Convolution of Two Weighted Orlicz Spaces on Hypergroups

Convolución de dos espacios de Orlicz con pesos sobre hipergrupos

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Abstract. Let $K$ be a locally compact hypergroup. In this paper, among other results we give a sufficient condition for the inclusion $L^\Phi_1(K) \ast L^\Phi_2(K) \subseteq L^\Phi_1(K)$ to hold. Also, as an application, we provide a new sufficient condition for the weighted Orlicz space $L^\Phi_w(K)$ to be a convolution Banach algebra.

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1. Introduction

For each locally compact group $G$ with a sub-multiplicative mapping $w$, $L^1(G)$ and $L^1_w(G)$ are convolution Banach algebras. If $1 < p < \infty$, then it is well-known that the Lebesgue space $L^p(G)$ is a convolution Banach algebra if and only if $G$ is compact [15]. But the situation for weighted ones is different: a weighted Lebesgue space $L^p_w(G)$, $p > 1$, can be a convolution algebra for some non-compact groups $G$. Yu. N. Kuznetsova (see [8, 9]) gave some conditions
under which the weighted Lebesgue space $L^p_w(G)$ is a convolution Banach algebra (see also [1]). In [16], this topic was studied for weighted Lebesgue spaces on locally compact hypergroups. Since Orlicz spaces are extensions of Lebesgue spaces, it is natural to study the same question about Orlicz spaces and it has been the motivation for many papers. For example, H. Hudzik, A. Kamiska and J. Musielak in [5, Theorem 2] proved that if $\Phi$ is a Young function with $\Phi \in \Delta_2$, then $L^\Phi(G)$ is a Banach algebra under convolution if and only if $\lim_{x \to 0^+} \frac{\Phi(x)}{x} > 0$ or $G$ is compact.

In [17] some necessary and sufficient condition is given for an Orlicz space $L^\Phi(G)$ to be a convolution Banach algebra, where $G$ is a compactly generated second countable abelian group and $\Phi$ belongs to a special class of Young functions.

A. Osançlıol and S.¨Oztop in [10] introduced and studied the weighted Orlicz algebras on locally compact groups, and proved that, if $L^\Phi_w(G) \subseteq L^1_w(G)$, then $L^\Phi_w(G)$ is a convolution Banach algebra. In [11], these results were extended to the hypergroup case. T.S. Quek and L.Y.H. Yap in the nice paper [12] showed that the generalized $L^p$-conjecture is true for locally compact abelian groups. More precisely, they proved that if $G$ is a locally compact abelian group and $1 < p, q < \infty$, then the inclusion

$$L^p(G) * L^q(G) \subseteq L^p(G)$$

holds if and only if $G$ is compact [12, Corollary 1.4]. In this paper we give a characterization for the existence a constant $k > 0$ such that $\|f * g\|_{\Phi_1,w} \leq k\|f\|_{\Phi_1,w} \|g\|_{\Phi_2,w}$ for all $f \in L^\Phi_1(K)$ and $g \in L^\Phi_2(K)$, where $K$ is a locally compact hypergroup, $\Phi_1$ and $\Phi_2$ are Young functions with $\Phi_1 \in \Delta_2$, and $w$ is a weight function on $K$. Since hypergroups are extensions of locally compact groups and Orlicz spaces are in turn extensions of Lebesgue spaces, this result is a weighted version of the mentioned fact [12, Corollary 1.4], to a much larger setting. As an application, we give a sufficient condition for the inclusion $L^\Phi_1(K) * L^\Phi_2(K) \subseteq L^\Phi(K)$ to hold. In particular, whenever $\Phi_1 = \Phi_2 = \Phi$, we provide a condition for the weighted Orlicz space $L^\Phi(K)$ to be a Banach algebra. This paper is organized as follows. In section 2, we recall some definitions, notations and facts about locally compact hypergroups and Orlicz spaces, which we will need in the sequel. The main results are in section 3.

