Arts and Sciences.[5] Students in this major take classes in biology and chemistry, as well as marketing, business, and entrepreneurship.

While there is significant focus on fermentation as it relates to beer and wine production, students also have the opportunity to take courses related to biotechnology, agriculture, and sustainable development.[6]

[1] "Diploma and Certificate Options," Master Brewers Association of America, accessed May 1, 2020, https://www.mbaa.com/education/Pages/HEC.aspx.

[2] "Program Options," Virginia Tech Department of Food Science and Technology, accessed May 1, 2020, https://www.fst.vt.edu/programs/undergraduate/Program_Options.html.

[3] "Freising, Germany: Practical and Theoretical Brewing and Culture at TUM Weihenstephan," Virginia Tech Department of Food Science and Technology, https://www.fst.vt.edu/programs/study-abroad/study-abroad-Germany.html.

[4] "Cooperative Education and Internship Program," Virginia Tech, accessed May 1, 2020, https://career.vt.edu/experience/ceip.html.

[5] "Fermentation Sciences," Appalachian State University, accessed May 1, 2020, https://fermentation.appstate.edu/.

[6] "Fermentation Sciences, BS," Appalachian State University, accessed May 1, 2020, http://bulletin.appstate.edu/preview_program.php?catoid=16&poid=6209&returnto=857.

4.3 Colorado State University: BS in Fermentation Science and Technology

Housed within the Department of Human Science and Nutrition of Colorado State University's College of Health and Human Sciences, the BS in Fermentation Science and Technology focuses on food and beverage fermentation.[7] The program prioritizes industry connections and input, requiring students to complete a capstone research project under the supervision of an industry mentor.[8] The program also has dedicated lab space that is open to both students and local industry.[9]

4.4 Metropolitan State University of Denver: BS in Brewery Operations, BS in Craft Brewing and Pub Operations

The Metropolitan State University of Denver offers two separate BS degrees: the major in Brewery Operations and the major in Craft Brewing and Pub Operations.[10] These programs are focused specifically on beer and include courses in biology, chemistry, economics, marketing, business, management, law, and engineering.[11] Students have the opportunity to interact with Denver's beer industry through the on-campus Tivoli Brewery, as well as the Quality Analysis & Quality Control (QA/QC) and Brewing Production Labs.[12]

4.5 Oregon State University: BS in Food Science and Technology, Fermentation Science Option

At Oregon State University, students pursuing a BS in Food Science and Technology can choose to study fermentation science within their major.[13] This applied science program focuses on food and beverage fermentation, though it is not solely focused on beer production. Students take courses in basic sciences (biology, chemistry, physics, mathematics), food sciences, and fermentation science. In addition to coursework, students have access to a variety of specialized facilities, including a brew house/malt house, a winery, a creamery, a baking lab, and a sensory science laboratory.[14]

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[7] "BS in Fermentation Science and Technology," Colorado State University College of Health and Human Sciences, accessed May 1, 2020, https://www.chhs.colostate.edu/fshn/programs-and-degrees/b-s-in-fermentation-science-and-technology/.

[8] "Experiential Learning—Research Opportunities," Colorado State University College of Health and Human Sciences, accessed May 1, 2020, https://www.chhs.colostate.edu/fshn/programs-and-degrees/b-s-in-fermentation-science-and-technology/experiential-learning/.

[9] "FST Custom Service Laboratory," Colorado State University College of Health and Human Sciences, accessed May 1, 2020, https://www.chhs.colostate.edu/fshn/programs-and-degrees/b-s-in-fermentation-science-and-technology/fst-custom-service-laboratory/.

[10] "Beer Industry Program," Metropolitan State University of Denver, accessed May 1, 2020, https://www.msudenver.edu/beer/.

[11] "Beer Industry Program—BS Degrees," Metropolitan State University of Denver, accessed May 1, 2020, https://www.msudenver.edu/beer/beerindustryprogramdegrees/.

[12] "Beer Industry Program—Facilities and Partnerships," Metropolitan State University of Denver, accessed May 1, 2020, https://www.msudenver.edu/beer/facilitiesandpartnerships/.

[13] "Fermentation Science Option," Oregon State University College of Agricultural Sciences," accessed May 1, 2020, https://agsci.oregonstate.edu/foodsci/fermentation-science-option.

[14] "Facilities and Equipment—Fermentation Science Option," Oregon State University College of Agricultural Sciences, accessed May 1, 2020, https://agsci.oregonstate.edu/foodsci/facilities-and-equipment-fermentation-science-option.

4.6 Southern Illinois University: BS in Fermentation Science

The BS in Fermentation Science at Southern Illinois University focuses on beverage and food fermentation.[15] Students are required to take core courses in fermentation science, basic sciences (biology, chemistry, physics, mathematics), and electives related to hospitality, economics, or management.[16] In addition to lecture and laboratory classwork, students can gain experience in the Fermentation Science Institute's Service Lab, which provides technical assistance and analytical testing for products made by local fermentation businesses.[17]

4.7 University of California Davis: BS in Food Science, Brewing Option

The University of California Davis offers a BS in Food Science, with the opportunity to focus on brewing.[18] Students in this major study basic sciences (chemistry, physics, and biology) before focusing on food science coursework. To pursue the brewing option, students are required to take courses in brewing/malting and enzymology, in addition to a variety of electives on topics such as fermented foods, viniculture, new product development, brewing and beer, or quality assurance.[19] Opportunities such as internships, a semester in Washington, DC, and independent/small group study supplement the academic curriculum.[20] The university also houses a brewery laboratory on campus and offers certificates/outreach activities focused on beer and wine through their extension programs.[21,22]

5.0 Methodology

Separate methodologies were utilized to analyze the demand for fermentation science graduates, as well as the supply of fermentation science graduates, in the state's economy.

