Applications of ñuña beans in food science: literature review

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ABSTRACT

The ñuña bean (ÑB), is a variety of the common bean (*Phaseolus vulgaris* L.) that is native to the Andes. Although morphologically similar to other bean varieties, the ÑB is cooked using dry heat, which causes the cotyledons to expand to create a tasty, nutrient rich snack, which has been enjoyed by Andean people long before the Colombian exchange. In this literature review, we will discuss the history, preparation, morphology, nutrition, food science applications, and agronomy of ÑB. We will also use references that might not be well-known to the scientific community. Although not a commonly evaluated food, the ÑB seems poised to become more well-known and cultivated worldwide, thanks to progress in breeding ÑB cultivars that can be grown outside of its native range.

**Keywords:** *Phaseolus Vulgaris*, Popping Bean, Ñuña.
HISTORY OF THE ÑUÑA BEAN

Phaseolus vulgaris L., or the common bean, has an ancient history of cultivation, originating in two separate domestication events in Mexico and the Andes (SCHMUTZ, et al., 2014). One domesticated Andean variety of P. vulgaris is the Andean popping bean, also known locally as ñuña, numia, chekche, angel purutu, kopuru, or q’opuru bean (ÑB) (ZIMMERER, 1992). Although other beans are cooked by boiling, ÑB has traditionally been toasted on hot rocks, limestone, or sand (PEARSON, et al., 2012; NATIONAL RESEARCH COUNCIL, 1989; CRUZ, et al., 2009). Upon heating, the cotyledons of ÑB rapidly expand in an audible popping noise, like popcorn, producing an edible food with a distinct flavor.

ÑB observed in caves in the Ancash region of Peru suggest that they have been available to humans for at least 11,000 years (GONZÁLEZ, et al., 2014). Therefore, it is likely that native Andeans were cultivating ÑB, or at least harvesting wild popping beans, before the advent of pottery, as roasting on a heated stone was sufficient to make them palatable. Analysis of the multiple phaseolin types in ÑB and wild beans has also provided insight into the early phases of domestication of ÑB, suggesting early and widely applied domestication selection pressure in the eastern valleys of the Andes between 8° and 19° S (TOHME, et al., 1995). However, genetic analysis of Andean beans used today suggested that Andean landraces were derived from a small population, perhaps from eastern Bolivia or northern Argentina, as wild beans from Peru and Mesoamerica were less closely related to domesticated varieties (BEEBE, et al., 2001). Interestingly, ÑB cultivation was confined to South America, and did not spread to Mesoamerica where other beans were being cultivated. This is likely because of the photoperiod response difference in the different gene pools. Even today, both wild and domestic varieties of ÑB are sympatric in Peru and Bolivia (SANTA CRUZ and VÁSQUEZ, 2021).

In pre-Columbian Peru and Bolivia, ÑB was a staple crop along with quinoa and the potato. Because of its vine-like growing habit, the ÑB was cultivated with maize, which provided support for the vines, while the nitrogen fixing capability of ÑB roots fertilized the soil (NATIONAL RESEARCH COUNCIL, 1989). Although some crops from the Americas, like corn, lima beans, red beans, tomatoes, and potatoes gained worldwide cultivation during the Colombian exchange, popping beans remained largely unknown to the rest of the world. For example, one of the first modern non-Andean references to the ÑB is a US government publication from 1968 (HYLAND, 1968). However, popping beans were included in the historical record as early as the 1650s (TOHME, et al., 1995).

Nonetheless, ÑB is becoming more well-known in recent decades, with some suppliers in the USA, Canada, and Spain (CHILI SMITH FAMILY FOODS, 2021; TAMBO NATURAL FOODS, 2021; SUPERMERCADO LATINO FLORES, 2021), and more research is being
done to understand its popping, nutritional, agronomical, and commercialization properties. The persistent reasons for the rarity of ÑB outside of its native range are numerous, and include a high susceptibility to pests, erratic yields, asynchronous fruiting, climbing growth habit, and probably most importantly, a high sensitivity to day length. However, several of these problems are either mitigated or being addressed, which is making the crop more suitable for mechanized agriculture (NATIONAL RESEARCH COUNCIL, 1989; EHLERS and STERNER, 1999). For example, acclimatized ÑB has been cultivated as far north as Wyoming (BOLAK, et al., 2021), Colorado (PEARSON, et al., 2012), and Washington (NATIONAL RESEARCH COUNCIL, 1989).

