FUNCTIONAL INGREDIENT: UTILIZING CALIFORNIA ALMONDS IN CHOCOLATE PRODUCTS

This two-part whitepaper summarizes consumer, sensory and flavor research that outlines the case for California almonds. Three studies referenced within also address common concerns over almond shelf-life– including surface fat bloom and rancidity– for diced almonds and almond butter-filled chocolate products.

Part one of this whitepaper details key insights from consumer research highlighting why almonds are an ideal ingredient in chocolate products and possess the attributes consumers find most important– like nutrition and texture.

Part two will focus on the science behind almond sensory attributes, roasting techniques, and shelf-stability and explore three new studies addressing almond stability in chocolate and consumer taste preferences.

PART ONE: CONSUMER DEMAND AND NEW FRONTIERS

Clean-label and natural products – even in the confectionery category – are key trends impacting innovative product development. The chocolate sector is well-primed to address the ever-growing consumer demand for "natural" and "clean" products. More and more, manufacturers are expanding the definition of these terms to include the addition of relevant functional nutritional and health benefits. As manufacturers look to strike a balance between health, nutrition, and simple indulgence, texture is also emerging as a promising way to craft unique experiences using novel techniques and ingredients to pique consumers' interest.

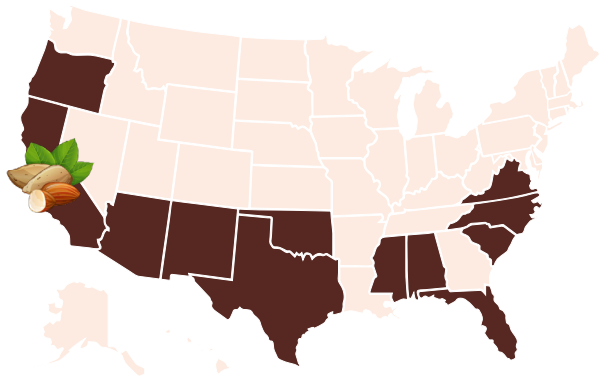
According to data presented in **the 2022 Global Chocolate Study by Sterling-Rice Group** for the Almond Board of California, which surveyed 5,000 consumers across 10 key markets, 59 percent of surveyed consumers report enjoying chocolate as an allowed indulgence. **Including almonds with chocolate can increase product appeal to health and wellness-focused consumers**, building on almonds' natural and nutritious qualities, and reducing guilt.[1] Additionally, Innova Market Insights research reflects that chocolate innovation is driven by consumers looking for products with "clean labels", as gluten-free and no additives/preservatives rank high among surveyed global consumers.[2]

Almonds remain the number one ingredient in surveyed global consumers' ideal chocolate products and almond butter is a top filling/flavor included in surveyed consumers' ideal chocolate products. Globally, almond butter is a top fifteen inclusion for surveyed consumers across milk, dark and white chocolate.[1] Available in more forms than any other tree nut, almonds are an essential ingredient with endless texture and flavor potential in product development across categories – including confectionery. Globally, confectionery products were the number one category for almond introductions at 22 percent in 2021.[4]

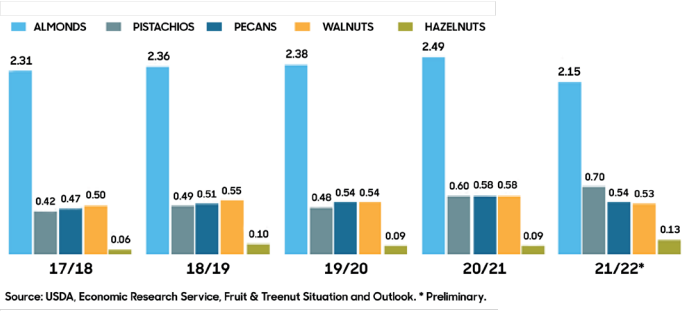
Where are your nuts grown?

Currently, the United States produces almonds, walnuts, pistachios, pecans, peanuts and hazelnuts.