5.1 Demand Analysis

To begin the demand analysis, RESI first defined the fermentation science industry based on existing North American Industrial Classification System (NAICS) codes. NAICS codes utilized in the analysis include those related to alcoholic beverage and fermented food production, pharmaceutical and medicine manufacturing, and research and development in the sciences.

[15] "Fermentation," Southern Illinois University, accessed May 1, 2020, https://fermentation.siu.edu/degree-program/.

[16] "Bachelor of Science Degree in Fermentation Science," Southern Illinois University, accessed May 1, 2020, catalog.siu.edu/programs/ferm/index.pdf.

[17] "Service Lab," Southern Illinois University, accessed May 1, 2020, https://fermentation.siu.edu/services/.

[18] "Brewing Option—BS in Food Science," University of California Davis, accessed May 4, 2020, https://foodscience.ucdavis.edu/academic-programs/undergraduate/bs-major-requirements.

[19] Ibid.; "Food Science Courses," University of California Davis, accessed May 4, 2020, https://foodscience.ucdavis.edu/academic-programs/undergraduate/courses.

[2020] "Special Study Courses," University of California Davis, accessed May 4, 2020, https://foodscience.ucdavis.edu/academic-programs/undergraduate/special-study-courses.

[21] "Brewing," UC Davis Continuing and Professional Education, accessed May 4, 2020, https://extension.ucdavis.edu/areas-study/brewing.

[22] "About," UC Davis Robert Mondavi Institute for Food and Wine Science, accessed May 4, 2020, https://rmi.ucdavis.edu/about.

Once the industry was defined, RESI analyzed a variety of publicly available and government data sources to study trends of the fermentation science industry. Data of interest related to consumer demand for final goods purchased by consumers, consumer interest in fermented goods, employment trends, and potential for future growth.

5.2 Supply Analysis

A scan of existing programs was conducted to identify institutions that offer educational opportunities related to fermentation science. From this scan, programs were categorized based on various characteristics, including:

- Proximity to College Park, MD;
- Degree level (bachelor's degree, certificate, etc.); and
- Scope of coursework.

In addition, the supply analysis identified elements from other programs that UMCP should consider integrating into its potential bachelor's degree offering, as well as any characteristics that could differentiate UMCP as a leader in academic fermentation science programs.

6.0 Demand Analysis

To understand the demand for a fermentation science degree, it is important to examine the industry structure and how that structure is changing over time. Because fermentation science is not typically defined within one industry, RESI identified primary industries associated with fermentation science.

Primary industries include:

1. Breweries
2. Wineries
3. Distilleries
4. Cheese Manufacturing

In addition to these four primary industries, secondary industries are also identified for context. While fermentation science may be utilized in these industries, they are likely to only form a small percentage.

Secondary industries include:

1. All Other Miscellaneous Food Manufacturing
2. Pharmaceutical and Medicine Manufacturing
3. Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

Graduates in these secondary industries, for example, may find themselves serving as a Fermentation Lead for vaccine development or using microbial fermentation to develop anticancer drugs.[23] Those in "All Other Miscellaneous Food Manufacturing" may find themselves working at the numerous small and medium-sized companies producing fermented food products like kimchi, tempeh, and krauts.

To assess the market demand for fermentation science graduates, a three-step approach was used. First, drivers of demand for the fermentation industry were examined, which included looking at commodities of the fermentation science industry. Next, the structure of the fermentation industry was analyzed in terms of employment, establishments, and location quotients. This was done both statically and over time to show industry trends. Finally, occupational projections within the fermentation science industry were examined to understand future growth in employment.

6.1 Fermentation Product Demand

One of the most in-demand fermented products in the United States is alcoholic beverages. Over five years from 2014 to 2018, consumer expenditures on alcohol have increased faster than overall expenditures. As seen in Figure 1, this is true for all regions of the U.S. except for the West. Maryland, categorized in the South region by the U.S. Census Bureau, has seen a drastic increase in alcohol expenditures over those five years. While alcohol expenditures in the South have risen by 19 percent, overall expenditures have only risen by 9 percent. This implies that alcohol purchases continue to form a larger share of residents' total expenditures in this region.

Figure 1: Percent Change in Consumer Expenditures between 2014 and 2018

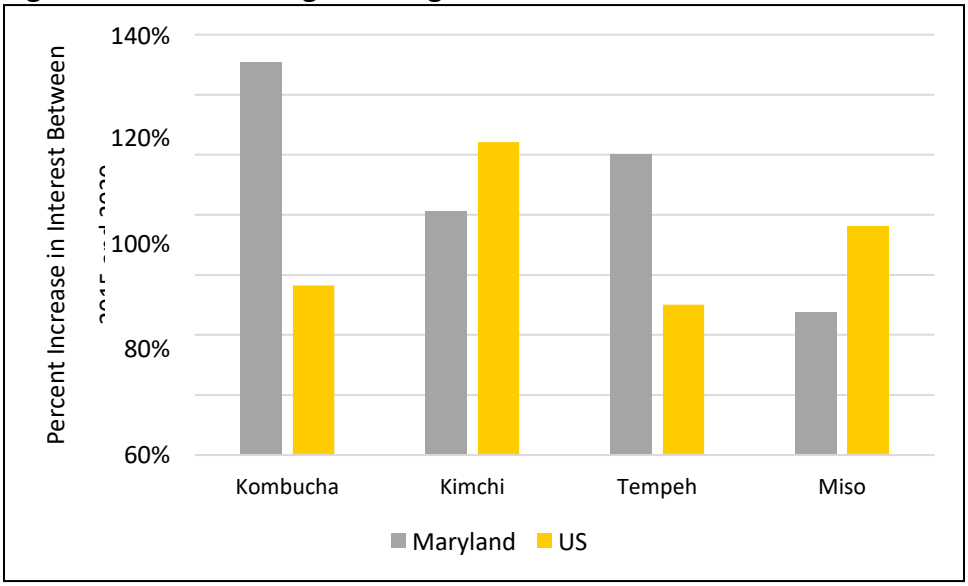
Region	Alcoholic Beverages	All Expenditures
Northeast	24%	11%
South	19%	9%
Midwest	16%	6%
West	4%	11%