At present, ÑB is mostly cultivated in its native mountainous range, from Cajamarca, Peru to Chuquisaca, Bolivia at elevations between 1900 and 2900 m (GUTIERREZ, 2011; TOHME, 1995; ZIMMERER, 1992). Production in Peru varied between 1218 and 1831 metric tons annually between 2013 and 2019 (INEI, 2021). There are over 100 different varieties of Andean ÑB cultivated today, which have different yields, grain size and color, maturation rate, and agro-industrial potential (SANTA CRUZ and VÁSQUEZ, 2021). ÑB remains an important food crop in several South American countries, especially Peru, Bolivia, and Ecuador, where it is widely available as a snack. (PIETRYSIAK, et al., 2020).

### ÑUÑA BEAN (ÑB) PREPARATION

Unlike other beans, popping varieties are not boiled in water until soft for consumption. Boiling ÑB takes twice as long to cook as other beans and produces a rather grainy, fibrous, and unpalatable product. Boiled ÑB also forms a watery broth, in contrast to other dry beans, which tend to disintegrate to form a thicker broth (VAN BEEM, KORNEGAY and LAREO, 1992). Instead ÑB are cooked using dry heat. Toasting was a familiar cooking technique to ancient Andeans, as other grains, like popcorn, were cooked this way (GONZÁLEZ, et al., 2014). Traditionally, this is done by parching on hot stones, in hot sand or limestone, or by using an earthenware container heated by fire (ZIMMERER, 1992). Important advantages of this cooking method include reduced fuel use, simple cooking technique, and short preparation time. These are especially important at high elevations, where wood is scarce and water boils at lower temperatures, causing boiled beans to cook at a slower rate. More modern preparation methods include microwaving for 2-4 minutes (TOHME, et al., 1995; PEARSON, et al., 2012), stirring in a saucepan with a small amount of oil or fat, or using an air popper (BOLAK, et al., 2021).

Dry heating the beans causes a buildup and then rapid release of pressurized steam trapped within and between the mesophyll cells of the cotyledons (SPAETH et al., 1989). This causes the cotyledons to expand by 30-75% in an audible “pop”, as they burst out of the
seed coat, or testa (TOHME, et al., 1995; CRUZ, et al., 2009). The cotyledons may expand uniformly or crack into small pieces. The testa usually remains attached but can be removed manually. Popping depends on seed moisture, cooking time, and cooking temperature. Optimum popping conditions for ŃB are seed moistures below 5%, temperatures of 244 °C or higher, and popping time of 90 s. These conditions can achieve a popping percentage of 90%. Too much moisture decreases popping percentage, likely because of steam channelling and adiabatic cooling resulting from steam escape. Popping percentage increases with temperature, but a balance must be struck between higher temperature and cooking time so that the popped beans do not become overcooked (VORWALD and NEINHUIS, 2009). Popping percentage also seems to vary with storage time, with 90% popping immediately after harvest, 100% popping 6 months after harvest, and only 87% popping after a year (BOLAK, et al., 2021); however, storage conditions, especially controlling moisture, is likely important in improving and maintaining popping ability for long-term storage.

The resulting product can be eaten with or without the remaining seed coat and has a distinct taste like popcorn, toasted soy nuts, or peanuts with a texture similar to malted milk ball (CRUZ, et al., 2009; PEARSON, et al., 2012; ZIMMERER, 1992). Throughout its native range, dried ŃB is widely available in traditional markets; toasted portions often sold by street vendors and in traditional markets where people gather. Toasted ŃB is frequently eaten as a lightweight, inexpensive, easily transportable, nutritious, and filling snack or side dish. It is also appealing because it does not spoil easily (CRUZ, et al., 2009; NATIONAL RESEARCH COUNCIL, 1989; ZIMMERER 1992). Some have reported flatulence upon consumption, but this doesn’t seem to be any greater than that associated with other bean varieties (ZIMMERER 1992; NATIONAL RESEARCH COUNCIL, 1989).

■ PLANT AND BEAN MORPHOLOGY

There is a wide variety of ŋuña ecotypes: 121 varieties have been catalogued in Peru alone (SANTA CRUZ and VÁSQUEZ, 2021). Furthermore, TOHME, et al. (1995) evaluated 305 records of ŃB, of which 283 are from Peru and 22 are from Bolivia. The differences between ŃB ecotypes are minimal when compared in terms of plant and seed morphology to other *P. vulgaris* varieties but distinguish themselves from other beans by their popping ability.