- Almonds are grown in the US only in California's Central Valley due to its Mediterranean climate. California produces over 79% of the worlds' supply of almonds.
- Peanuts are grown primarily in the Southeastern US, with Georgia producing nearly half (49%) of the US crop
- Pecans are grown in the Southern states– from Georgia to Arizona
- Hazelnuts are grown in Oregon
- Walnuts, pistachios and almonds are grown in California



Domestic Per Capita Consumption of Tree Nuts
Crop Years 2017/18-2021/22 | Pounds per capita



Source: USDA, Economic Research Service, Fruit & Treenut Situation and Outlook. * Preliminary.

Since 2014, almonds have continued to increase in consumption in the US leading overall in tree nuts.

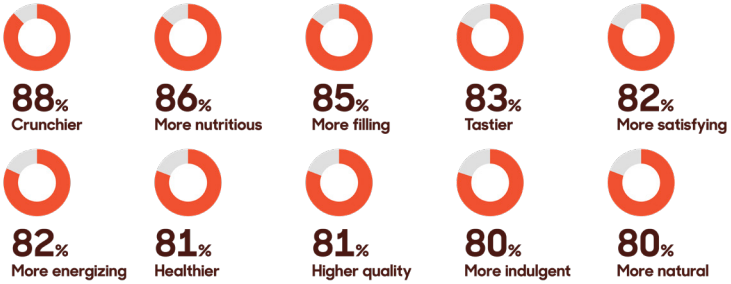
California Almonds: Consumers' Ideal Inclusion for Chocolate Products

Since 2008, almonds have held the top spot among inclusions that surveyed global consumers include in their ideal chocolate product.[1] Almonds outperformed all nuts in nine of ten key benefits consumers feel add to chocolate, including "more natural," "more indulgent," "more satisfying," and "higher quality."[1]

Increasingly, chocolate is bridging the gap between the confectionery and snacking categories, and nuts provide even more snacking relevancy for chocolate. **Nearly 80 percent of surveyed chocolate snackers say chocolate is either their number one go-to snack or one of their top choices**. Surveyed consumers are snacking on chocolate more frequently in the mid-afternoon (68%), evening (50%) and mid-morning (37%). However, when eating chocolate across dayparts, consumers are looking for an indulgent experience as well as something to help them relax.[1] For the nearly 80% of chocolate snackers reporting chocolate is either their #1 go-to snack or one of their top choices, nuts can increase the snack appeal of chocolate.

Almonds can lend a healthy halo to chocolate products. In all forms, California **almonds can help deliver holistic "better-for-you" claims as they are a natural ingredient and nutritional powerhouses** offering plant-based protein (6g) and satiating fiber (4g) in every serving. Almonds' nutritional profile allows consumers to feel good about choosing almond-packed chocolate as a snack. One ounce of almonds is an excellent source of vitamin E and magnesium, and supplies 13 grams of unsaturated fat and one gram of saturated fat*.

Top 10 benefits of almonds in chocolate[1]



Global Chocolate Study, Sterling Rice Group, 2022

The Innova Global New Products Report on 2021 launches highlighted the top claims used on packaging of products with almonds, noting that "gluten-free" was the top claim used (20.6 percent) worldwide. Following trends and consumer demands for clean label products, claims of "no additives/preservatives" were the second most used on almond product introductions globally, communicated on 15.7 percent of almond products.[4] According to the Innova report, in general, introductions with almonds lead to a higher likelihood of health claims.

Tools for Texture

The versatility of almonds provides endless possibilities for product manufacturers. With over 14 forms – both natural and blanched – almonds can offer unique texture and flavor functions that provide endless options for creative chocolate development. While 84 percent of surveyed consumers agree that almond butter enhances the taste of other foods when used as an ingredient,[5] global consumers also find almonds make chocolate crunchier (88%) and more nutritious (86%)[1]. Using almond slivers or diced almonds and creamy almond milk and almond paste will create the ideal mouthfeel when indulging.

To build texture within chocolate products, developers can utilize multiple forms of almonds at once. For example, a chocolate bar can use almond butter as an inclusion and diced almonds, or even almond flour, can be used as a coating for added crunch. Formulators can also work with roasted almonds to create a crispier, crunchier texture.