Sources: US Census Bureau, RESI

[23] Production of pharmaceutical compounds through microbial fermentation, Manufacturing Chemist, accessed April 28, 2020, https://www.manufacturingchemist.com/news/article_page/Production_of_pharmaceutical_compounds_through_microbial_fermentation/61614.

Alcohol is not the only commodity driving demand in the fermentation science industry. Other non-alcoholic food and beverages—such as kombucha, kimchi, tempeh, and miso—have witnessed significant growth over the past five years.[24,25] As seen in Figure 2, there has been a sharp uptick in interest since 2015, with kombucha and tempeh trending particularly well in Maryland compared to the United States.

Figure 2: Percent Change in Google Trends Interest for Select Fermentation Products



Sources: Google Trends, RESI

6.2 Employment in the Fermentation Industry

In Maryland and across the U.S., this increased demand has led to a significant rise in both the number of establishments and employment within the industries related to fermentation science. As of 2018, almost 1,300 workers were employed in breweries, wineries, or distilleries across the state. In addition, graduates of fermentation science may find themselves in other industries, such as “All Other Misc. Food Manufacturing,” “Pharmaceutical and Medicine Manufacturing,” and “Research and Development,” all of which have relatively high employment levels not just in Maryland, but across the region.

[24] "Kombucha Market Size & Share: Industry Analysis Report," Grand View Research, Inc, February 2020, https://www.grandviewresearch.com/industry-analysis/kombucha-market.

[25] Amelia Nielson-Stowell, "Global Fermented Food & Ingredients Market, Analysis and Forecast (2017-2023)," The Fermentation Association, December 12, 2017, https://fermentationassociation.org/global-fermented-food-ingredients-market-analysis-and-forecast-2017-2023/.

Figure 3: Employment by Fermentation Science Industry

Industry NAICS	Maryland Annual Employment Level	Region Annual Employment Level	US Annual Employment Level
31212 – Breweries	745	7,582	77,911
31213 – Wineries	324	4,773	67,832
31214 – Distilleries	213	721	15,839
311513 – Cheese Manufacturing	*	1,569	50,267
311999 – All Other Misc. Food Manufacturing	317	1,386	33,575
32541 – Pharmaceutical and Medicine Manufacturing	2,471	6,633	35,551
541715 - Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)	17,848	61,342	413,853
Total	**21,918**	**84,006**	**694,828**

Sources: BLS, RESI

(*) Indicates data suppressed by BLS

Not only do the fermentation science industries employ thousands of people across Maryland, these industries continue to grow. Between 2014 and 2018, “Breweries” and “All Other Misc. Food Manufacturing” grew the most at 216 percent and 166 percent, respectively. Maryland has also seen significant growth in “Wineries,” “Distilleries,” and “Research and Development in the Physical, Engineering, and Life Sciences.”

Figure 4: Percent Change by Industry between 2014 and 2018 for Maryland[26]

Industry	Number of Establishments	Employment	Location Quotient
Breweries	218%	216%	68%
Wineries	43%	33%	13%
Distilleries	375%	39%	-1%
Cheese Manufacturing	33%	-32%	-29%

All Other Misc. Food Manufacturing	75%	166%	132%
Pharmaceutical and Medicine Manufacturing	54%	-6%	-11%
Scientific Research and Development	8%	66%	58%

Sources: BLS, RESI

[26] The change was between 2014 and 2018. However, a number of data points were suppressed by BLS due to confidentiality concerns. For these cases, the suppressed values were assumed the same as the nearest value in the percent change calculation.

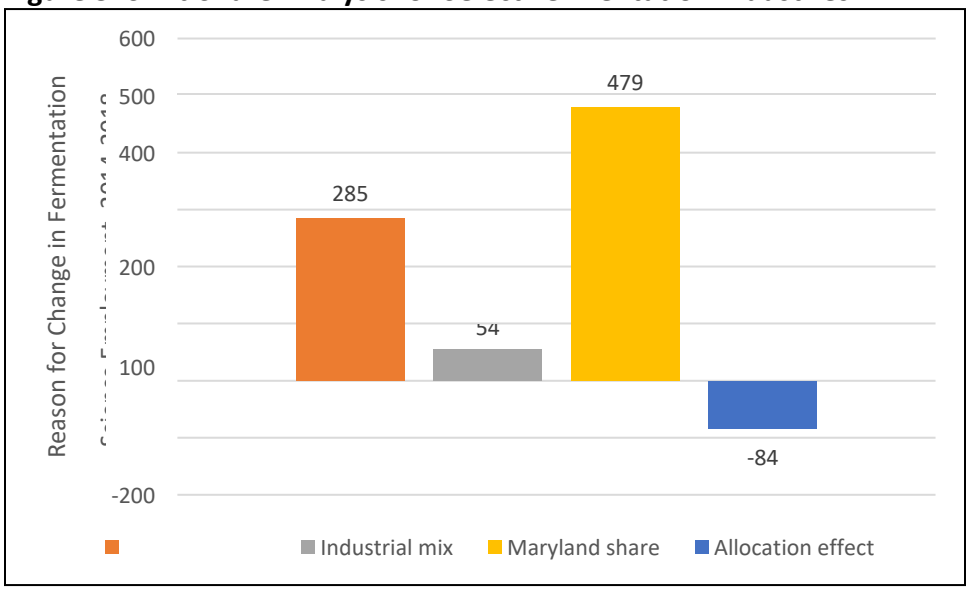
In terms of the number of establishments, Maryland has seen a particularly large increase in "Breweries" and "Distilleries," growing by 218 percent and 375 percent, respectively.

