Carotenoid Processing: The Effects of Microwave-assisted Processing on Carotenoid Ingredients

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Abstract

Cardiovascular disease (CVD) is the #1 cause of death in America. Nearly one in three US. adults, or 68 million people, have hypertension; and nearly 30% of all US adults are pre hypertensive. Hypertension is a major contributor to cardiovascular diseases, which are a leading cause of death, disability, and health-care costs in the United States. Currently, there is a broad societal need to improve the nutrient density of foods to a degree that a functional benefit is achieved through dietary consumption. Today's consumers expect the availability of healthy food options to maintain good health.

Tomatoes contain carotenoids with 40-hydrocarbon chain structures possessing the ability to indirectly protect cells from damage by absorbing free radicals and directly stimulating metabolism-regulating human biological responses. Tomato processing is a mature domestic market that produces over 30 million tons of carotenoid material annually consumed at a rate of 73lbs per capita.

The purpose of this academia-industry privately funded R&D work was to use microwave assisted heating to develop a tomato processing model that can be utilized to investigate knowledge gaps pertaining to processing of frequently consumed carotenoid-containing fruit crops for added value effects and identify industrial applications for energy efficient processing technologies. Tomatoes were purchased, washed, homogenized and sterilized using microwave assisted thermal processing. Carotenoid bioaccessibility was determined using a high throughput, three-phase in vitro digestion model. Transfer of *trans*-lycopene and cis-lycopene isomers from tomato to micellar fractions were quantified by HPLC to determine bioaccessibility.

After treatment of tomato homogenate with or without processing aids with microwave heating, lycopene bioaccessible content was increased 5-fold ($P < 0.01$) and 6.5-fold ($P < 0.01$) for cis lycopene and *trans*-lycopene, respectively. Heated Roma tomato with oil (HRO) treatment showed the largest decrease ($P < 0.05$). in *trans*-lycopene isomer content compared to control. Cis-beta carotene bioaccessible content increased 5-fold ($P < 0.01$) in processing aid incorporated microwave heated treatment conditions.

In summary, we provide proof of concept that microwave-assisted heating may be used to induce optimization of lycopene and beta-carotene bioavailability. This system may be used to investigate some of the emerging questions in fat soluble antioxidant bioaccessibility pertaining to micellarization efficiency, micelle speciation, micelle morphology distribution, process specific carotenoid isomer speciation and electromagnetic energy mediated hydrocarbon energy transfer characterization complemented by mechanism elucidation in cultivar-specific foodstuffs. We provide evidence of translational research and development for post-harvest processing with microwave heating adding value to carotenoid-containing tomato ingredients that may provide functional benefits and industrial applications for the bioprocessing technologies. We extrapolate from our findings to suggest that microwave heating involved with our established bioprocessing method algorithms provide predictable enhanced absorption opportunity for carotenoids and other commercially viable fat-soluble antioxidants paving the way for year round large scale functional ingredient bioprocessing in the sunshine state of Florida. However, results indicate cultivar and harvest season may impact microwave assisted heating-induced micellarization without processing aids. Exploring innovations in food ingredient processing to improve the nutrient profile of food products provides an opportunity to improve public health. Acceptance of new ingredients will be a key to ensuring a healthier and more sustainable future for the food supply chain as demand for food grows alongside rises in global population.

The Total Addressable Market (TAM) for personalized proinflammatory disease specific processed tomato value-added products in the USA is roughly $250 Billion. Novel consumer accepted functional tomato condiments were commercialized by Michael Lloyd in 2008 through a collaboration with specialty retailer Whole Foods Market. Proceeds were reinvested into the described tomato functional ingredients R&D effort from 2009-2021 through an Academica Industry collaboration spearheaded by the founder of Num Num Sauce Company, Dr. Michael Lloyd. The goal is to establish tomato bioprocessing industry and infrastructure in Florida to meet the commercial demand for carotenoid functional ingredients and to a lesser extent facilitate supply of natural replacements for recently banned red food dyes (Red 40).