With new frontiers for almond inclusions in chocolate products in mind, continue reading for part two, which will focus on the science behind the sensory attributes of almonds and how manufacturers can maximize product potential through roasting techniques and food quality parameters, detailing three new studies addressing almond stability in chocolate and consumer taste preferences.

PART TWO: EXPLORING THE SENSORY ATTRIBUTES OF ALMONDS

Consumers are seeking excitement in their chocolate products, according to the Almond Board of California's latest Global Chocolate Study[1], creating an opportunity for manufacturers to innovate with ingredients like almonds. California almonds help product developers meet multiple criteria when developing a new product for consumers. Known for their signature crunch, aesthetic appeal and subtle yet pleasing flavor profile, almonds add ideal texture to sweet and savory confections.

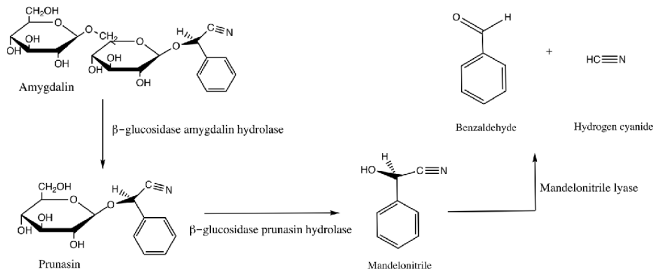
Did You Know? Nine attributes account for 92% of almond sensory variations:

Crunchiness	Cohesiveness	Benzaldehyde
Chewiness	Hardness	Hay
Fracturability	Moistness	Sweet Aromatics

Maximizing Almond Flavor: Understanding Volatiles

Benzaldehyde is the compound that gives almonds their unique flavor. Benzaldehyde is generated by the disruption of almond tissue (e.g., chewing) which enables amygdalin to meet hydrolytic enzymes and form hydrogen cyanide and benzaldehyde. Sweet almonds, which encompass all California almond varieties, contain trace amount of amygdalin compared to bitter almonds.

Chart showcasing the molecules of the different flavor volatiles in almonds.



Bitterness = Combination of amygdalin levels and enzymatic hydrolysis rates

Almond Roasting

Roasted almonds, in contrast to raw almonds, are found to contain many more volatile organic compounds, as the heating process generates new volatile products through a number of reaction pathways, including lipid oxidation, sugar pyrolysis and browning – or Maillard reactions.[6]

Almond roasting emphasizes the flavor and textural attributes of almonds – deepening the color and taste profile, and creating a crispier, crunchier exterior. These treatments can ensure that the desired texture is consistent and stays intact throughout the rest of the product development process.

The roasting process heats the almond kernel, and once the temperature approaches the boiling point, the almonds will lose moisture from evaporation. After the kernel is dehydrated and its temperature reaches above 250°F, the Maillard reaction occurs between amino acids and reducing sugars naturally occurring in the almond. This reaction generates a desirable darker color— this is non-enzymatic browning—and many flavor compounds, like short-chain aldehydes and heterocyclic pyrazines. These compounds give the roasted almond a more pronounced nutty flavor, while other chemical reactions break down fatty acids into a completely different set of volatile flavor and aroma compounds, like short-chain aldehydes.

Remember: the roasting process will compromise cellular structure of nuts. An optimal roasting temperature will minimize impact on the integrity of the cellular structure of the kernel intact, which also helps to maintain a longer shelf life.

Oil vs. Dry Roasting

Oil has a higher heat-transfer coefficient than air, so even if the oil and air are at the same temperature, the oil will roast almonds to a given degree in a shorter time than hot air. A percentage of the oil will be absorbed into the product, so the flavor profile, texture and color difference of oil-roasted almonds will be slightly different than with air-roasting.

Dry roasting is the more common method for the snack and retail sectors; because oil is not added or absorbed by the product, there are fewer concerns about oil quality, flavor, and the potential for residual oil oxidation.

Ideal Parameters for Managing Shelf Life of Almonds

The almond is a living kernel, and it interacts with its environment. To keep almonds stable and provide a long shelf life of up to two years, the almond's moisture content needs to stay below six percent—ideally between 3.5 and 5.5 percent. High humidity and high temperatures can accelerate the release of fatty acids which can become oxidized. It's important to maintain a storage environment that is between 50 and 60 percent relative humidity and temperatures below 59°F. Ideally, store almonds in sealed plastic bags or tightly sealed storage containers.