Furthermore, all industries have shown growth in the number of establishments over the time period.

The location quotient is one way of assessing the competitive advantage or disadvantage a state or region may have in an industry. Maryland has seen particularly large increases in its competitive advantage in both "Breweries" and "All Other Misc. Food Manufacturing." In absolute numbers—as seen in Figure 11 in Appendix B—Maryland still does not possess a competitive advantage in these industries. However, the state's disadvantage is lessening.[27]

Another way of assessing the economic performance of industries is through a shift-share analysis, which examines how employment growth in the fermentation science industry in Maryland relates to the national economy and broader industry trends. This allows RESI to comment on whether Maryland holds an advantage in a particular industry and whether the state is experiencing growth in that particular industry. For more details regarding the shift-share analysis, see Appendix A.

Figure 5: Shift-Share Analysis for Select Fermentation Industries[28]



Source: BLS, RESI

Figure 5 presents the results for the fermentation science industry in Maryland. If employment in Maryland kept pace with employment nationwide, the industry would be expected to have added 285 jobs (represented by the orange bar). In other words, 235 of the 735 total jobs

[27] A location quotient that is less than one indicates that the industry is less concentrated compared to national levels. On the other hand, a location quotient greater than one means that the state or region has a competitive advantage since industry concentration is higher than national levels.

[28] Only industries that had complete data from 2015 to 2018 were used. These include Breweries, Wineries, Distilleries, and All Other Misc. Food Manufacturing.

added in Maryland are due to conditions at the national level. The industrial mix (represented by the grey bar) shows that 54 jobs (of the total 735 jobs added) are due to differences in the fermentation science industry composition between Maryland and the national level.

Most notably, local conditions are responsible for 479 jobs (represented by the gold bar). This indicates that Maryland is increasing its specialization in the fermentation science industry, adding 194 more jobs than expected. The allocation effect (represented by the blue bar) shows that Maryland is specializing in an industry where it does not historically hold a competitive advantage—that is, at least an additional 83 jobs would have been added if the state held a competitive advantage in the fermentation science industry.

These favorable local conditions are likely due to not only increased demand for fermentation products, but also to changes in state policy that previously held the industry back. For example, in 2017 Maryland increased the limit on brewery taproom sales from 500 barrels per year to 3,000, coinciding with a 35 percent increase in brewery employment between 2017 and 2018 (as shown in Figure 9 in Appendix B). [29]

In addition to whether national or local conditions are responsible for the growth, two other effects are noted in the shift-share analysis. The small industrial mix share shows that very little of the shift is due to changes occurring within the industry structure itself. The negative allocation effect indicates that Maryland still lacks a competitive advantage in the industries.

Coupled with the high Maryland share, this infers that Maryland is experiencing significant growth in industries where it is at a competitive disadvantage. This means that while Maryland currently does not have a competitive advantage in these industries, its advantage is growing relative to other states.

Further strengthening this potential for growth in the state are data that show the industry's resilience in light of unanticipated emergencies. As the economic impacts of COVID-19 loom over almost every industry, fermented products are currently enjoying stable growth. In fact, the Fermentation Association reports that kombucha sales increased 10 percent during March 2020.[30] The rationale for this growth is that consumers are seeking healthy foods that boost immunity with a longer shelf-life, making fermented foods a natural choice during the pandemic.[31]

In addition to industries, it is important to look at the relevant occupations in the fermentation science. To find relevant occupations, RESI used the O*NET technology skills and tools search to

[29] Chris Tomlinson, "Say 'Cheers' to Craft Beer Industry in Carroll County and Maryland," Baltimore Sun, August 18, 2019, https://www.baltimoresun.com/maryland/carroll/opinion/cc-op-tomlinson-081919-20190819-42jamovjfzbx5dtkbcdwq5wf3u-story.html.

[30] Amelia Nielson-Stowell, "Fermentation Booms During Pandemic," The Fermentation Association, April 1, 2020, https://fermentationassociation.org/fermentation-brands-experience-sales-boom-during-coronavirus/.

[31] Ibid

filter occupations by those that used fermentation technologies.[32] These occupations were then mapped to the Maryland Department of Labor's occupational projections data.[33] As seen in Figure 6, fermentation science occupations are projected to experience a robust growth rate of almost 7 percent (14,736 jobs) by 2026.This is compared to a 7.7 percent growth rate for all occupations in Maryland.

Figure 6: Fermentation Science Occupation Growth Through 2026

Occupation	Growth Through 2026	Jobs in 2026
Medical Scientists, Except Epidemiologists	9.6%	5,090
Biochemists and Biophysicists	8.6%	1,814
Bakers	5.6%	3,759
Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders	5.3%	474
Microbiologists	5.1%	2,059
Environmental Engineering Technicians	4.8%	374
Chemical Equipment Operators and Tenders	1.5%	1,018
Food Scientists and Technologists	1.4%	148
Total	**6.9%**	**14,736**

Sources: Maryland Department of Labor, RESI

The top growing occupations tend to be in the Life Sciences, with "Medical Scientists" and "Biochemists and Biophysicists" growing the fastest at 9.6 and 8.6 percent, respectively. Fermentation science graduates may find themselves in this burgeoning field helping to develop biofuels—this is particularly important as Maryland continues its aggressive push to reduce greenhouse gas emissions. Brewers, winemakers, and distillers (reflected in the "Separating, Filtering, Clarifying, Precipitating, and Still Machine Setters, Operators, and Tenders" occupation) are also projected to grow at a healthy pace of 5.3 percent through 2026.