2. Preliminaries

2.1. Locally Compact Hypergroups

Let $K$ be a locally compact Hausdorff space. We denote the space of all bounded Radon measures on $K$ by $\mathcal{M}(K)$, and the set of non-negative elements of $\mathcal{M}(K)$ is denoted by $\mathcal{M}^+(K)$. The support of each measure $\mu \in \mathcal{M}(K)$ and the Dirac measure at the point $x \in K$ are denoted by $\text{supp}\mu$ and $\delta_x$, respectively.
Definition 2.1. Let $K$ be a locally compact Hausdorff space with the following property:

1. there is a mapping $\ast : \mathcal{M}(K) \times \mathcal{M}(K) \to \mathcal{M}(K)$ (called convolution) such that $(\mathcal{M}(K), \ast, +)$ is a complex Banach algebra;

2. for each $\mu, \nu \in \mathcal{M}^+(K)$, $\mu \ast \nu$ is a non-negative measure in $\mathcal{M}(K)$ and the mapping $(\mu, \nu) \mapsto \mu \ast \nu$ from $\mathcal{M}^+(K) \times \mathcal{M}^+(K)$ into $\mathcal{M}^+(K)$ is continuous, where $\mathcal{M}^+(K)$ is equipped with the cone topology;

3. for all $x, y \in K$, $\delta_x \ast \delta_y$ is a compact supported probability measure;

4. the mapping $(x, y) \mapsto \text{supp}(\delta_x \ast \delta_y)$ from $K \times K$ into the space of all non-empty compact subsets of $K$, equipped with the Michael topology, is continuous;

5. there is an element $e$ (called the identity) such that for each $x \in K$, $\delta_e \ast \delta_x = \delta_x = \delta_x \ast \delta_e$;

6. there is a homeomorphism $x \mapsto x^{-}$ from $K$ onto $K$ (called involution) such that for each $x, y \in K$ we have $(x^{-})^{-} = x$ and $(\delta_x \ast \delta_y)^{-} = \delta_{y^{-}} \ast \delta_{x^{-}}$, where for each $\mu \in \mathcal{M}(K)$ and Borel set $E \subseteq K$, $\mu^{-}(E) := \mu(\{x^{-} : x \in E\})$;

7. for each $x, y \in K$, $e \in \text{supp}(\delta_x \ast \delta_y)$ if and only if $x = y^{-}$.

Then, $K \equiv (K, \ast, \cdot^{-}, e)$ is called a (locally compact) hypergroup.

A non-zero non-negative Radon measure $\mu$ on a hypergroup $K$ is called a left Haar measure if for each $x \in K$, $\delta_x \ast \mu = \mu$. Throughout, we assume that $(K, \ast, \cdot^{-}, e)$ is a locally compact hypergroup with a left Haar measure $\mu$. Also, the integrals without any specified measure are considered with the given left Haar measure $\mu$. Any locally compact group equipped with the usual convolution and the inverse mapping as involution is a hypergroup. In general, a topological space can be a hypergroup without necessarily an action between its elements. See the book [2] and the papers [3, 6] and [4, 19] for more examples and details about this structure.

For each measurable function $f : K \to \mathbb{C}$ and $x, y \in K$ we put

$$f(x \ast y) := \int_K f(t) d(\delta_x \ast \delta_y)(t).$$

Also, we denote $L_x f(y) := f(x^{-} \ast y)$. By [6, Theorem 5.1D], for each measurable functions $f, g : K \to \mathbb{C}$, if either $f$ or $g$ is $\sigma$-finite with respect to $\mu$, then

$$\int_K f(y \ast x) g(x) \, dm(x) = \int_K f(x) g(y \ast x) \, dm(x). \quad (2)$$
The **convolution** of $f$ and $g$ is defined by

$$(f * g)(x) := \int_K f(y)g(y + x) \, dm(y), \quad (x \in K),$$

whenever this integral exists.

### 2.2. Orlicz Spaces

The main references for Orlicz spaces are the books [13, 14]. Before giving the definition of an Orlicz space one needs to introduce Young functions.

A convex even mapping $\Phi : \mathbb{R} \to [0, \infty)$ is called a **Young function** if $\Phi(0) = \lim_{x \to 0} \Phi(x) = 0$ and $\lim_{x \to \infty} \Phi(x) = \infty$.

The **complementary** of a Young function $\Phi$ is defined by

$$\Psi(x) := \sup\{y|x| - \Phi(y) : y \geq 0\}, \quad (x \in \mathbb{R}).$$

In this case, $(\Phi, \Psi)$ is called a **complementary pair**.