Almond Quality Preservation

Like all nuts, almonds are high in oil, and any food containing high levels of oil can be vulnerable to lipid oxidation, especially when exposed to high temperatures or a high-oxygen environment. Lipid oxidation starts with the release of fatty acids. If the free fatty acids become exposed to oxygen or free radicals, they oxidize and generate intermediary compounds that gradually break down into volatile compounds, like aldehydes, that can produce rancid notes.

While there are key steps to take to keep almonds shelf-stable, almonds also have built-in protections that give them naturally long shelf life, including:

- Inherently low moisture – around 3 to 6 percent
- Proper fatty acid profile – almonds' lipids are primarily monosaturated and more stable than polyunsaturated fats.
- High level of vitamin E – a natural antioxidant that defends against oxidation.
- Polyphenols – another group of natural antioxidants found in almond skin.
- Tight cellular structure – that protects oil droplets in a honeycomb-type network.

Proper Packaging

To create a long-lasting product that keeps consumers wanting more, packaging almonds properly is an important step.

Packaging is especially important with roasted almonds because high roasting temperatures initiate some lipid oxidation. Use packaging that provides a better oxygen barrier – particularly nitrogen flushing or vacuum packaging – to keep oxygen away to slow down oxidation. Packaging also prevents or slows down product water absorption from humid environments to further extend shelf life.

Maximizing almond flavor through roasting and understanding almond quality preservation techniques, including packaging, will allow product manufacturers to develop high-quality and long-lasting products for their target consumers.

Experiments Exploring Almond Stability & Consumer Acceptance in Chocolate Products

California almonds and chocolate are a craveable combination, but how can manufacturers ensure they are using the right formulations to get a delicious end result with long-lasting shelf-life?

Three experiments were conducted in conjunction with the Professional Manufacturing Confectioners Association (PMCA) to better understand how various chocolate confections containing almond ingredients performed over shelf life in regard to the presence or absence of bloom and overall sensory acceptance. The study findings, *Nuts, Almonds, Chocolate–Functionality, Shelf Life & Liking*, were published in Manufacturing Confectioner and presented during PMCA's 2021 Annual Production Conference.

Experiment #1 - Impact of Almond Roast Level on Shelf Life & Sensory Acceptance of a Dark Chocolate Confection

This experiment focused on the impact of roasting parameters on both shelf life and sensory acceptance of a dark chocolate confection. Two rounds of experimentation were done, the first of which focused on diced almonds (size) that had been exposed to either a high roast condition (340°F for 40 minutes; direct heating) or a low roast condition (340°F for 35 minutes; indirect heating). The appearance of the diced almonds was discernably different when viewed side by side (Figure 1).

Figure 1. High Roast (Left) and Low Roast (Right) Almond Samples

The diced almond samples were used to prepare dark chocolate bars for the shelf life and sensory evaluations. One hundred gram dark chocolate bars were prepared with 18 grams of almonds in each bar, then remained being chocolate of approximately 50 percent cacao. Temper of the chocolate mass was measured at the time of molding, and was +0.26 temper slope. The bars were visually inspected and photographed after demolding to capture T=0 reference images (Figure 2).

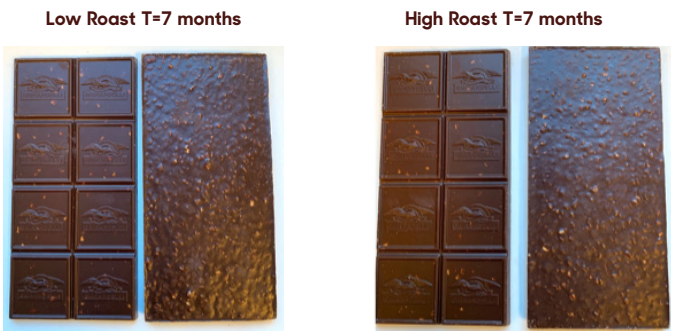
Figure 2. Low Roast and High Roast Dark Chocolate Bars at T=0 months

Low Roast Almond Bars

High Roast Almond Bars

A total of 10 bars were made for each set of roast parameters. Five each were used for initial sensory testing to record T=0 sensory acceptance. The remaining bars were wrapped in aluminum foil and placed in 19°C, 55 percent relative humidity environmental chambers (Darwin Chambers, St Louis MO) for seven months. Once a month, a representative bar from each roast parameter was visually inspected for the appearance of bloom on any of the surfaces of the bar. During this study, no bloom appeared on the surface of these or any other bar, regardless of the roast parameters.