Through this analysis, it can be seen that while the fermentation industry is relatively small in Maryland, growth has been robust through 2018. Graduates in fermentation science will enjoy a healthy market not just in traditional industries, such as breweries, wineries, and distilleries, but also through growing niche industries, such as kombucha, kefir, tempeh, and kimchi.

As consumer preferences change to opt for higher-quality, locally sourced products, the knowledge and skills cultivated in a fermentation science program may help the industry adapt

[32] "Technology Skills & Tools Search for: Fermentation," O*NET OnLine, accessed April 28, 2020, https://www.onetonline.org/search/t2/?s=fermentation&g=Go).

[33] "Maryland Occupational Projections - 2016-2026 - Workforce Information and Performance," Maryland Occupational Projections - Office of Workforce Information and Performance (OWIP), accessed April 28, 2020, https://www.dllr.state.md.us/lmi/iandoproj/maryland.shtml).

to meet those needs. [34] In addition, Maryland's thriving biotechnology and pharmaceutical manufacturing industries could be attractive employers for any fermentation science graduates.

7.0 Supply Analysis

In order to understand the existing supply of fermentation science or related degrees and programs, RESI looked at the existing programs offered at colleges and universities across the United States. For this analysis, RESI included any programs that offered an advanced degree or formal post-baccalaureate certificate. As an example, this includes an 18-credit Brewing Science Certificate offered by the University of the Sciences, but excludes the Business of Craft Beer Certificate offered by the University of Vermont, which requires the completion of three eight- week online courses.[35,36]

There are four significant factors to consider when comparing a potential fermentation science degree at UMCP with existing programs in the United States:

1. Proximity to College Park, MD;
2. Degree level;
3. Scope of program; and
4. Enrollment / Size of program.

This section will examine each of the above factors to determine the current supply of comparable programs, as well as how these factors may inform the parameters of the program being proposed by UMCP.

7.1 Geographic Location of Comparable Programs

Distance from home is one of many factors that potentially affects where students enroll. The results of a 2016 survey showed that 56.2 percent of students attending a public four-year college remained within 50 miles of home, with an additional 12.7 percent within 100 miles of home.[37] Because of this, Maryland students are far less likely to attend comparable fermentation science programs that are not within the state. The proximity effect continues after students graduate from college, with 40 percent of graduates from state universities remaining within 50 miles of campus.[38] This limits the ability of Maryland industries to benefit from programs located outside of the state.

[34] Jill McCluskey, "Changing Food Demand and Consumer Preferences," Federal Reserve Bank of Kansas City, July 2015, https://www.kansascityfed.org/~/media/files/publicat/rscp/2015/mccluskey-paper.pdf?la=en.

[35] "Brewing Science Certificate," University of the Sciences, accessed April 23, 2020, https://www.usciences.edu/misher-college-of-arts-and-sciences/biological-sciences/brewing-science-certificate/index.html.

[36] "Business of Craft Beer Certificate," University of Vermont, accessed April 23, 2020, https://learn.uvm.edu/program/business-of-craft-beer/business-of-craft-beer-certificate/courses/.

[37] Abigail Wozniak, "Going Away to College? School Distance as a Barrier to Higher Education," EconoFact, March 22, 2018, https://econofact.org/going-away-to-college-school-distance-as-a-barrier-to-higher-education.

[38] Rob Sentz et al.,"How Your School Affects Where You Live," Emsi, accessed April 23, 2020, https://www.economicmodeling.com/how-your-school-affects-where-you-live/.

None of the current programs in Fermentation Science are offered within Maryland, and very few could be considered to be within close proximity of the state. Figure 7 shows all programs offered by schools within regional proximity of College Park, defined as a driving distance of 500 miles or less.

Figure 7: Comparable Programs Within Regional Proximity of College Park[39]

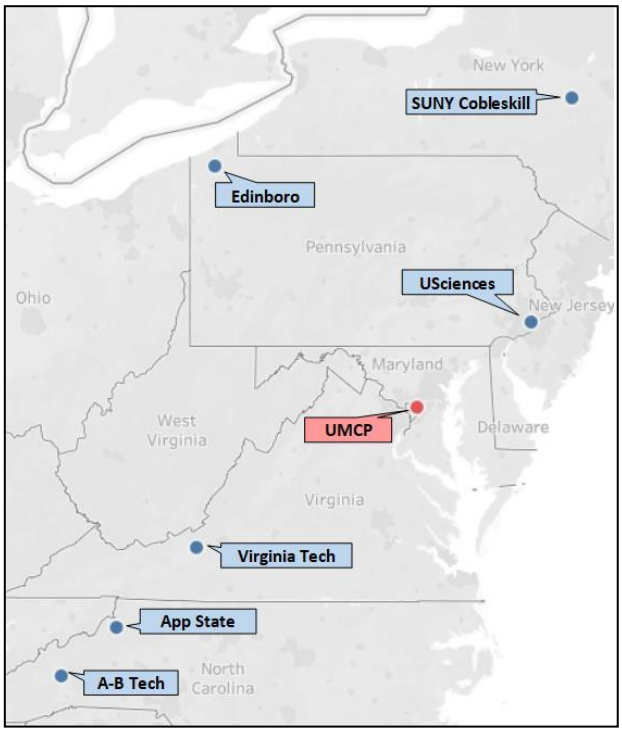
School	City	State	Degree Name	Degree Level
University of the Sciences	Philadelphia	PA	Brewing Science	Post-Bac Certificate
Virginia Tech	Blacksburg	VA	Food and Beverage Fermentation	B.S.
Edinboro University	Edinboro	PA	Fermentation Science	B.S.
SUNY Cobleskill	Cobleskill	NY	Applied Fermentation	B.T.
Appalachian State University	Boone	NC	Fermentation Sciences	B.S.
A-B Tech Community College	Asheville	NC	Brewing, Distillation, and Fermentation	A.A.S.

