Idaho Incubation Fund Program

Final Report Form

Proposal No. _IF11-013_____
Name: _Kerry C. Huber_____
Name of Institution: _University of Idaho_____
Project Title: _Generation of Potato-Based Resistant Starch (RS) Ingredients for Testing within Commercial Product Prototypes by an Industrial Partner_____

Information to be reported in your final report is as follows:

1. Provide a summary of the overall project accomplishments to include goals/milestones met, any barriers encountered, and how the barriers were overcome:

The overall goal of this project was to generate potato resistant starch (RS) materials that could be tested by an industrial partner (J.R. Simplot Co.) for incorporation into various end-use products (e.g., instant mashed potatoes, restructured products, etc.). Potato RS ingredients have potential to provide advantages of a moderated glycemic response and digestive health benefits (emerging market trends) to potato products, which otherwise lack these characteristics. However, the incorporated RS ingredients must also exhibit appropriate functionality within a specific food application to maintain an acceptable food product. The following paragraphs outline the series of steps taken to address these project goals.

- Project personnel, consisting of a Visiting Research Scientist (30% effort) and a Scientific Aide Senior (50% effort), were trained in the methods and protocols for modification of potato granules, as well as measurement of rapidly digestible starch (RDS), slowly digestible starch (SDS), resistant starch (RS), estimated glycemic index (eGI), and degree of molar substitution (MS). Commercial potato granules were obtained from the J.R. Simplot Co. for use as a substrate, and methods were adapted and validated to utilize J.R. Simplot potato granules in modification trials.

- Potato RS ingredients were successfully generated in our laboratory at the bench-top level for testing by the J.R. Simplot Co. within their commercial products. Three primary types of potato RS ingredient variations were generally prepared and provided to the J.R. Simplot Co. for in-house testing: 1) Dual-modified (low-level substitution and cross-linking), 2) Substituted 1 (low-level substitution) and, 3) Substituted 2 (high-level substitution). Modified potato RS ingredients submitted to J.R. Simplot were analyzed in our laboratory for RDS, SDS, RS and MS attributes (i.e., quality control measures) to verify that modified potato RS ingredients possessed appropriate RS characteristics (see example in Table 1). As anticipated, various treatments resulted in different RS levels.

Table 1. Summary of Rapidly Digestible Starch (RDS), Slowly Digestible Starch (SDS), Resistant Starch (RS) and Molar Substitution (MS) Characteristics for Modified Potato Granule RS Ingredients provided to the J.R. Simplot Co. for in-house testing.

Treatment	RDS	SDS	RS	MS[3]
Substituted 1	**55.619**	**0.000**	**26.430**	**0.1911**
Substituted 2	**34.422**	**1.668**	**45.836**	**0.3742**
Dual Modified	**53.598**	**1.080**	**27.248**	**0.1799**
Simplot Potato Granules (Control)	**66.778**	**0.000**	**2.487**	**N/A**

- RS potato ingredients generated in our laboratory were also compared to Simplot commercial potato granules in regard to rheological behavior, and were demonstrated to possess similar flow properties to commercial potato granules across a range of shear rates. This result provided a key assurance that modified potato RS ingredients would likely behave similarly to their commercial potato granule counterparts within potato product applications.