Figure 3. Low Roast and High Roast Bars at T=7 months



After six months, another round of Sensory Acceptance testing was conducted on the dark chocolate bars.

Sensory Acceptance testing was conducted through a one-day hedonic test in July 2019 for T=0. The test population consisted of 76 people who indicated they liked dark chocolate that contained fruit or nuts. Each panelist was served a one-half square (1/16th of a bar) and asked to eat enough of the sample in order to form an opinion.

Overall, both products performed similarly across all attributes, purchase intent after tasting, and perceived freshness at T=0. Both high and low roast almonds in chocolate were liked highly, with almost all consumers perceiving the product as fresh. This methodology was repeated in January of 2020 with 48 panelists for T=6. The results at T=6 showed no significant difference across all liking attributes. However, both samples did show a significant drop in perceived freshness compared to the scores of T=0 (Figure 4).

Figure 4. Perceived Freshness, Mean Score

	T=0	T=6
Low Roast	50.26a	45.83b
Hight Roast	48.68a	43.83b

Scale: 0: "Not Fresh at All" 60: "Very Fresh"

Additionally, Purchase Intent After Trying (PIAT) increased for the low roast samples after six months, whereas it decreased for the high roast samples (Figure 5).

Figure 5. Purchase Intent After Tasting

(Top 2 Box – "Probably Would Buy" and "Definitely Would Buy")

	PIAT T=0	PIAT T=6
Low Roast	64.5%	68%
Hight Roast	67.1%	60%

While the scores for the individual product attributes were not significantly different for either roast level at both T=0 and T=6, panelist comments did indicate some notable trends regarding both flavor and texture of the samples. The most notable comment about the samples made with low roast almonds was that the chocolate flavor overpowered the almond flavor, making the almond flavor not noticeable. To supplement the comment above, a handful of panelists said that they would have like the product more if the almonds had more of a roasted flavor. Several panelists also mentioned that the almonds tasted like "raw almonds", thus giving a sweeter almond flavor. The panelists also described the high roast samples at T=6 as "stale" or "old tasting" while the low roast samples at T=6 were described as "fresh". However, the comments regarding texture would indicate that the trade-off of using a lower roast almond is a less satisfying crunchy texture, as the panelists indicated that the chocolate made with low roast almonds were not crunchy enough. The high roast samples were described as crunchy.

Overall these findings would indicate that using high versus low roast diced almonds in a dark chocolate confection does not significantly impact the consumer acceptance or shelf-life, although directional information indicates **consumers enjoy the texture of high roast almonds and the flavor of low roast almonds at the end of shelf-life**. Additional studies would be warranted that explored more extreme roast profiles of different forms of almonds as well as longer shelf-life periods and different storage conditions.

Experiment #2 - Impact of Fat Level in Almond Filling on the Acceptance in a Dark Chocolate Truffle

As previously mentioned, almonds are surging in popularity in confections in various forms. Nut butters beyond peanut butter are showing up in many forms of confections as a result and present a different set of challenges and opportunities when compared to a solid inclusion form. This study set out to focus on the level of fat used to formulate a nut butter truffle and how that impacted consumer acceptance at the beginning and end of shelf life.

Almond butter fillings were created with a high fat content (50 percent fat) and a lower fat content (37 percent), with the same amount of sugar and salt being added to both formulas to ensure the driver of any differences would be the result of the fat content. Rounded truffle molds were used to create shells with dark chocolate (about 50 percent cacao, three percent AMF, -0.32 temper slope). Then, 3.5 grams of either filling was piped into the center. The entire mold was chilled, then the same dark chocolate was used to back off the molds to create finished truffles with a finished shell weight of 4.5-5 grams.