The ŋuña plant is an herbaceous annual that produces climbing pubescent herbaceous stems, with buds appearing in the axils that later differentiate into lateral branches, inflorescences, and/or compound leaves. The plant is an aggressive climber and exhibits indeterminate growth (growth habit IVb); a mature plant can have stems that exceed 4 meters, but some type of support is required. ŃB continues to flower and produce pods throughout its lifetime, but it will not flower when the photoperiod exceeds 12 ½ hours (CRUZ, et al. 2009;
Flowers are self-fertilizing and hermaphroditic and develop in a cluster inflorescence. The fruit, originating from the ovary, is a pod that is usually glabrous or subglabrous with very small hairs and contains approximately 5-6 seeds (SANTA CRUZ and VÁSQUEZ, 2021).

Pods tend to be distributed throughout the plant, in the basal, medial, and apical regions. Plants typically flower 100-130 days after planting, and harvest usually takes place between 220 and 240 days after planting. The plant grows well between 10 and 25 °C, but the vegetative growth phase is favored at lower temperatures. Resistance to common agricultural pest fungi, such as *Uromyces phaseoli*, *Erysiphe polygoni*, and *Colletotrichum lindemuthianum* has been shown to vary widely in different varieties. It should also be protected from earthworms. Crop yields are between 500 and 1500 kg/ha, but one of the limiting yield factors is loss of flowers and immature fruits, as 70 to 80% of buds do not result in mature fruit (CRUZ et al., 2009; SANTA CRUZ and VÁSQUEZ, 2021).

As with other bean species, the roots of the plant produce nodules which harbor symbiotic nitrogen-fixing bacteria, especially *Rhizobium*. Inoculating ÑB with *Rhizobium phaseoli* produces a statistically significant larger number of pods per plant, beans per pod, dry seed weight, and overall crop yields when compared with uninoculated cultivation. Uninoculated plants fertilized with urea recover some yield characteristics, but these still tend to be slightly lower than that of inoculated plants (CUADROS and GÓMEZ, 2016).

Perhaps the greatest variation between ÑB varieties can be seen when the seeds are compared. ÑB seed can have a wide variation in color and shape, but, like other beans, the seeds are surrounded by a testa and contain two cotyledons, an embryo, and a hilum from where it was attached to the ovary. Seed shape can be elongated to round, with wide range of colors, which can be solid, including light gray, tan, black, brown, red, and white. There are even some purple varieties. Other varieties have spotted or mottled surfaces with distinct black, orange, purple, or red on a white or light grey background. Seed mass between varieties varies from between about 0.3 g up to about 1.0 g per seed. Seed size is also related to expansion upon cooking; larger grains have a greater expansion (CRUZ, 2009; PESANTES and RODRÍGUEZ, 2013; SANTA CRUZ and VÁSQUEZ, 2021; VAN BEEM, KORNEGAY and LAREO, 1992).

## NUTRITIONAL EVALUATION

As with other beans, ÑB contain both nutritional and antinutritional factors. Proximate analysis of ÑB has revealed a protein content of approximately 20%, which is somewhat lower than other bean varieties. ÑB has also been shown to be comparatively deficient in phosphorus (0.36%), iron (66.2 ppm), and boron (7.2 ppm). This is compensated by a higher
level of starch (41%), amylose (18%), and copper (8.31 ppm) than other beans. Levels of potassium (1.43%), calcium (0.116%), magnesium (0.175%), sodium (18.0 ppm), manganese (4.86 ppm), and zinc (26.02 ppm) were similar to that of dry beans (VAN BEEM, KORNEGAY and LAREO, 1992). A second proximal analysis of Peruvian ÑB varieties “pava” and “mani” revealed 12.3% humidity, 3.5% ash, 1.3% fat, 3.4% fiber, 18.9% protein, and 61% carbohydrates for “pava”, and 14.0% humidity, 3.3% ash, 1.4% fat, 3.2% fiber, 20.2% protein, and 58% carbohydrates for “mani” (CASTILLO, 2013). Whole ÑB flour was found to be 8.86% moisture, 21.71% protein, 60.80% starch, 3.95% crude fiber, 2.11% crude fat, and 2.61% ash (PIETRYSIAK, et al., 2020), while BALTODANO (2016) found 10.5% moisture, 17.8% protein, and 5.4% ash for a similar ÑB flour. The fatty acids present in ÑB are predominately polyunsaturated (63%), followed by saturated and monounsaturated fatty acids (22 and 11% respectively) (BOLAK, et al., 2021). Digestibility of toasted ÑB is slightly lower than boiled dry beans (NATIONAL RESEARCH COUNCIL, 1989; SPAETH et al., 1989), but toasted dry beans have the same digestibility of toasted ÑB. The texture and unique flavor of ÑB may be related to its high starch content (VAN BEEM, KORNEGAY and LAREO, 1992). Other nutritional components of ÑB are expected to be similar to related dry bean cultivars.