We say that a Young function $\Phi$ satisfies $\Delta_2$-**condition** (and write $\Phi \in \Delta_2$) if for some constants $c > 0$ and $x_0 \geq 0$,

$$\Phi(2x) \leq c \Phi(x), \quad (x \geq x_0).$$

Let $\Phi$ be a Young function with the complementary $\Psi$. The set of all Borel measurable functions $f : K \to \mathbb{C}$ such that for some $\alpha > 0$,

$$\int_K \Phi(\alpha|f(x)|) \, dm(x) < \infty,$$

is denoted by $L^\Phi(K)$. We identify two elements of $L^\Phi(K)$ if they are equal a.e. For each $f \in L^\Phi(K)$ we define

$$\|f\|_\Phi := \sup\left\{ \int_K |fv| \, dm : \int_K \Psi(|v|) \, dm \leq 1 \right\}.$$ 

Then, $\|\cdot\|_\Phi$ is a complete norm on $L^\Phi(K)$ and the pair $(L^\Phi(K), \|\cdot\|_\Phi)$ is called an **Orlicz space**; see [13, Chapter III, Proposition 11].

For each $1 < p < \infty$, the function $\Phi_p$ defined by $\Phi_p(x) := |x|^p$ for all $x \in \mathbb{R}$, is a Young function and the Orlicz space $L^{\Phi_p}(K)$ is the same as the usual Lebesgue space $L^p(K)$. Orlicz spaces, as extensions of Lebesgue spaces, have been studied in several recent decades; see for example [7], a recent paper about Orlicz spaces on locally compact hypergroups.

Set

$$N_\Phi(f) := \inf\left\{ \lambda > 0 : \int_K \Phi\left(\frac{1}{\lambda} |f(x)|\right) \, dm(x) \leq 1 \right\}, \quad (f \in L^\Phi(K)).$$
Then, $\mathcal{N}_\Phi(\cdot)$ is also a norm on $L^\Phi(K)$ and for each $f \in L^\Phi(K)$,

$$\mathcal{N}_\Phi(f) \leq \|f\|_{\Phi} \leq 2\mathcal{N}_\Phi(f).$$

If $f \in L^\Phi(K)$ and $g \in L^\Psi(K)$, then by [13, Page 58] we have

$$\int_K |f(x)g(x)| \, dm(x) \leq 2\|f\|_{\Phi} \|g\|_{\Psi},$$

which is the Hölder’s inequality for Orlicz spaces.

Any continuous function $w : K \to (0, \infty)$ is called a weight, and we write $w^{-1} := \frac{1}{w}$. The space of all measurable functions $f$ on $K$ such that $wf \in L^\Phi(K)$ is called the weighted Orlicz space and is denoted by $L^\Phi_w(K)$. For each $f \in L^\Phi_w(K)$ we put $\|f\|_{\Phi,w} := \|wf\|_{\Phi}$. The space $(L^\Phi_w(K), \|\cdot\|_{\Phi,w})$ is a Banach space. The weighted Orlicz space $L^\Phi_w(K)$ is called a convolution Banach algebra if there exists a constant $c > 0$ such that for all $f, g \in L^\Phi_w(K)$,

$$\|f * g\|_{\Phi,w} \leq c \|f\|_{\Phi,w} \|g\|_{\Phi,w}.$$

If $\Phi \in \Delta_2$, then just as in the non-weighted case [13, Page 111] (see also [10]), the dual of the Banach space $L^\Phi_w(K)$ equals $L^\Psi_{w^{-1}}(K)$ via the duality formula

$$\langle f, g \rangle = \int_K f(x)g(x) \, dm(x).$$

### 3. Main Results

For each pair $x, y \in K$ we define

$$\Omega(x, y) := \frac{w(x * y)}{w(x)w(y)}.$$

Also, for each Borel measurable functions $f, g : K \to \mathbb{C}$ we denote

$$\Lambda_w(f, g) := \int_K f(x)g(x)w(x) \, dm(x),$$

whenever this integral exists.

In the sequel, sometimes we specify the position of a variable by $(\cdot)$. We define

$$\Lambda_w \left( g, L(\cdot) \left( \frac{f}{w} \right) \right)(x) := \Lambda_w \left( g, L_x \left( \frac{f}{w} \right) \right), \quad (x \in K).$$

Comparing with [12, Corollary 1.4] (see the inclusions (1) and (12)), the following theorem and its corollary can be considered as a positive solution for the generalized weighted $L^p$-conjecture for Orlicz spaces, although it is stated on the more general framework of hypergroups.