Sources: RESI, Program Websites

Of all the programs within Maryland's region, most are still on the edge of the defined distance, with four of the above programs being located 350 miles or further from College Park. Figure 8 visualizes the location of each program in relation to the main UMCP campus.

[39] An additional A.A.S. program in Brewing and Fermentation Science is currently being offered at the Pennsylvania College of Technology, located in Williamsport, PA. However, this program is being converted into a one-year certificate program beginning in Fall 2021. As the outline of this new program is currently unclear, it was dropped from the analysis.

Figure 8: Map of Program Locations within Regional Proximity of College Park



Sources: RESI, Tableau

When considering the location of existing programs, it is also important to consider the effect of tuition costs on the enrollment decisions of a prospective student. Most importantly, there is a significant difference between in-state and out-of-state tuition at many schools, creating a major barrier to entry for prospective students outside of the state.

The size of this barrier depends on the tuition premium charged by each school. For example, Virginia Tech more than doubles the cost of tuition for out-of-state students, while Edinboro University charges a premium of approximately 43 percent.[40,41] Notably, the University of the Sciences provides no in-state discount to PA residents.[42]

Despite multiple programs being within a day's drive of Maryland, there are currently no fermentation science programs within the state, preventing Maryland residents from taking

[40] "Expenses and Financial Aid," Virginia Tech, accessed April 28, 2020. https://vt.edu/admissions/undergraduate/cost.html.

[41] "Tuition and Fees," Edinboro University, accessed April 28, 2020, https://www.edinboro.edu/directory/offices-services/bursar/tuition-and-fees/.

[42] "Cost and Financial Aid – Students in Certificate Programs," University of the Sciences, accessed April 28, 2020, https://www.usciences.edu/admission/cost-financial-aid/information-for-students-certificate-programs.html.

advantage of in-state tuition rates.[43,44] Given the tendency for graduates to enter the workforce either close to home or close to their school, this creates a disadvantage for Maryland industries that require workers with skills and knowledge related to fermentation.

7.2 Level of Degree Offered by Comparable Programs

Even for those programs in closer proximity to Maryland, it is important to consider that not all programs in the region offer the same degree, with one program geared towards a two-year Associate of Applied Science (A.A.S.) degree, and another offering an 18-credit post-baccalaureate certificate. In contrast, the proposed UMCP degree program would award graduates a four-year bachelor's degree. These differences are important in determining the career prospects of graduates and potential workforce benefits of the specific program.

Bachelor's degree programs, such as the one proposed by UMCP, use the additional two years of education to provide knowledge in a wider variety of topics related to their discipline. These degrees are considered more valuable in a competitive job market, and allow graduates to continue their education in a master's or doctorate program. Associate degree programs use the shorter timeframe to focus more specifically on skills in a particular career field.[45]

These differences are important when considering how much each regional program overlaps with the proposed UMCP degree. Each of the non-bachelor's programs previously listed in Figure 7 address a more narrow selection of industries than the bachelor's-level programs. At A-B Tech, the program limits its focus to the beverage industries of breweries, wineries, and distilleries. At the University of the Sciences, students are prepared for multiple careers specifically within the brewing industry.

In total, only four comparable degree programs within 500 miles of College Park offer a bachelor's degree to graduates. When reconsidering proximity with this in mind, the closest fermentation science program is offered at Virginia Tech, located over four hours of driving time from College Park.

7.3 Scope of Industries Supported by Comparable Programs

As noted above, programs may provide a different scope as to the industry applications of fermentation science. Still, these differences in scope are not limited to those programs with differences in degree level.

[43] While Maryland does participate in the Academic Common Market, a program that offers some in-state reciprocity for students enrolled at out-of-state universities in programs that are not offered in their state of residence, none of the universities included in this section participate in the program.

[44] "Search and View Program Information," Southern Regional Education Board, accessed April 28, 2020, https://home.sreb.org/acm/choosestate.aspx.

[45] "Associate vs. Bachelor's: Which is the Right Degree For You?," Ashford University, accessed April 24, 2020, https://www.ashford.edu/online-degrees/online-learning/associate-vs-bachelors-which-is-the-right-degree-for-you.

Edinboro University in Pennsylvania provides an example of a wider scope, highlighting both dairy and pharmaceutical fermentation, as well as the craft beer and alcohol industries.[46] In concert with the scope, the Fermentation Science program is established under the Chemistry Department in the College of Science and Health Professions. At Virginia Tech, the Food and Beverage Fermentation program limits its emphasis to "fermented foods and beverages," such as beer, wine, and healthy foods.[47]

Notably, each of these programs offers a wider scope than non-bachelor's programs, such as the one offered by USciences. Coursework in this certificate program focuses entirely on beer, though the program may prepare students for a wider variety of careers within that specific industry.[48]

Given that Maryland has a varied economy with many different industries, it would likely benefit the state for UMCP to approach their own program with the widest possible scope in mind. As seen in the demand analysis, statewide employment in "Pharmaceutical and Medicine Manufacturing" is currently higher than employment in all combined fermentation-related food and beverage industries. In order for any new program to have the largest possible impact on Maryland's workforce, it is important that graduates have the skills and knowledge to fill jobs in all industries that utilize fermentation.