One important factor to be considered with bean consumption is that raw beans contain lectin, a toxin that can cause nausea, diarrhea, and vomiting. Cooking, such as boiling, for several minutes inactivates these toxins, and the dry heating methods for cooking ÑB also have a similar effect, with cooking times greater than 90 seconds sufficient to deactivate lectin (VAN BEEM, KORNEGAY and LAREO, 1992). Likewise, heating also may increase bioavailability of nutrients by inactivating hemagglutinins and trypsin inhibitors (THARANATHAN and MAHADEVAMMA, 2003). The other protein of concern in ÑB is phaseolin, which can inhibit α-amylase, which can decrease absorption of carbohydrates. Phaseolin is likewise deactivated by dry heating for 90 seconds. Tannins may or may not be present in the testa depending on the color of the variety but can be eliminated by removing the testa after toasting (VAN BEEM, KORNEGAY and LAREO, 1992). A second study on tannins in ÑB found relatively low tannin content in ground ÑB flour, indicating that this antinutritional factor has a small impact on the digestibility of ÑB and can likely be avoided by using white or light-colored beans (MELO and LIGARRETO, 2010).

### FOOD SCIENCE USE

Given that consumption of beans is associated with decreased risks of chronic diseases such as coronary heart disease, obesity, diabetes, and some types of cancer, using beans as high-protein additives in processed foods may have some health benefits. Additionally, amylose, fiber, and resistant starches present in processed beans have been associated with
improved digestive health (THARANATHAN and MAHADEVAMMA, 2003). Aside from being nutritious, ÑB has a unique nutty flavor, which adds a taste dimension as a food additive (PIETRYSIAK, et al., 2020). The water absorption capacity of ÑB seed was approximately 100%, which is about double what was measured for other non-popping dry bean varieties. It is likely that the elevated starch and fiber content of ÑB contributes to this increased water absorption ability (RODRÍGUEZ, GUTIÉRREZ, and PRETEL, 2014).

Nearly pure (~90%) protein extracts can be obtained from ÑB through a straightforward extraction and precipitation process; a defatting step is unnecessary due to the low-fat content of raw ÑB. The amino acid profile of ÑB protein extract is very similar to that of other dry beans and legumes, in that it has high levels of glutamine and glutamic acid, asparagine and aspartic acid, leucine, lysine, phenylalanine, and serine and is deficient in sulfur-containing amino acids (methionine and cysteine). This high similarity between and among ÑB protein and other bean varieties holds true over place and time (RODRÍGUEZ, GUTIÉRREZ and PRETEL, 2014; VARGAS-SALAZAR, et al., 2020). ÑB protein isolates have good functional properties: when extracted at pH 8 it has a water absorption capacity of 1.52 g water / g sample, oil absorption capacity of 1.13 g oil / g sample and foam formation capacity of 29.97% with foam stability of 40% at 60 minutes (RODRÍGUEZ, GUTIÉRREZ and PRETEL, 2014). It was less efficient at foaming or increasing viscosity in solution than other similar protein extracts (VARGAS-SALAZAR et al., 2020). Therefore, the unique properties of ÑB protein extract would make it an easily extractable protein source for applications where foaming and high viscosity is undesirable, as in protein shakes and fortified drinkable yogurts, milk, dairy and bakery products, and weight-loss supplements (RODRÍGUEZ, GUTIÉRREZ and PRETEL, 2014; VARGAS-SALAZAR, et al., 2020). ÑB protein hydrolysate may also have antibacterial properties that can be exploited to preserve raw meat. Various hydrolysis degrees were challenged against Staphylococcus aureus, and it was found that a moderate degree of alkaline protease-mediated hydrolysis (3% at 15 minutes) gave the best antimicrobial activity (BALTODANO, 2016). It remains to be determined what peptides are responsible for this activity.