Truffles were then divided into two sets, half being placed in boxes and then stored in a 19°C environmental chamber for six months. The remaining truffles were tested with 35 sensory panelists who had indicated they liked dark chocolate and nuts. The test was conducted as a one-day hedonic test to obtain T=0 data. This methodology was repeated six months later with the truffles aged in the 19°C chamber, this time with 30 panelists who met the same criteria.

Figure 6. Truffle Filling Formulas and Cross Section of the Finished Truffle

· High Fat Filling Recipe - 50% Fat

Ingredient	%
Almond Butter Blanched Dry Roasted	77.6
28% Fat Almond Meal	7
Powdered Sugar	14
Salt	1.4

· Low Fat Filling Recipe - 37% Fat

Ingredient	%
Almond Butter Blanched Dry Roasted	65.6
12% Fat Almond Meal	19
Powdered Sugar	14
Salt	1.4

Truffles were served to the panelists in a sequential monadic design. Panelists were instructed to consume enough of the truffle to form an opinion, in a manner that would constitute how they typically consume a product like this. Results from this testing showed a significantly higher purchase intent and liking scores for the truffle that was made with the high fat filling. Panelist comments indicated the main driver of the differences was driven by the texture of the filling - with several panelists expressing that they liked the high fat filling sample better because of the smoother and creamier texture of the almond butter filling. The low-fat filling comments indicated that the panelists found this sample as "too thick", "too sticky", "gunky", "crumbly", or "lumpy". One consumer described the filling "like a spoonful of peanut butter", while another consumer described it as "so thick, it sticks to my mouth and doesn't have a nice mouthfeel". Additionally, both samples were thought to be somewhat lacking in almond flavor intensity.

Figure 7. T=0 Sensory Scores for Almond Butter Truffles

T=0	Purchase Intent (Top 2 Box)	Overall Liking*	Overall Flavor Liking*	Filling Texture Liking*
Low Fat Truffle	37.10%	6.63b	6.60b	6.37b
High Fat Truffle	57.14%	7.37a	7.20a	7.31a

*On a 9-pt hedonic scale

After six months of storage at 19°C, the remaining truffles were tested with the same sequential monadic design. Samples were served under a red light to the panelists, as many of the truffles had evidence of bloom due largely to oil that had leaked out via pinholes or surface cracks. This occurred on both sets of truffles with no clear indication that the filling recipe had impacted the degree or severity of the bloom. This also did not appear to affect the liking or purchase intent of the truffles. Once again, the panelists indicated a higher purchase intent for the high fat truffle over the low-fat truffle. Liking, on the other hand, was much closer after six months for both recipes, and there was not a significant difference in any of the liking attributes between the two samples. The reason for this shift was not entirely clear based on the verbatim comments, however based on the liking scores, the scores dropped overall for the high fat filling truffle, which may indicate that this filling recipe does not hold up as well as the low fat filling over time when it comes to overall sensory quality.

Figure 8. T=6 months Sensory Scores for the Almond Butter Truffles

T=6	Purchase Intent (Top 2 Box)	Overall Liking*	Overall Flavor Liking*	Filling Texture Liking*
Low Fat Truffle	53%	6.87ab	6.70ab	6.77ab
High Fat Truffle	63%	6.87ab	6.93ab	6.83ab

Experiment #3 - Impact of Percent Milkfat in the Retardation of Surface Bloom of Chocolate Bars Containing High Roast Diced Almonds

This experiment focused on isolating the impact of percent milkfat on the propensity of surface bloom only in chocolate bars. In order to achieve this, chocolate mass formulations representative of what would be commercially available were selected for this experiment. Anhydrous Milk Fat was chosen as the main contributor of milkfat in the dark chocolate masses, due to the availability and known efficacy of this ingredient on preventing surface bloom in dark chocolates. The four chocolate mass formulations are represented in the following table:

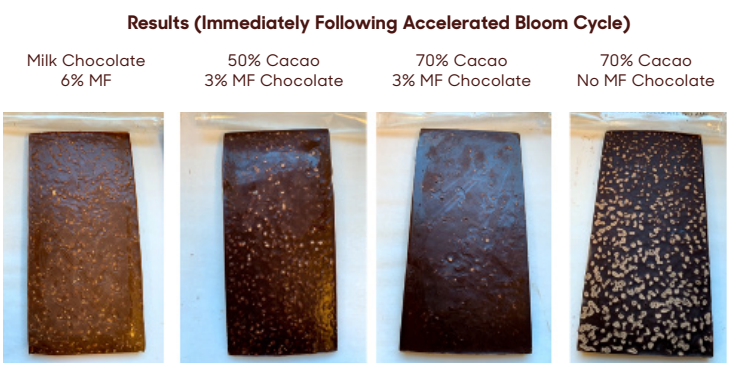
Figure 9. Test Design for Accelerated Bloom Study

Mass Name	Milk Chocolate	Dark Chocolate (Moderate cacao + AMF)	Dark Chocolate (High Cacao + AMF)	Dark Chocolate (High Cacao; no AMF)
% Cacao	~30%	~50%	~70%	~70%
% Milkfat	~6%	~3%	~3%	0%

Once again, 100 gram solid bars were produced using chocolate masses that had a temper slope of no less than -1.0 and no more than +1.0 to minimize the impact of under or over tempering on the outcome of the experiment. Each bar was produced with 18 percent inclusions (18 grams in the 100 gram bar) using the same lot of high roast diced almonds (roasting parameters here). These bars were then subjected to an accelerated bloom cycle using a Mini Incubator (Labnet International, Inc Woodbridge, NJ). Bars were placed into the incubator for four hours at 25°C, then the temperature was increased to 31°C for 12 hours. Afterwards, the bars were allowed to cool to 19°C, then placed in a 19°C chamber (Darwin Chambers, St Louis MO) and monitored weekly for 12 weeks.

Immediately following the accelerated bloom cycle, the high cacao chocolate with no AMF presented significant surface bloom on both faces of the bar, with the most severe presence on the back face of the bar.

Figure 10. Bar Visuals after Accelerated Bloom Cycle



All other bars did not experience any observable surface bloom immediately following the acceleration cycle. Bars were observed weekly for additional progression of bloom, but after 12 weeks, only the 70 percent cacao dark chocolate exhibited any surface bloom.

Figure 11. Bar Visuals After 12 Week Storage at 19°C

This study successfully showed that the addition of a bloom-retarding fat such as anhydrous milkfat can prevent surface bloom in a variety of chocolate formulations, regardless of cacao content. Additional work in this area could be explored with even higher percent cacao dark chocolate mass formulations to determine if there is a point where efficacy is diminished. Additionally, the percent of anhydrous milkfat added to the chocolate mass could be explored to determine the minimum percentage necessary in a formulation to achieve the desired effects.

Conclusion

In closing, this two-part whitepaper and research within indicates almonds and chocolate are a compelling combination for consumers, regardless of the form. The appearance of surface bloom as well as the degradation of flavor and texture of the almonds are the primary modes of failure in these types of confections.

In order to minimize or mitigate these issues, confectioners should carefully consider the almond form, the way it has been processed as well as the chocolate mass itself in order to ensure a high-quality consumer experience when formulating these products.

*http://www.agmcr.org Reprinted with Permission from Truly Good Foods (www.trulygoodfoods.com)

1. Global Chocolate Study, Sterling Rice Group, 2022.
2. Innova Market Insights, Global Chocolate Report, July 2021.
3. 2018 United Statues AAU: User Group Analysis, Almond Board of California, December 2018.
4. Innova Market Insights, 2021 Global New Product Introductions Report, May 2022.
5. Almond Butter Attitude & Usages. Sterling Rice Group, April 2018.
6. Review of the Sensory and Chemical Characteristics of Almonds (Prunus dulcis) Flavor L. Franklin, A. Mitchell. 2019

*Good news about fat. U.S. Dietary Guidelines recommend that the majority of your fat intake be unsaturated. One serving of almonds (28g) has 13g of unsaturated fat and only 1g of saturated fat.