Revista Colombiana de Matemáticas
Theorem 3.1. Let $K$ be a locally compact hypergroup, and $\Phi_1$ and $\Phi_2$ be Young functions with $\Phi_1, \Psi_1 \in \Delta_2$, where $\Psi_1$ is the complementary of $\Phi_1$. Let $w$ be a weight function on $K$. Then, the following are equivalent:

(1) There is a constant $k > 0$ such that for each $f \in L^\Phi_1(K)$ and $g \in L^\Phi_2(K)$,
$$\|f \ast g\|_{\Phi_1, w} \leq k\|f\|_{\Phi_1, w} \|g\|_{\Phi_2, w}.$$ 

(2) There is a constant $c > 0$ such that for each $f \in L^\Phi_2(K)$ and $g \in L^\Psi_1(K)$, we have
$$\Lambda_w \left( g, L_{\lambda}(\frac{f}{w}) \right) \in L^{\Psi_1}_{w^{-1}}(K)$$
and
$$\left\| \Lambda_w \left( g, L_{\lambda}(\frac{f}{w}) \right) \right\|_{\Phi_1, w^{-1}} \leq c\|f\|_{\Phi_2} \|g\|_{\Psi_1}.$$ 

Proof. (1)$\Rightarrow$(2): Note that in this proof, we will use the identity $(L^\Phi_1(K))^* \cong L^{\Psi_1}_{w^{-1}}(K)$. For this step, we use the assumption that $\Phi_1 \in \Delta_2$, but we do not require the assumption for $\Phi_2$.

Suppose that there is a constant $k > 0$ such that for each $h_1 \in L^\Phi_1(K)$ and $h_2 \in L^\Phi_2(K)$,
$$\|h_1 \ast h_2\|_{\Phi_1, w} \leq k\|h_1\|_{\Phi_1, w} \|h_2\|_{\Phi_2, w}.$$ 

(6) Let $f \in L^\Phi_2(K)$ and $g \in L^\Psi_1(K)$. Then by (1), for each $h \in L^\Phi_1(K)$ we have
$$\left\| \frac{h}{w} \ast \frac{f}{w} \right\|_{\Phi_1} = \left\| \frac{h}{w} \ast \frac{f}{w} \right\|_{\Phi_1, w} \leq k\left\| \frac{h}{w} \right\|_{\Phi_1, w} \left\| \frac{f}{w} \right\|_{\Phi_2, w} < \infty$$ 
(7) since $\frac{h}{w} \in L^\Phi_1(K)$ and $\frac{f}{w} \in L^\Phi_2(K)$. This implies that $(\frac{h}{w} \ast \frac{f}{w})w \in L^\Phi_1(K)$.

We define the mapping $T$ on $L^\Phi_1(K)$ by
$$T(\varphi) := \int_K \Lambda_w \left( g, L_y(\frac{f}{w}) \right) \varphi(y) \, dm(y), \quad (\varphi \in L^\Phi_1(K)).$$ 
(8)
Then, by the Fubini’s Theorem and the Hölder’s inequality (3), for each \( h \in L_{\Phi_1}^1(K) \) we have
\[
\left| T \left( \frac{h}{w} \right) \right| = \left| \int_K \int_K g(x) \left( \frac{f}{w}(y - x)w(x) \frac{h(y)}{w(y)} \right) dm(x) dm(y) \right|
\]
\[
= \left| \int_K g(x) \left( \int_K \left( \frac{h}{w}(y) \frac{f}{w}(y - x) \right) dm(y) \right) dm(x) \right|
\]
\[
= \left| \int_K \left( \frac{h}{w} \ast \frac{f}{w} \right)(x)w(x)g(x) dm(x) \right|
\]
\[
\leq \int_K \left( \frac{h}{w} \ast \frac{f}{w} \right)(x)w(x)g(x) dm(x)
\]
\[
\leq 2 \left\| \frac{h}{w} \ast \frac{f}{w} \right\|_{\Phi_1} \| g \|_{\Psi_1}
\]
\[
= 2 \left\| \frac{h}{w} \right\|_{\Phi_1,w} \left\| \frac{f}{w} \right\|_{\Phi_2,w} \| g \|_{\Psi_1}
\]
\[
= 2k \left\| h \right\|_{\Phi_1} \left\| f \right\|_{\Phi_2} \| g \|_{\Psi_1}.
\]