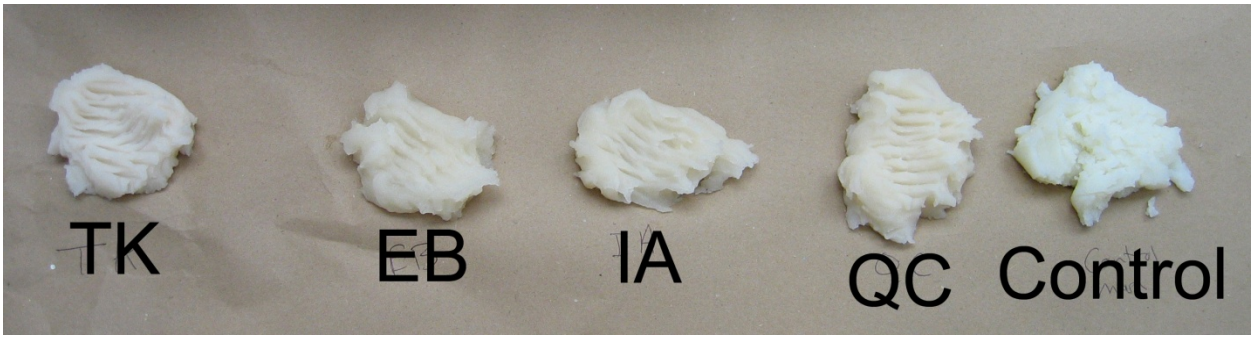

Figure 1. Mashed potatoes made from one part modified potato RS ingredients (TK= Dual Modified + added protein; EB=Substituted 2; IA=Substituted 1; QC=Dual Modified) and one part commercial potato granules relative to the commercial control (Simplot Traditions Instant Mashed Potatoes).

- Evaluations of potato RS ingredients conducted by the J.R. Simplot Co. focused primarily on a mashed potato application. One part modified potato RS ingredient was blended with one part commercial potato granules, as well as a dairy/flavoring blend, and processed into an agglomerated/powdered instant mashed potato mix. Mixes were reconstituted with water to mashed potatoes and evaluated on the basis of hydration rate, appearance/color, and texture (Figure 1). In general, mashed potatoes containing potato RS ingredients exhibited a typical mashed potato texture, though that possessing Substituted 2 potato RS material (which also had the highest RS value) possessed the least acceptable (e.g., sticky) texture. All mashed potatoes containing potato RS ingredients generally exhibited more rapid hydration rates, but a slightly darker (i.e., tan) color, than that of the control (Simplot Traditions). Nevertheless, J.R. Simplot personnel were generally upbeat about the functional performance of potato RS ingredients within a mashed potato

format, as their overall functionality was much better than other commercial RS materials previously evaluated.

- Agglomerated/powdered instant mashed potato mixes (containing 50% potato RS ingredients) prepared by J.R. Simplot were subsequently analyzed in our laboratory for estimated glycemic index (eGI) to determine the overall reduction in glycemic response. However, the potential glycemic benefits of potato RS ingredients in mashed potatoes were less than expected (only a 9-12% overall reduction), as they were significantly diluted by the presence of commercial potato granules (50% inclusion) and dairy ingredients (contributed glycemic sugars such as lactose). In contrast, eGI values for the pure potato RS ingredients themselves (without other additions) ranged from 20-40% compared to Simplot commercial potato granules. Thus, it was determined that potato RS ingredients would likely need to be utilized at full strength (and in the absence of other high glycemic ingredients) within potato applications to fully realize their glycemic benefits (though digestive health benefits could likely be achieved at lower addition levels).

- With the need to evaluate potato RS ingredients at full strength in potato product applications (as opposed to partial incorporation as originally proposed), generation of sufficient amounts of potato RS ingredients for additional end-use applications (aside from mashed potatoes) at the benchtop level became a limiting factor. A decision was made, based on discussions with J.R. Simplot, to move forward with pilot scale-processing to efficiently generate needed amounts of potato RS materials for testing within additional product applications (e.g., croquettes, restructured hash browns, French-fries, etc.). A third party manufacturer, Penford Food Ingredients, was identified and invited to participate in pilot-scale processing trials (after appropriate non-disclosure forms were in place), since they already possess needed starch modification equipment for production of potato RS starch ingredients. This arrangement also has the added advantage of converting our benchtop production scheme to something more akin to an industrial-scale process. Over the past several months, Penford Food Ingredients has now generated its first preliminary potato RS samples using our benchtop process. Our laboratory recently analyzed these materials and validated their RS levels (Table 2). Thus, Penford Food Ingredients has been able to successfully replicate the production process, and is continuing to move ahead with pilot scale development. As these pilot-scale activities are expensive, J.R. Simplot has agreed to assume the continued cost of pilot-scale production of potato RS ingredients as the effort continues.

Table 2. Simplot potato granules modified by Penford Food Ingredients according to the Huber laboratory method with propylene oxide (20% w/w starch basis).

Modification	RDS	SDS	RS	MS
Penford Sample	24.291	0.407	57.227	0.2408

- In the interim other research activities have been conducted by our laboratory group in support of the pilot-scale production exercises mentioned in the previous paragraph. A few of these activities are highlighted below.