Designing a degree program to have a broad scope nevertheless means that UMCP should continue to pursue excellence in more specific areas. For example, the Master Brewers Association of America (MBAA) provides recognition to programs that prepare students for careers in both large and craft-scale brewing operations.

In four-year degree programs, recognition is based on achieving learning outcomes that cover multiple aspects of the brewing industry, including the science of brewing, operating a brewhouse, understanding flavor, and quality assurance.[49] There are also guidelines to the facilities and equipment that are made available to students, the expertise of faculty, and the completion of internships within the industry.[50]

Prospective students with a specific interest in breweries may be more likely to attend a program with this recognition, as it indicates that graduates will be qualified for jobs within the industry. Of those programs included in Figure 7, this recognition has been granted to the

[46] "Fermentation Science," Edinboro University, accessed April 23, 2020, https://www.edinboro.edu/academics/majors-and-programs/programs/fermentation-science/index.html.

[47] "Program Options," Virginia Tech, accessed April 24, 2020, https://www.fst.vt.edu/programs/undergraduate/Program_Options.html.

[48] "Brewing Science Certificate," University of the Sciences.

[49] "Summary of Essential Learning Outcomes for a Four-Year B.A. Degree in Brewing," Master Brewers Association of the Americas, accessed April 28, 2020, https://www.mbaa.com/education/Documents/4-year_BachelorDegree_LearningOutcomes.pdf.

[50] "Pathway to Recognition Program Guidelines for a Four-Year Degree in Brewing or Fermentation Science," Master Brewers Association of the Americas, accessed April 28, 2020, https://www.mbaa.com/education/Documents/4-year_BachelorDegree_Guidelines.pdf.

degrees offered at Virginia Tech and Appalachian State University.[51] UMCP should consider the guidelines set by MBAA when building their program, in order to maximize both the appeal to prospective students and the value of the program to the brewing industry in Maryland.

7.4 Regional Enrollment at Comparable Programs

Even if every existing program offered the same degree level and scope as the one proposed by UMCP, there is still demand for an additional program, as long as the number of graduates is lower than what will be required by Maryland's industries. Current enrollment figures at regional programs suggest there is still significant room for growth in this educational space.

According to enrollment data from each institution, the four programs listed in Figure 7 that offer a bachelor's degree had less than 213 total students enrolled in fermentation science programs as of Fall 2018. The highest enrollment was seen at Appalachian State, with 102 enrolled students, while SUNY Cobleskill reported only a single enrolled student in their program at that time.[52,53] Virginia Tech reported 91 students across the Food Science & Technology department, which offers four undergraduate degree options.[54] They do not report numbers for each specific option, including Food and Beverage Fermentation. The program at Edinboro University was started in 2018, and has no enrollment data available. However, Edinboro enrolls less than 4,000 undergraduates total and is therefore likely to have relatively low enrollment in their Fermentation Science program. In addition to the four-year programs, A-B Tech Community College reported enrollment of 38 students for their related associate degree.[55]

When considering the size of these enrollment figures, it is important to note that these are not annual graduates but rather total enrollment across a two-year or four-year program. Given the state-wide job growth figures provided previously in Figure 5, current enrollment in these programs is unlikely to fulfill the workforce demand in Maryland's fermentation-related industries. This is even less likely when considering that these programs are all located in neighboring states with their own workforce needs.

8.0 Conclusion

UMCP's BS in Fermentation Science would be a unique addition to Maryland's educational offerings. Currently, no such program exists within the state. While a few programs exist within

[51] "Diploma and Certificate Programs," Master Brewers Association of the Americas, accessed April 23, 2020, https://www.mbaa.com/education/Pages/HEC.aspx.

[52] "Enrollment Profiles – Public," Appalachian State University, accessed April 29, 2020, https://irap.appstate.edu/enrollment_profiles_public.

[53] "SUNY Cobleskill Program Enrollments," SUNY Cobleskill, accessed April 29, 2020, https://www.cobleskill.edu/about/institutional-research/pdfs/Enrollment_Program_2014-19.pdf.
[54] "Headcounts by Major," Virginia Tech, accessed April 19, 2020, https://www.ir.vt.edu/data/student/headcountsByMajor.html.

[55] "Curriculum Annual Program Headcounts, 2014-15 to 2018-19," A-B Tech Community College, accessed April 29, 2020, https://www.abtech.edu/sites/default/files/users/valerieddaniels/CU%20Headcount%20Annual%2018-19.pdf.

a day's drive, most are more limited in scope and/or do not prepare students at the bachelor's degree level. The UMCP program would benefit both students and the community at large through academic and extension programming, and could also allow the university to apply for and/or obtain additional external research funding for which it is currently less competitive.

Educating students in fermentation science in Maryland can also benefit the state's economy. Maryland's fermentation science industry is growing and encompasses a variety of activity in the region, including brewing and distilling, but also biofuels and vaccine or medicine production. Furthermore, occupations that require knowledge of fermentation science are expected to continue growing.

Based on existing successful programs, UMCP should consider the following recommendations as it develops its own fermentation science program:

- Establish an academic curriculum that focuses both on the basic sciences underlying fermentation and more specialized coursework on food science and fermentation;
- Engage with the MBAA to ensure that the BS in Fermentation Science is well aligned to the organization's criteria;
- Determine if the scope of the fermentation science program will focus on food and beverage fermentation or will also incorporate biotechnology and pharmaceutical applications;
- Consider allowing students to cross-register in courses/colleges across UMCP—for example, in entrepreneurship, marketing, chemistry, or engineering;
- Provide students with the initiative to customize their studies through a variety of electives, internships, and/or independent study options;
- Foster relationships with state fermentation industry leaders to augment students' learning through experiential opportunities;
- Collaborate with industry/employers in the development of facilities and laboratories for the program; and
- Engage with relevant federal agencies (the United States Department of Agriculture, the Food and Drug Administration, et cetera) to further develop opportunities for students.