In other words, for each \( \varphi \in L_{\Phi_1}^\Phi(K) \) we have
\[
| T(\varphi) | \leq 2k \| \varphi w \|_{\Phi_1} \| f \|_{\Phi_2} \| g \|_{\Psi_1} = 2k \| \varphi \|_{\Phi_1,w} \| f \|_{\Phi_2} \| g \|_{\Psi_1}.
\] (9)

This relation shows that \( T \in \left( L_{\Phi_1}^\Phi(K) \right)^* \cong L_{\Psi_1}^{\Psi_1}(K) \). So, there is a unique function \( u \) such that
\[
T(\varphi) = \int_K u(y)\varphi(y) dm(y)
\]
for all \( \varphi \in L_{\Phi_1}^\Phi(K) \), \( u \in L_{\Psi_1}^{\Psi_1}(K) \) and \( \| T \| = \| u \|_{\Psi_1,w^{-1}} \). By (8) we have
\[
\Lambda_w \left( g, L(\frac{f}{w}) \right) = u \quad a.e.
\]

Therefore, \( \Lambda_w \left( g, L(\frac{f}{w}) \right) \in L_{\Psi_1}^{\Psi_1}(K) \), and by the relation (9),
\[
\left\| \Lambda_w \left( g, L(\frac{f}{w}) \right) \right\|_{\Psi_1,w^{-1}} = \| T \| \leq 2k \| f \|_{\Phi_2} \| g \|_{\Psi_1}.
\]

(2)\Rightarrow(1): Suppose that there is a constant \( c > 0 \) such that for each \( f \in L_{\Phi_2}(K) \) and \( g \in L_{\Phi_1}(K) \),
\[
\left\| \Lambda_w \left( g, L(\frac{f}{w}) \right) \right\|_{\Psi_1,w^{-1}} \leq c \| f \|_{\Phi_2} \| g \|_{\Phi_1}.
\]
Let \( h \in L^\Phi_w(K) \) and \( f \in L^\Phi_w(K) \). We define
\[
S(\varphi) := \int_K (h \ast f)(x)\varphi(x) \, dm(x)
\]
for all \( \varphi \in L^\Phi_{w^{-1}}(K) \). Then, for each \( g \in L^\Phi_w(K) \) we have
\[
|S(gw)| = \left| \int_K (h \ast f)(x)g(x)w(x) \, dm(x) \right|
\]
\[
= \left| \int_K \int_K h(y)L_yf(x)g(x)w(x) \, dm(y)dm(x) \right|
\]
\[
= \left| \int_K h(y) \left( \int_K L_yf(x)g(x)w(x) \, dm(x) \right) dm(y) \right|
\]
\[
= \left\langle \frac{1}{w}\Lambda_w \left( g, L(\cdot) f \right) , wh \right\rangle
\]
\[
\leq 2 \left\| \Lambda_w \left( g, L(\cdot) \left( \frac{f}{w} \right) \right) \right\|_{\Phi_1,w^{-1}} \left\| wh \right\|_{\Phi_2}
\]
\[
\leq 2c\|h\|_{\Phi_1,w} \|f\|_{\Phi_2,w} \|g\|_{\Phi_1}
\]
\[
= 2c\|h\|_{\Phi_1,w} \|f\|_{\Phi_2,w} \|gw\|_{\Phi_1,w^{-1}}.
\]
In other words, for each \( \varphi \in L^\Phi_{w^{-1}}(K) \) we have
\[
|S(\varphi)| \leq 2c\|h\|_{\Phi_1,w} \|f\|_{\Phi_2,w} \|\varphi\|_{\Phi_1,w^{-1}}.
\]
Hence, \( S \in \left( L^\Phi_{w^{-1}}(K) \right)^* \). This implies that there is a unique function \( u \) such that
\[
S(\varphi) = \int_K u(x)\varphi(x) \, dm(x) \quad (\varphi \in L^\Phi_{w^{-1}}(K)),
\]
u \( \in L^\Phi_w(K) \) and \( \|S\| = \|u\|_{\Phi_1,w} \). So, by definition of \( S \) we have \( u = h \ast f \) a.e., and therefore by (11),
\[
\|h \ast f\|_{\Phi_1,w} = \|S\| \leq 2c\|h\|_{\Phi_1,w} \|f\|_{\Phi_2,w},
\]
and the proof is completed. □