    - A limitation of the current benchtop modification process is that some of the native potato granule protein is lost and/or destroyed in the modification process. Protein is important to potato products from both a nutritional and sensory (i.e., flavor/appearance) standpoint. Two possible solutions to this challenge have been explored. First, potato RS ingredients were simply supplemented with a commercially available potato protein (1942 Solathin Potato Protein Extract, Cyvex Nutrition, Irivine, CA) after modification. This potato RS material was amongst those samples initially evaluated by J.R. Simplot in mashed potato trials (Figure 1, Sample TK), and was noted to possess a bland flavor and a texture similar to the reference commercial product. A second approach has been to extract the native protein from commercial potato granules prior to modification, for the purposes of being able to add it back after the modification process (thus, retaining its native functionality and biological activity). Water extraction alone was able to remove more than 40% of the native protein from commercial potato granules. It might also be that a combination of the two approaches could ultimately provide a viable solution.
    - Other starch modifying agents (sodium trimetaphosphate, sodium tripolyphosphate, octenyl succinic anhydride, etc.) were also explored for generating potato RS ingredients. In short, no other modifying agents were found to be as effective as those initially proposed (propylene oxide, phosphorous oxychloride) for generating RS within potato granules.
    - In pilot-scale interactions with Penford Food Ingredients, the amount of base (NaOH) required to drive the starch modification was observed to be relatively high (most likely due to the nature of the solvent reaction medium). Efforts to address this challenge indicate that a reduction in the amount of base translates into a lesser amount of modification and decreased generation of RS. Further ongoing studies are being conducted to identify the amount of base needed to generate most efficiently generate RS within potato granules at a production cost that is not cost-prohibitive.

- Though pilot scale production of potato RS ingredients has required more time than originally anticipated (pilot work is yet ongoing), this grant has successfully provided gap funds needed to initiate a successful and ongoing collaborative partnership between UI researchers and the J.R. Simplot Co. In summary, the J.R. Simplot Co. is committed and continues

to fund needed research efforts beyond those of this initial grant to further explore the commercialization potential of potato RS ingredients.

2. Describe the current state of the technology:

   Over the course of this grant, research efforts have satisfied a technology readiness level of 5, with continuing expected to achieve a technology readiness level of 6 in the very near future (based on ongoing pilot scale production efforts).

3. List the number of faculty and student participants as a result of funding:

   Dr. Kerry C. Huber (Principle Investigator), Dr. Jong-Yea Kim (Visiting Research Scientist), and Kathleen Hendrix (Scientific Aide Senior).

4. What are the potential economic benefits:

   The potato RS technology offers the possibility of developing potato products with moderated glycemic response and/or improved digestive health benefits, which would allow Idaho potato processors to gain entry into new markets (traditional potato products do not currently qualify for these trends). Expanded markets for potato products would likely increase end-use demand for potatoes and increase economic growth associated with new business ventures in this agricultural sector.

5. Description of future plans for project continuation or expansion:

   The following activities are planned in partnership with the J.R. Simplot Co., based on their continued interest in this technology, and presumes continued funding from Simplot to support these research efforts.

   - Continue to work with Penford Food Ingredients (third party manufacturer) to generate large-scale pilot quantities of potato RS ingredients to facilitate broader and larger-scale application testing by the J.R. Simplot Co. Assist J.R. Simplot during continued application testing to fine tune RS ingredient characteristics (sensory) and physical properties according to end-use application needs. Additional effort will likely be required to balance functionality and physiological efficacy.

   - Conduct further kinetic work to optimize/streamline the chemical modification process parameters to minimize production cost/time and improve potato RS characteristics (color, nutritional content) in advance of full industrial scale-up. Assist with industrial-scale process development and/or optimization, which is anticipated to occur at the UI Food Technology Center in Caldwell, ID.

   - Once the industrial scale process for potato RS ingredients has been established and production costs are deemed to be feasible, potato RS ingredients will be subjected to animal and human clinical trials to

establish physiological benefits/efficacy (glycemic response, colonic fermentation) and safety.

- Continue to develop and expand additional potato RS technologies (some are already in the pipeline) to build upon and address emerging potato RS market needs.