Extrusion is a frequently used process to make breakfast cereal, pasta, and snack foods, but the ingredients used in this process are frequently nutrient deficient and calorie dense. Adding bean flour to extruded products or using it for new products can improve their nutrient density and nutritional profile, but this has been difficult because high-protein additives negatively affect expansion and texture. Whole ÑB flour seems to be especially well-suited to this process because it possesses both superior expansion characteristics and high nutritional content. It was found that ÑB flour exhibited satisfactory expansion under comparatively lower barrel temperatures and moisture content and that product characteristics were impacted
the most by water content, which can be optimized easily (PIETRYSIAK, et al., 2020). The economic aspects of using extrusion to prepare a flake cereal based on ÑB and cocoa flour with honey was evaluated extensively, with favorable acceptance (CUETO, 2019). ÑB flour can be used in the preparation of pasta, which can increase its nutritional value by complementing the amino acid profile of wheat protein, as well as increasing mineral and dietary fiber content. ÑB flour substitution of whole wheat flour up to 10% does not show a significant effect on the noodles produced (BERNA, 1995), but the appropriate concentration should be determined for each application so that it does not negatively influence the taste or acceptability of the final products. Thus, ÑB represents an attractive high protein and fiber feedstock for appealing extruded food products, like breakfast cereals and pasta.

TENA (2021) evaluated the functional properties of flour prepared from “blanca nube” ÑB without testa for use in processed foods. Water absorption capacity at pH 3 and 5 was 104.97 and 100.97%; but in 0.1M and 1M NaCl solution, the water absorption capacity was increased to 117.97 and 131.08%. Oil absorption was 0.96 g oil / g sample. These properties indicate that the flour can be used as fortifying agents for drinks or soups. The foaming capacity at pH 3 and 5 were 41.51% and 47.78%. The gelling capacity was weak at concentrations higher than 18% at pH 7; at lower concentrations there was no gelation. These results are similar for isolated ñuña protein reported by VARGAS-SALAZAR, et al., (2020).

Given the characteristics of popped ÑB, other applications in processed foods are likely. Additional applications include cereal bars and snack nut mixes. For example, a snack mix of toasted ÑB and oca (Oxalis tuberosa) flakes (HARO, et al., 2018) and popped ÑB cotyledons coated with sugary flavoring (MARTÍNEZ, 1986) have been satisfactorily evaluated as potential commercial products.

### AGRONOMY ASPECTS

Perhaps the most common agronomy research in both Andean countries and elsewhere on the ÑB is the collection and identification of cultivars planted in its native range suitable for commercial exploitation. Parameters commonly studied are seed weight, pod size, yield, pest resistance, and maturation times (BOLAK, 2021; CASTILLO, 2013; CRUZ, et al., 2009; CUADROS and GÓMEZ, 2016; GONZÁLEZ, et al., 2014; GUTIERREZ, 2011; PEARSON, et al., 1989; PESANTES and RODRÍGUEZ, 2013; SANTA CRUZ and VÁSQUEZ, 2021; SPAETH et al., 1989; TOHME, et al., 1995; ZIMMERER, 1992).

A 2021 study from the Peruvian National Institute of Agrarian Innovation evaluated 121 cultivars and concluded that 11 had excellent agro-industrial fitness (SANTA CRUZ and VÁSQUEZ, 2021), such as “negra grande”, “vaquita”, “huevo de vishlan”, “granate”, “chocolate”, “ñuña roja”, and “pava”. Of these, the “pava” has received some attention by researchers
The “pava” bean is light gray with black spots with an average weight ranging from 0.6 to 1.0 g, depending on subtype and local characteristics (SANTA CRUZ and VÁSQUEZ, 2021). Seed shape is oval to round, depending on the type. It has low to medium susceptibility to fungal pests, requires about 230 days from planting to harvest, and yields between 500 and 1200 kg/ha.