**Corollary 3.2.** Let \( K \) be a locally compact hypergroup, and \( \Phi_1 \) and \( \Phi_2 \) be Young functions with \( \Phi_1, \Psi_1 \in \Delta_2 \), where \( \Psi_1 \) is the complementary of \( \Phi_1 \). Let \( w \) be a weight function on \( K \). Suppose that there is a constant \( c > 0 \) such that for each \( f \in L^\Phi_w(K) \) and \( g \in L^\Phi_w(K) \),
\[
\left\| \Lambda_w \left( g, L(\cdot) \left( \frac{f}{w} \right) \right) \right\|_{\Phi_1,w^{-1}} \leq c\|f\|_{\Phi_2} \|g\|_{\Psi_1},
\]
where \( \Lambda_w \left( g, L(\cdot) \left( \frac{f}{w} \right) \right) \) is defined as in (5). Then,
\[
L^\Phi_w(K) \ast L^\Phi_w(K) \subseteq L^\Phi_w(K).
\]

Volumen 54, Número 2, Año 2020
Proof. The assumption is same as the condition (2) in Theorem 3.1. So, by the equivalence given in Theorem 3.1, for each \( f \in L^\Phi_w(K) \) and \( g \in L^\Psi_w(K) \), we have \( \|f \ast g\|_{\Phi,w} < \infty \), i.e. \( f \ast g \in L^\Phi_w(K) \), and the inclusion (12) follows. \( \Box \)

Corollary 3.3. Let \( K \) be a locally compact hypergroup with a weight function \( w \), and \((\Phi, \Psi)\) be a complementary pair with \( \Phi, \Psi \in \Delta_2 \). Then, \( L^\Phi_w(K) \) is a convolution Banach algebra if and only if there is a constant \( c > 0 \) such that for each \( f \in L^\Phi(K) \) and \( g \in L^\Psi(K) \),

\[
\left\| \Lambda_w \left( g, L_{(\cdot)} \left( \frac{f}{w} \right) \right) \right\|_{\Psi, w^{-1}} \leq c \|f\|_{\Phi} \|g\|_{\Psi}.
\]

If \( K \) is a locally compact group, then using a change of variables we have

\[
\Lambda_w \left( g, L_{(\cdot)} \left( \frac{f}{w} \right) \right)(x) = \Lambda_w \left( g, L_x \left( \frac{f}{w} \right) \right) = \int_K g(y)L_x \left( \frac{f}{w}(y) \right) w(y) \, dm(y)
= \int_K g(y) \frac{f(x^{-1}y)}{w(x^{-1}y)} w(y) \, dm(y)
= \int_K f(y) g(xy) \frac{w(xy)}{w(y)} \, dm(y).
\]

With this relation, one can easily conclude the following two facts from the above results in the context of locally compact groups.

Corollary 3.4. Let \( K \) be a locally compact group with a weight function \( w \), and \( \Phi_1 \) and \( \Phi_2 \) be Young functions with \( \Phi_1, \Psi_1 \in \Delta_2 \), where \( \Psi_1 \) is the complementary of \( \Phi_1 \). Then, the followings are equivalent:

(i) There is a constant \( k > 0 \) such that for each \( f \in L^\Phi_1(K) \) and \( g \in L^\Phi_2(K) \),

\[
\|f \ast g\|_{\Phi_1,w} \leq k \|f\|_{\Phi_1,w} \|g\|_{\Phi_2,w}.
\]

(ii) There is a constant \( c > 0 \) such that for each \( f \in L^\Phi_2(K) \) and \( g \in L^\Psi_1(K) \),

\[
\left\| \int_K f(y) g(\cdot, y) \Omega(\cdot, y) \, dm(y) \right\|_{\Psi_1} \leq c \|f\|_{\Phi_2} \|g\|_{\Psi_1}.
\]

We can also conclude Theorem 3.1 of [18] from Corollary 3.3.