6. Please provide a final expenditure report (attached) and include any comments here:

   Some travel and operating expense (OE) funds were transferred to wages (IH) and fringe benefits in support of project needs. Original plans included travel of UI personnel twice to Simplot Headquarters in South Idaho. However, Simplot executives and research personnel were frequently on the UI campus over the course of the project, so almost all face-to-face meetings were held on the UI campus (The project PI only had need to travel once to Southern Idaho to meet with Simplot personnel). Further, some of the initial pilot scale work was routed through a third-party manufacturer (Penford Food Ingredients), freeing up funds for support project personnel working on the project (wages (IH) and fringe benefits).

7. List invention disclosures, patent, copyright and PVP applications filed, technology licenses/options signed, start-up businesses created, and industry involvement:

   U.S. Provisional Patent Application of Kerry C. Huber, Serial No. 13/366,900, Title: Methods of Preparing Potato Food Products with Enhanced Resistant Starch Content, Feb 9, 2012.

   U.S. Patent Application of K. C. Huber and W. C. Yu, Title: Potato Products with Enhanced Resistant Starch Content and Moderated Glycemic Response and Methods thereof. Filed October 2, 2010 (pending U.S. Application No: 12896542; International Application No: PTC/US10/51164).

   The potato RS concept served as the basis for multiple entries into various business plan competitions throughout the U.S., providing interaction with entrepreneurs and business leaders.

   - Took top honors in the 2011 UI Business Plan Competition
   - Was awarded 6th place in the 2011 University of Washington Business Plan Competition
   - Was awarded 5th place in the 2011 Rice University Business Plan Competition

   The potato RS technology was recognized as the 2011 Early-Stage innovation of the Year by the Idaho Technology Council in Boise, ID.

There are ongoing deliberations between the UI and J.R. Simplot regarding formation of a start-up company (Solanux) to continue to move potato RS ingredients toward commercialization. In the interim, J.R. Simplot has demonstrated continued commitment to the project by providing additional “gap” funds to the university to allow the project to keep moving forward until negotiations are complete. Further, J.R. Simplot has committed to fund U.S. and world patent applications currently in process.

FINAL EXPENDITURE REPORT

A. FACULTY AND STAFF		
Name/Title	$ Amount Requested	Actual $ Spent
B. VISITING PROFESSORS		
Name/Title	$ Amount Requested	Actual $ Spent
C. POST DOCTORAL ASSOCIATES/OTHER PROFESSIONALS		
Name/Title	$ Amount Requested	Actual $ Spent
Jong-Yea Kim (Visiting Research Scientist, 30% Effort)	$9,700.00	$20,636.36
Kathy Hendrix (Scientific Aide Senior, 50% Effort)	$18,500.00	$ 9,788.27
D. GRADUATE/UNDERGRADUATE STUDENTS		
Name/Title	$ Amount Requested	Actual $ Spent
E. FRINGE BENEFITS		
Rate of Fringe (%)	$ Amount Requested	Actual $ Spent
Jong-Yea Kim (30% fringe rate)	$2,900.00	$9,415.97
Kathy Hendrix (41% fringe rate)	$7,600.00	$2,936.48
PERSONNEL SUBTOTAL:	$38,700.00	$42,777.08
F. EQUIPMENT: (List each item with a cost in excess of $1000)		
Item/Description	$ Amount Requested	Actual $ Spent
1.		
2.		
3.		
4.		
EQUIPMENT SUBTOTAL:		
G. TRAVEL		
Description	$ Amount Requested	Actual $ Spent
1.Huber rental car and per dium	$2,100.00	$512.26
2.		
3		
TRAVEL SUBTOTAL:	$2,100.00	$512.26

H. PARTICIPANT SUPPORT COSTS:		
Description	$ Amount Requested	Actual $ Spent
1.		
2.		
3		
PARTICIPANT SUPPORT COSTS SUBTOTAL:		

I. OTHER DIRECT COSTS:			
Description		$ Amount Requested	Actual $ Spent
1.Materials and Supplies		$9,200.00	$6,710.66
2.			
3.			
OTHER DIRECT COSTS SUBTOTAL:		$9,200.00	$6,710.66
TOTAL COSTS (Add Subtotals):		$50,000.00	$50,000.00
TOTAL AMOUNT REQUESTED:			$50,000.00
TOTAL AMOUNT SPENT:			$50,000.00