With this context in mind, UMCP should consider that the BS in Fermentation Science could fill a gap in the state's educational system, which could benefit businesses in the state's economy and incentivize students to study—and likely remain—within the state's borders. Pending funding and resource availability, a dedicated program in fermentation science could be a sound investment for UMCP.

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Appendix A—Detailed Methodology

The shift-share analysis is a tool used by regional economists to assess specialization and competitive advantages in particular industries.[56] The basic premise of a shift-share is that changes in industry employment are due to a number of different factors, including how well the national economy is doing, regional conditions that are impacting growth, and patterns of change within the industry itself. The structure for this analysis follows the Esteban-Marquillas model[57]:

$$\Delta e = N + I + R + A$$

The change in employment for Maryland's fermentation industry between 2014 and 2018 (Δe), is the sum of the national share of employment growth (*N*), the share due to industrial mix (*I*), the regional share of employment growth (*R*), and the allocation (or interaction) effect (*A*).

The national share represents the employment growth for the region if the industries would have grown at the same level as the national economy. The industrial mix number represents the employment change due to differences in industry make-up of Maryland compared to the U.S. For example, this shows the growth for the brewery industry versus the national average.

The next variable—the regional share component—is often the main focal point in any shift-share analysis. This variable shows how the region or state is growing relative to the national levels, and thus represents a measure of growth in the state's competitive advantage. Finally, the allocation effect reflects the remaining contribution to the change in employment. This effect measures the job growth due to a region's competitive advantage. A positive number implies that the state or region is growing (declining) in an industry where they have a competitive advantage (disadvantage). On the other hand, a negative value indicates that a state or region is growing (declining) in an industry where the state has a competitive disadvantage (advantage).

[56] Implementation of this shift-share analysis was completed using the REAT R package: https://cran.r-project.org/web/packages/REAT/REAT.pdf.

[57] J.m. Esteban-Marquillas, "A Reinterpretation of Shift-Share Analysis," Regional and Urban Economics 2, no. 3 (1972): pp. 249-255, https://www.sciencedirect.com/science/article/abs/pii/0034333172900334.

Appendix B—Detailed Results

This appendix contains additional results from the demand and supply analyses.

B.1 Additional Demand Analysis Results

In this section, any data that are suppressed by BLS are presented with a * in the figures.

Figure 9: Maryland Annual Employment Level Changes by Industry

Year	31212	31213	31214	311513	311999	325414	541715
2014	236	*	*	60	119	*	*
2015	352	243	153	16	116	*	*
2016	450	368	90	41	305	*	*
2017	553	305	127	*	288	2,616	10,740
2018	745	324	213	*	317	2,471	17,848
Change	**216%**	**33%**	**39%**	**-32%**	**166%**	**-6%**	**66%**

Sources: BLS, RESI

Figure 10: Maryland Annual Number of Establishments by Industry

Year	31212	31213	31214	311513	311999	325414	541715
2014	22	28	4	3	8	13	*
2015	31	25	6	3	9	13	*
2016	43	30	8	4	11	15	*
2017	52	34	14	4	13	17	546
2018	70	40	19	4	14	20	589
Change	**218%**	**43%**	**375%**	**33%**	**75%**	**54%**	**8%**

Sources: BLS, RESI

Figure 11: Maryland Annual Location Quotient Level by Industry

Year	31212	31213	31214	311513	311999	325414	541715

2014	0.31	*	*	0.07	0.22	*	*
2015	0.39	0.23	0.74	0.02	0.21	*	*
2016	0.41	0.33	0.40	0.05	0.52	*	*
2017	0.44	0.26	0.50	*	0.47	4.25	1.49
2018	0.52	0.26	0.73	*	0.51	3.79	2.35
Change	**68%**	**13%**	**-1%**	**-29%**	**132%**	**-11%**	**58%**

Sources: BLS, RESI

B.2 Additional Supply Analysis Results

Prior to introducing regional proximity as a limiting factor, RESI compiled a national list of programs identified as comparable to the Fermentation Science program proposed by UMCP.

Figure 12: Full List of Comparable Programs within the Continental United States

School	City	State	Degree Name	Degree Level
U.C. Davis	Davis	CA	Food Science and Technology, with Brewing Option	B.S.
Colorado State University	Fort Collins	CO	Fermentation Science and Technology	B.S.
University of Idaho	Moscow	ID	Fermentation Science	B.S.
Southern Illinois University	Carbondale	IL	Fermentation Science	B.S.
Western Michigan University	Kalamazoo	MI	Sustainable Brewing	B.S.
A-B Tech Community College	Asheville	NC	Brewing, Distillation, and Fermentation	A.A.S.
Appalachian State University	Boone	NC	Fermentation Sciences	B.S.
Wayne State College	Wayne	NE	Fermentation Science	B.A. or B.S.
SUNY Cobleskill	Cobleskill	NY	Applied Fermentation	B.T.
Oregon State University	Corvallis	OR	Food Science Technology, Fermentation Option	B.S.
Edinboro University	Edinboro	PA	Fermentation Science	B.S.
University of the Sciences	Philadelphia	PA	Brewing Science	Post-Bac Certificate
Pennsylvania College of Technology	Williamsport	PA	Brewing and Fermentation Science	A.A.S.
Middle Tennessee State University	Murfreesboro	TN	Fermentation Science	B.S.

Virginia Tech	Blacksburg	VA	Food and Beverage Fermentation	B.S.
Washington State University	Pullman	WA	Food Science, Specialization Track in Fermentation Science	B.S.

Source: RESI, Program Websites

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