Corollary 3.5. Let \( K \) be a locally compact group with a weight function \( w \), and \((\Phi, \Psi)\) be a complementary pair with \( \Phi, \Psi \in \Delta_2 \). Then, \( L^\Phi_w(K) \) is a convolution Banach algebra if and only if there is a constant \( c > 0 \) such that for each \( f \in L^\Phi(K) \) and \( g \in L^\Psi(K) \),

\[
\left\| \int_K f(y) g(\cdot, y) \Omega(\cdot, y) \, dm(y) \right\|_{\Psi} \leq c \|f\|_{\Phi} \|g\|_{\Psi}.
\]

Revista Colombiana de Matemáticas
Thanks to Corollary 3.3, in the following result we find a sufficient condition for a weighted Orlicz space on a hypergroup to be a convolution algebra. For each \( g \in L^\Psi(K) \) and \( x, y \in K \) we put

\[
H^g(x, y) := \frac{(gw)(y \ast x)}{w(x)w(y)}.
\]

Also, we denote the set of all measurable functions \( v \) with \( \int_K \Phi(|v|) \leq 1 \) by \( \Gamma_\Phi \).

**Theorem 3.6.** Let \( K \) be a hypergroup with a weight function \( w \), and \((\Phi, \Psi)\) be a complementary pair with \( \Phi, \Psi \in \Delta_2 \). Suppose that

\[
\sup\{ \left\| H^g_{(\cdot)} \right\|_\Psi : \|g\|_\Psi \leq 1 \} < \infty,
\]

where \( H^g_{(\cdot)}(x) := H^g(x, y) \) for all \( x, y \in K \), and

\[
\|H^g_{(\cdot)}\|_\Psi(y) := \|H^g_y\|_\Psi, \quad (y \in K).
\]

Then, \( L^\Phi_w(K) \) is a convolution Banach algebra.

**Proof.** If we put

\[
M := \sup\{ \left\| H^g_{(\cdot)} \right\|_\Psi : \|g\|_\Psi \leq 1 \},
\]

then for each \( g \in L^\Psi(K) \) and \( v \in \Gamma_\Phi \),

\[
\int_K \|H^g_y\|_\Psi |v(y)| \, dm(y) \leq M \|g\|_\Psi.
\]

This implies that for almost every \( y \in K \), \( H^g_y \in L^\Psi(K) \). By the duality relation (4),

\[
\|H^g_y\|_\Psi = \sup_{\|f\|_\Phi \leq 1} \left| \int_K H^g_{(\cdot)}(x) f(x) \, dm(x) \right|.
\]

Hence, for each \( v \in \Gamma_\Phi \) we have

\[
\int_K \sup_{\|f\|_\Phi \leq 1} \left| \int_K H^g(x, y) f(x) \, dm(x) \right| |v(y)| \, dm(y) \leq M \|g\|_\Psi.
\]

Thus,

\[
\int_K \left| \int_K \frac{(gw)(y \ast x)}{w(x)w(y)} f(x) \, dm(x) \right| |v(y)| \, dm(y) \leq M \|f\|_\Phi \|g\|_\Psi.
\]
for all \( f \in L^\Phi(K) \). Now, applying the relation (2), for each \( v \in \Gamma_\Phi \) we have

\[
\int_K \left| \int_K \frac{g(x)}{w(y)} \frac{f(y)}{w(y)} (y^{-} * x) w(x) \, dm(x) \right| |v(y)| \, dm(y) \\
= \int_K \frac{1}{w(y)} \left| \int_K (gw)(x) \frac{f(y)}{w(y)} (y^{-} * x) \, dm(x) \right| |v(y)| \, dm(y) \\
= \int_K \frac{1}{w(y)} \left| \int_K (gw)(y * x) \frac{f(x)}{w(x)} \, dm(x) \right| |v(y)| \, dm(y) \\
= \int_K \left| \int_K \frac{(gw)(y * x)}{w(x)w(y)} f(x) \, dm(x) \right| |v(y)| \, dm(y) \\
\leq M \|f\|\|g\|\Psi.
\]

So,

\[
\left\| \Lambda_w \left( g, L_\cdot\left(\frac{f}{w}\right) \right) \right\|_{\Psi, w^{-1}} \leq c \|f\|\|g\|\Psi
\]

and, thanks to Corollary 3.3, this inequality completes the proof.

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References


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