Additional research is being conducted to make ÑB cultivars that are commercially relevant in temperate regions. The photoperiod sensitivity and long maturation times of native ÑB precludes its growth in temperate regions which have long summer days and a short growing season. Additionally, the growth habit and nonsynchronous fruiting of ÑB precludes the use of mechanical harvesters. Thus, finding ways to add commercial characteristics to ÑB, adding popping ability to commercial varieties, and understanding the heritability of popping, seed, and pod characteristics has received considerable attention. This research also has the secondary advantages of providing a source of genetic diversity that may be exploited to improve present bean crops, increasing understanding of the genetics of popping ability and photoperiod sensitivity, and identifying ÑB with particularly good popping, flavor, and texture characteristics (CAMPA, et al., 2011; GONZALEZ, et al., 2014; MARMOLEJO, 2018; YUSTE-LISBONA, et al., 2012; YUSTE-LISBONA, et al., 2014; YUSTE-LISBONA, et al., 2014b; VORWALD and NEINHUIS, 2009b). One approach that can both improve ÑB characteristics and enhance genetic diversity in other bean varieties is crossing ÑB with more commercially suitable bean varieties to either maintain genetic diversity or impart popping ability.

Simple crossing of ÑB with a red kidney cultivar did not yield desirable popping percentage although some lines were better adapted to temperate climates and mechanical harvest, so additional backcrossing was evaluated (OGG, BRICK and PEARSON, 2008). PEARSON, et al., 2012 further built on this early work in four experimental farms in Colorado by including a backcross with the ÑB parent to increase popping percentage in lines with determinate growth and early (>105 d) plant maturity. Popping percentage varied between 81 and 17%, and yield varied between 859 to 2151 kg/ha, and average seed weight ranged from 0.3 to 0.5 g. Additionally, these new cultivars are susceptible to several common viruses and fungi, which will require additional breeding to address.

Heritability of popping characteristics was evaluated in a temperature-adapted, photoperiod insensitive strain of ÑB to understand the genetic relationship between seed characteristics like weight, coefficient of expansion, and popping percentage (VORWALD and NEINHUIS, 2009b). This strain was selected through a cross and backcross of a ÑB with a dry bean suited for agriculture followed by pedigree selection among and within inbred-backcross
families. It was observed that photosensitivity appeared to segregate as a single recessive gene. Furthermore, the only significant phenotypic correlation among traits tested (color, weight, popping percentage, and coefficient of expansion) was between popping percentage and coefficient of expansion, which are both desirable characteristics. Therefore, these traits can be selected together during crop improvement without affecting seed weight.

GONZALEZ, et al., 2014 evaluated the genetics of popping characteristics by performing a series of crosses and backcrosses with a commercial variety of bean, revealing that the genetic basis of the popping phenotype is complex and involves multiple genetic factors, heterosis and epistasis, but it is possible to transfer this ability to new cultivars. A simplistic additive-dominance model did not explain most popping traits observed. Rather, multiple types of gene action are important for the various aspects of popping ability, such as dimensions of popped seeds, expansion coefficient and percentage of popping. Nonetheless, understanding these genetics will likely improve breeding programs to create cultivars with popping and other desirable characteristics.

The economic potential of popping beans has not escaped the interest of industry. Indeed, two patents were granted in the USA for cultivars of popping beans with early maturity, bush type growth habit, synchronous fruiting, and photoperiod insensitivity (EHLERS and STERNER, 2000; EHLERS and STERNER, 2002). The patent cites the use of 33 Andean NB varieties as parent germplasm. Beans with desirable popping characteristics were to be created by crossing and backcrossing NB with common beans. The granting of these patents has created consternation among traditional farmers and scientific breeders of these beans, resulting in several questions into the nature of patents, biopiracy, and appropriation of traditional foodstuffs (GEPTS, 2004; PALLOTINI, et al., 2004; RAFI, 2001). However, the patents were not rescinded.

Taken together, it appears that new popping bean varieties are becoming well-suited for expansion to commercial agriculture in other parts of the world, making possible widespread use of this nutritious bean. It is likely only a matter of time and consumer education before NB will be frequently consumed worldwide, as popping bean varieties already exist that can grow in temperate climates.

■ FINAL CONSIDERATIONS

Although other crops of Andean origin, like the tomato, potato, and quinoa have a high level of world-wide acceptance, the NB is not widely known outside of its native range. This provides both a challenge and an opportunity for agronomists and food scientists. Significant progress has been made to produce new cultivars that allow for mechanized agriculture in temperate regions, but still more progress needs to be made to produce reliable high-yielding
cultivars resistant to common pests. Once the production difficulties are mitigated, it seems that the food science applications for ÑB will be numerous, such as a high protein additive to beverages and extruded products, a food preservative, as well as commercialization of the popped product, which may be included in snack mixes, or coated, to create other snack foods. It is likely that the ÑB will become much more commonly known in the future.

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